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Study the Impact of Short-Term Training on Anthropometric, Physiological and Physical Fitness Variables of Long-Distance Runners

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Abstract

Introduction: The impact of structured training on the anthropometric, physiological, and physical fitness variables of long-distance runners is crucial for optimising performance. This study examines how systematic training influences key parameters such as body composition, cardiovascular efficiency, muscular endurance, and overall physical fitness of long-distance runners. **Methods:** Ninety-eight healthy male volunteers between ages 18 to 20 years (forty eight sedentary controls and fifty long-distance runners) were included randomly from Midnapore, W.B., India. Volunteers underwent a medical check up performed by physicians, and based on their decision, 10 long-distance runners and 08 control subjects were excluded. The rest were divided into (i) the Sedentary Control Group (SCG, *n*=40) and the Long Distance Runners (LDR, *n*=40). The long-distance runners received a training program (4 hours/day, 5 days/week for 6 weeks); no training was given to the control group volunteers. The selected anthropometric, physical fitness, and physiological variables were measured at the beginning of the training (baseline data, 0 wk) and at the end (06 wks) of the study and analysed. **Results:** A significant increase (p<0.05) in VO_{2max}, lung volumes, strength, power, speed, and flexibility; and a reduction (p<0.05) in body fat, sprint time, heart rate (during rest, sub-maximal exercise, and recovery), resting blood pressure, and peak blood lactate were observed after six weeks of training among the long-distance runners. **Conclusion:** The findings highlight the significance of specialised training programs in improving the performance of long-distance runners by enhancing both physiological and physical efficiency.

Keywords: Body Fat, VO_{2max}, Anaerobic Power, Lactate threshold, Training, Running athletes

Resumen

Introducción: El impacto del entrenamiento estructurado en las variables antropométricas, fisiológicas y de aptitud física de los corredores de larga distancia es crucial para optimizar el rendimiento. Este estudio examina cómo el entrenamiento sistemático influye en parámetros clave como la composición corporal, la eficiencia cardiovascular, la resistencia muscular y la aptitud física general de los corredores de larga distancia. **Métodos:** Noventa y ocho voluntarios varones sanos entre 18 y 20 años (cuarenta y ocho controles sedentarios y cincuenta corredores de larga distancia) fueron incluidos aleatoriamente de Midnapore, W.B., India. Los voluntarios se sometieron a un chequeo médico realizado por médicos y, en función de su decisión, se excluyeron 10 corredores de larga distancia y 08 sujetos control. El resto se dividió en (i) el Grupo de Control Sedentario (SCG, n = 40) y los Corredores de Larga Distancia (LDR, n = 40). Los corredores de larga distancia recibieron un programa de entrenamiento (4 horas / día, 5 días / semana durante 6 semanas); Los voluntarios del grupo control no recibieron entrenamiento. Las variables antropométricas, de aptitud física y fisiológicas seleccionadas se midieron y analizaron al inicio del entrenamiento (datos iniciales, semana 0) y al final (semana 6) del estudio. **Resultados:** Se observó un aumento significativo (p<0,05) en el VO2máx, los volúmenes pulmonares, la fuerza, la potencia, la velocidad y la flexibilidad; y una reducción (p<0,05) en la grasa corporal, el tiempo de sprint, la frecuencia cardíaca (en reposo, ejercicio submáximo y recuperación), la presión arterial en reposo y el lactato sanguíneo máximo tras seis semanas de entrenamiento en los corredores de fondo. **Conclusión:** Los hallazgos destacan la importancia de los programas de entrenamiento especializados para mejorar el rendimiento de los corredores de fondo, mejorando tanto laeficiencia fisiológica como la física.

Palabras Clave: Grasa corporal, VO2máx, Potencia anaeróbica, Umbral de lactato, Entrenamiento, Atletas de carrera.

Introduction

The long-distance running events typically cover a distance of 5000 meters to 42 km and are highly demanding endurance sports that require a combination of optimal anthropometric characteristics, superior physiological efficiency, and well-developed physical fitness attributes (Smarkusz-Zarzecka et al., 2020). The long-distance runners rely on structured training programs to enhance their performance, endurance, and recovery (Haugen et al., 2022). The impact of short-term training on body composition, cardiovascular function, muscular endurance, and blood lactate level plays a crucial role in determining an athlete's success (Haugen et al., 2022). Anthropometric variables, including body fat percentage, lean muscle mass, and body mass index (BMI), significantly influence running efficiency and energy expenditure (Muñoz et al., 2020). Physiological factors such as maximal oxygen uptake (VO_{2max}), lactate threshold, and heart rate variability are essential indicators of an athlete's aerobic capacity and endurance potential (Myrkos et al., 2020). Additionally, physical fitness components, including strength, speed, agility, and flexibility, contributes to enhanced running economy and injury prevention (Lesinski et al., 2020).

Training programs designed for long-distance runners typically involve a combination of endurance training, strength conditioning, interval workouts, and recovery strategies (Haugen et al., 2022). These training modalities aim to improve oxygen utilization, muscular efficiency, and neuromuscular coordination, thereby enhancing overall performance. Understanding the extent to which training influences these anthropometric, physiological, and physical fitness parameters is essential for athletes, coaches, and sports scientists to develop evidence-based strategies for maximising athletic potential (Kenneally et al., 2018). This study aims to examine the impact of short-term training on these key variables and provide insights into how long-distance runners can optimise their performance through scientifically designed training interventions. By analysing changes in body composition, physiological adaptations, and physical fitness improvements, this study will contribute to the existing knowledge on endurance training and its effectiveness in long-distance running.

Materials and Methods

Subjects

Ninety-eight healthy male volunteers (age: 18-20 yrs.) (forty-eight sedentary controls and fifty long-distance runners) were included randomly from Midnapore, West Bengal, India. The sample size for this study was calculated by G*Power software (Kang, 2021). According to the software, a minimum of fifty-four subjects were required to carry out the study; however, ninety-eight volunteers were taken to avoid dropouts of the volunteers. Medical examinations were performed by physicians for all the volunteers before joining the study, and based on their decision; ten long-distance runners and eight control subjects were excluded. The rest of the volunteers were divided into (a) Sedentary Control Group (SCG, n = 40) and (b) Long Distance Runners (LDR, n = 40).

Training

General and specific training related to long-distance running was given by the qualified coaches to the long-distance runners following the schedule (4 hrs/day, 5 days/week for 6 weeks) (Bompa & Buzzichelli, 2021). The training includes a combination of long runs, tempo runs, interval training, strength training, and cross-training activities. The primary focus was to build endurance by gradually increasing running distance and managing intensity to prevent injuries, all while considering proper nutrition and hydration strategies. The volunteers of the sedentary control group did not receive any training and were allowed for recreational activities only (Table 1).

Experimental design

The volunteers were acclimatised 15 days prior to the study. The long-distance runners received training for 06 weeks under the guidance of a well-trained coach following a standard protocol, whereas the volunteers of the sedentary control group were involved in recreational activities only. All volunteers were asked to maintain their normal traditional diet and stay away from smoking, consumption of alcohol, fast food, carbonated cold drinks, etc. Selected anthropometric, physiological, and physical fitness variables were measured at 0 weeks and after 6 weeks of study. Data were statistically analysed (Figure 1).

Table 1. Six weeks training plan for long distance runners

Phases			6 weeks Training Plan		
Phases of Training			Baseline	General Preparation (Physical Preparation)	Specific Preparation (Technical and tactical Preparation)
Sub-Phases			Zero level baseline		
Period		Strength	-	Anatomical adaption	Maximal Strength
		endurance	-	aerobic	Anaerobic
		Speed	-	Specific high	
		Skills	-	Foundation	Advanced
Macro Cycles			0 weeks	1-3 weeks	4-6 weeks
Training Factors	Volume	100%	-	80-90%	70%
	Intensity	90 %	-	70-80%	80%
	Peaking	80%	-	70-75%	80%
	Physical Preparation	70%	-	50-55%	40-45%
	Technical Preparation	60%	-	40-45%	40-45%
	Tactical Preparation	50%	-	10%	10%
	Psychological Preparation	40%	-	10%	10%

Ethical Considerations

The purpose and possible complications of the study were explained to all participants, and a written consent was obtained from them. The Institutional Ethical Committee (Human Studies) approval was taken [Ref. No. MC/IEC (HS)/PHY/Ph.D.RF/02/2023].

Measurement of anthropometric variables

The stature (height) was recorded by stadiometer (Seca 220, UK) with an accuracy of 0.5 centimetres (cm). The stature was recorded in centimetres (Chandrasekar et al., 2023). The body mass was measured by an electronic weighing machine (Seca Alpha 770, UK), having an accuracy recorded to the nearest 50 grams (gm), and was recorded in kilograms (Chandrasekar et al., 2023). The skin fold was taken from the biceps, triceps, sub-scapular, and suprailiac using the skin fold calliper (Cescorf, USA) on the right side of the body. The data of skin fold were used for the determination of body density (BD) (Durnin and Womersley, 1974). Computation of percent body fat was derived using the standard equation (Siri, 1956). Computation of lean body mass (LBM) was derived by subtracting fat mass from total body mass (Chandrasekar et al., 2023). The waist and hip circumference was measured with a non-stretchable tape (Chandrasekar et al., 2023). Waist-hip ratio was calculated from waist and hip circumference.

Measurements of physiological variables

The volunteers were asked to take a rest for fifteen minutes in a sitting position, and resting heart rate (HRrest) and blood pressure were measured using an electronic sphygmomanometer (Omron, Japan) (McArdle et al., 2015). Heart rates were measured during sub-maximal exercise, maximal exercise, and recovery by using a Polar H10 heart rate monitor (Polar, USA). A treadmill test was used to determine the sub-maximal exercise heart rate (HR_{SM}) at 6 km/hr and 8 km/hr for two minutes in each load.

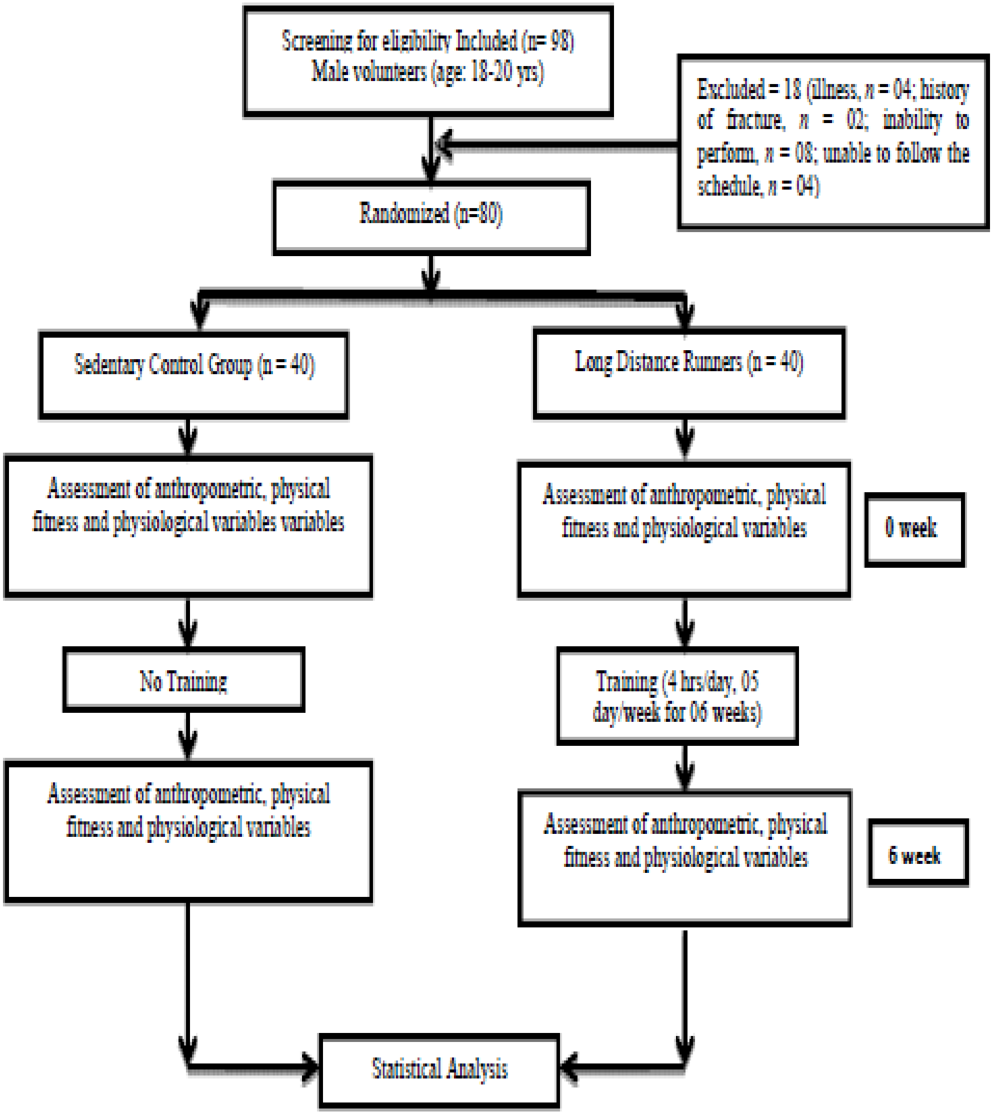

Figure 1. The experimental design

Thereafter, the volunteer was asked to continue the exercise, and the treadmill speed was increased by 2 km/hr every 2 minutes until volitional exhaustion; the maximum heart rate (HRmax) and recovery heart rate (HRrec) were taken (McArdle et al., 2015). The maximum oxygen consumption (VO_{2max}) was determined by *the Yo-Yo Intermittent* Recovery *Test* (YYIR1) (Bangsbo et al., 2008). The subject performed a running test for a 20 m distance. A track was prepared for 20 m and 5 m for recovery. The athletes ran in a specific rhythm, and with the duration, the speed of the athlete increased. After the exhaustion, the specific lap and shuttle were noted, and from that specific lap and shuttle, the VO_{2max} was calculated. The lung functions viz. forced vital capacities (FVC), forced expiratory volume in the 1st second (FEV1), and peak expiratory flow rate (PEFR) were assessed by digital spirometer (Micro I Spirometer, Care Fusion, Japan) (Gallucci et al., 2019). The resting and peak blood lactate levels were measured using a portable blood lactate monitor (Lactate Scout 4, EKF Diagnostics, USA) (Bosquet et al., 2001).

Measurements of physical fitness variables

A hand grip dynamometer (Baseline, USA) was used for the measurement of the hand grip strength of the volunteers (Chandrasekar et al., 2023). The back and leg strength of the volunteers was measured using a back and leg dynamometer (Baseline, USA) following standard methodology (Chandrasekar et al., 2023). The explosive strength of the lower limbs of the volunteers was determined by the standing broad jump test; lower body strength and power of the volunteers were evaluated by the vertical jump test; endurance of the abdominal and hip-flexor muscles was measured by the sit-up test; and upper body strength and endurance were evaluated using the push-up test (Chandrasekar et al., 2023). The maximum speed of the volunteers was determined by the 30 m sprint test (Chandrasekar et al., 2023). The modified sit-and-reach test was used to assess the athlete's hip and trunk flexibility using the modified sit-and-reach box (Baseline, USA) (Chandrasekar et al., 2023). The running-based anaerobic sprint test (RAST) was performed to determine the anaerobic power (Andrade et al., 2015). The test was repeated 3 times, and the times taken for six sprints were recorded separately. The anaerobic power was determined by a standard equation.

Statistical Analysis

All the collected data were analysed by using a standard statistical software package, IBM SPSS Statistics for Windows, Version 28.0.1 (IBM Corp., Armonk, NY: USA). To check whether the data were normally distributed, the Shapiro–Wilk normality test was conducted. The anthropometric, physiological, and physical fitness variables were expressed as mean and standard deviation (SD). To find out the differences among the variables within the selected groups and between the groups, a paired sample t-test was performed. The significant level was chosen at $p \leq 0.05$ (Banerjee, 2018).

Results

Effects of training on anthropometric variables of long-distance runners

In the present study, a significant ($p<0.05$) reduction in percent body fat and total fat mass was noted after six weeks of training among the long-distance runners. No significant difference was noted in height, body mass, BMI, BSA, LBM, and WHR among the volunteers following the training program. The long-distance runners had possessed lower ($p < 0.05$) body fat and higher ($p< 0.05$) LBM than control group volunteers (Table 2).

Table 2. Effects of training on anthropometric variables of long distance runners

Parameter	SCG (n=40)		LDR (n=40)	
	0 Weeks	6 Weeks	0 Weeks	6 Weeks
Height (cm)	168.4 ±5.5	168.4 ± 5.6	169.8 ±5.8	169.8 ± 5.8
Weight (kg)	57.5 ± 5.8	58.2 ± 5.9	58.1 ± 5.9	58.3 ± 5.8
BMI (kg/m2)	20.2 ± 1.4	20.2 ± 1.4	20.1 ± 1.5	20.1 ± 1.4
BSA (m2)	1.6 ± 0.1	1.6 ± 0.1	1.7 ± 0.1	1.7 ± 0.1
Body fat (%)	11.9 ±1.6	11.9 ± 1.6	11.8 ± 1.4	$10.8^{*\#}$ ± 1.5
Fat mass (kg)	7.5 ±1.7	7.6 ±1.8	7.2 ± 1.5	$6.4^{*\#}$ ±1.5
LBM (kg)	48.9 ± 4.6	48.8 ± 4.5	50.7 ± 4.1	$51.9^{\#}$ ± 4.3
Waist-Hip Ratio	0.8 ± 0.1	0.8 ± 0.1	0.8 ± 0.04	0.8 ± 0.1

Data presented as mean ± SD, n = 40, when compared to '0 week' and '6 week- *p<0.05; when compared to CG and EG- #p<0.05; BMI = Body mass index, BSA = Body surface area, LBM = lean body mass.

Effects of training on physiological variables of long-distance runners

In the present study, a significant ($p<0.05$) increase in maximum aerobic capacity (VO_{2max}), force expiratory volume in 1st sec (FEV1), force vital capacity (FVC), peak expiratory flow rate (PEFR), and decrease ($p<0.05$) in resting heart rate (HRrest), sub-maximal exercise heart rate (HR_{SM}), maximum heart rate (HRmax), and recovery heart rate (HRrec1-3), resting blood pressure, and peak blood lactate (BL_{peak}) were noted after six weeks of training among the long-distance runners. No significant difference was noted in resting blood lactate (BL_{rest}) among the volunteers of the long-distance runners group following the training program.

Table 3. Effects of training on physiological variables of long distance runners

Parameter	SCG (n=40)		LDR (n=40)	
	0 Weeks	6 Weeks	0 Weeks	6 Weeks
SBP (mmHg)	114.3 ± 10.5	116.3 ± 11.5	115.2 ± 10.4	108.5$^{*\#}$ ± 12.3
DBP (mmHg)	70.2 ± 9.2	74.3 ±9.4	71.7 ± 8.6	66.5$^{*\#}$ ± 9.4
HR_{rest} (bpm)	66.3 ± 5.2	67.4 ± 4.7	64.3 ± 3. 4	61.8$^{*\#}$±4.2
HR_{SM1} (bpm)	130.3 ± 4.8	133.4 ± 4.4	128.4 ± 4.5	126.4$^{\#}$ ± 4.5
HR_{SM2} (bpm)	146.4 ± 4.8	149.4 ± 4.7	145.9 ± 4.4	143.3$^{*\#}$ ± 5.3
HR_{max} (bpm)	195.3 ± 4.6	198.5 ± 4.8	198.4 ± 4.8	195.4$^{*\#}$ ± 5.2
HR_{rec1}(bpm)	168.2 ± 5.5	166.2 ± 5.7	163.4 ± 5.1	160.3$^{*\#}$ ± 5.5
HR_{rec2} (bpm)	130.5 ± 5.8	129.4 ± 5.3	129.3 ± 5.4	126.3$^{\#}$± 5.7
HR_{rec3}(bpm)	107.8 ± 5.4	106.3 ± 5.7	103.5 ± 4.8	100.4$^{*\#}$ ± 5.5
VO_{2max}(ml/kg/min)	70.4 ± 5.4	71.2 ± 5.8	72.1 ±5.4	75.5$^{*\#}$ ± 5.6
FEV1 (l)	3.6 ± 0.3	3.6 ± 0.4	3.7 ± 0.3	3.9$^{*\#}$ ± 0.2
FVC (l)	3.6 ± 0.3	3.6 ± 0.4	3.7 ± 0.3	3.9$^{*\#}$ ± 0.4
FEV1/FVC	98.5 ± 1.3	98.2 ± 1.3	98.7 ± 1.4	98.9$^{\#}$± 1.4
PEFR (l/min)	443.6 ± 34.6	455.3 ± 32.2	461.4 ± 32.2	478.2$^{*\#}$ ± 28.5
BL_{rest} (mmol/l)	2.2 ± 1.5	2.2 ± 1.5	2.2 ± 1.5	2.1 ± 1.6
BL_{peak} (mmol/l)	22.5 ± 4.1	23.5 ± 3.3	21.4 ±3.2	19.0$^{*\#}$ ± 4.3

Data presented as mean ± SD, n = 40, when compare to '0 week' and '6 week- *p < 0.05; when compare to CG and EG- #p <0 .05; SBP = Systolic blood pressure, DBP = Diastolic blood pressure, HRrest = Resting heart rate, HRsubmax1 = Sub-maximal heart rate 1st load, HRsubmax2 = Sub-maximal heart rate 2nd load, HRmax = Maximum heart rate, HRrec1 = Recovery heart rate in 1st min, HRrec2 = Recovery heart rate in 2nd min, HRrec3 = Recovery heart rate in 3rd min, VO2max = Maximum aerobic capacity, FEV1 = Force expiratory volume in 1st sec, FVC = Force vital capacity, PEFR = Peak expiratory flow rate. BLrest = Resting blood lactate, BLpeak = Peak blood lactate.

The long-distance runners group had higher (p<0.05) VO_{2max}, FEV_1, FVC, and PEFR; and lower (p<0.05) heart rate (during rest, sub-maximal exercise, and recovery), resting blood pressure, and peak blood lactate (BL_{peak}) than the volunteers of the sedentary control group (Table 3).

Effects of training on physical fitness variables of long-distance runners

A significant (p<0.05) increase in strength of grip, back, leg strength, upper body; highest power output, lowest power output, average power output, anaerobic capacity, fatigue index, and flexibility; and a decrease (p<0.05) in 30-meter sprint time was noted among the long-distance runners after six weeks of training. No significant difference was noted in abdominal strength, explosive power of legs, and fatigue index among the volunteers following the training program. The long-distance runners had higher (p<0.05) grip strength, back and leg strength, and upper body strength; the highest power output; anaerobic capacity; and flexibility when compared to volunteers of the sedentary control group (Table 4).

Table 4. Effects of training on physical fitness variables of long distance runners

Parameter	SCG (n=40)		LDR (n=40)	
	0 Weeks	6 Weeks	0 Weeks	6 Weeks
GSTR (kg)	36.13 ± 5.22	37.3 ± 5.4	37.0 ± 4.5	40.1$^{*\#}$± 4.9
GSTL (kg)	34.26 ± 5.08	35.2 ± 5.2	35.6 ± 4.9	37. 4 ± 4.8

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Back strength (kg)	102.3 ± 8.4	103.4 ± 8.1	102.7 ± 8.3	108.2$^{*\#}$±8.5
Leg strength (kg)	119.3 ± 6.2	120.4 ±7.4	121.4 ±6.7	126.4$^{*\#}$± 7.4
Push up test (No/min)	24.2 ± 4.6	24.6 ± 4.4	25.0 ± 4.8	27.3$^{\#}$ ± 4.5
Sit up(No/min)	36.1 ± 4.5	37.1 ± 4.7	37.3 ± 4.6	39.3 ± 4.8
30m sprint test (sec)	4.8 ± 0.4	4.8 ± 0.4	4.7 ± 0.3	4.5$^{*\#}$ ± 0.4
Standing broad jump (m)	2.6 ± 0.4	2.6 ± 0.5	2.6 ± 0.4	2.7 ± 0.4
Vertical jump (m)	0.5 ± 0.1	0.5 ± 0.1	0.5 ± 0.1	0.6* ± 0.1
Maximum Power (watt)	637.5 ± 65.4	628.2 ± 71.4	644.3 ± 67.5	682.4$^{*\#}$ ± 62.3
Average Power (watt)	483.6 ± 67.2	456.3 ± 65.4	493.2 ± 62.4	513.5$^{\#}$ ± 73.2
Minimum Power (watt)	308.3 ± 59.3	347.3 ± 55.6	314.2 ± 57.1	348.4* ± 63.5
Anaerobic capacity (watt)	2887.4 ± 262.2	2737.7 ± 268.5	2959.3 ± 254.6	3078.8$^{\#}$ ± 274.4
Fatigue Index (watt/sec)	11.1 ± 2.4	11.5 ± 2.5	10.8 ± 2.8	10.9 ± 2.7
Flexibility (cm)	32.6 ± 4.1	31.4 ± 4.4	33.5 ± 4.5	36.5$^{*\#}$ ± 4.3

Data presented as mean ± SD, n = 40, when compared to '0 week' and '6 week- *p<0.05; when compared to CG and EG- #p <0.05; GSTRH = Grip strength of right hand, GSTLH = Grip strength of left hand.

Discussion

The anthropometric variables, including height, body mass, body fat, lean body mass and waist-hip ratio, are considered as predictions of the body composition of the athletes. These variables are associated with the performance of long-distance runners. In the present study, a significant reduction in percent body fat and total fat mass was noted after six weeks of training among the long-distance runners. No significant difference was noted in height, body mass, BMI, BSA, LBM and WHR among the volunteers following the training program. The long-distance runners had possessed lower body fat and higher LBM than control group volunteers. These changes might be due to training. The control group volunteers did not receive training, thus higher body mass and body fat were reported in this group. Aerobic endurance training leads to greater utilization of fat as fuel, which might be the cause of reduced body fat after training (Browning & Evans, 2015; Muñoz et al., 2020; Smarkusz-Zarzecka et al., 2020). Excess body fat causes difficulty to perform skillful activities during the athletic events (Browning & Evans, 2015; Muñoz et al., 2020; Smarkusz-Zarzecka et al., 2020).

The physiological determinants, including VO2max, lung functions, heart rate, blood lactate levels, etc., have an important role in long-distance runners (Lundstrom et al., 2025; Myrkos et al., 2020; Smarkusz-Zarzecka et al., 2020). In the present study, a significant increase in maximum aerobic capacity (VO2max), force expiratory volume in 1st sec (FEV1), force vital capacity (FVC), peak expiratory flow rate (PEFR), and decrease in resting heart rate (HRrest) sub-maximal exercise heart rate (HRSM), maximum heart rate (HRmax) and recovery heart rate (HRrec1-3); resting blood pressure, peak blood lactate (BLpeak) were noted after six weeks of training among the long distance runners. No significant difference was noted in resting blood lactate (BLrest) among the volunteers of the long distance runners group following the training program. The long-distance runners group had higher VO2max, FEV1, FVC, PEFR, and lower heart rate (during rest, sub-maximal exercise, and recovery), resting blood pressure, and peak blood lactate (BLpeak) than the volunteers of the sedentary control group. It has been reported that endurance training improved VO2max and pulmonary functions of the athletes (Khosravi et al., 2013; Scribbans et al., 2016). The improvement in VO2max might be because of an increase in cardiac output, oxygen delivery and utilization of oxygen for aerobic metabolism (Lundstrom et al., 2025; Myrkos et al., 2020; Smarkusz-Zarzecka et al., 2020). Endurance training might improve the efficiency of the respiratory muscles, which might be because of an increase in FEV1, FVC and PEFR after training (Khosravi et al., 2013; Scribbans et al., 2016; Milanović et al., 2015). The quick acceleration and deceleration training improve the recovery process, which helps the athletes to perform repeated activities (Borresen & Lambert, 2008; Lundstrom et al., 2025). The heart rate during rest and recovery reduced after the training among the athletes. This might be due to parasympathetic activation, which helps in quick recovery after an exercise (Borresen & Lambert, 2008; Khosravi et al., 2013; Scribbans et al., 2016; Milanović et al., 2015). Previous investigations noted that aerobic training reduced heart rate during rest, sub-maximal, and maximum exercise (Lundstrom et al., 2025; Myrkos et al., 2020; Smarkusz-

Zarzecka et al., 2020). It can be suggested that improvements in VO2max and lung functions and reductions in heart rates during rest, sub-maximal exercise, maximal exercise and recovery improve the performance of the long-distance runners.

Long-distance running involves high-intensity activities that require high levels of physical fitness. The athletes execute running skills throughout the race, which require high levels of endurance, strength, power, speed and flexibility (Lum & Barbosa, 2019). A significant increase in strength of grip, back, leg strength, and upper body; highest power output, lowest power output, average power output, anaerobic capacity, fatigue index and flexibility; and a decrease in 30-meter sprint time were noted among the long-distance runners after six weeks of training. No significant difference was noted in abdominal strength, explosive power of legs, or fatigue index among the volunteers following the training program. The long-distance runners had higher strength of grip, back, leg strength, upper body, highest power output, anaerobic capacity, and flexibility when compared to volunteers of the sedentary control group. It can be stated that the increase in strength, power output, anaerobic capacity, and flexibility and decrease in sprint time of the athletes might be due to training (Lesinski et al., 2020; Lundstrom et al., 2025; Seitz et al., 2014). Similar observations have been noted by other research groups (Lum & Barbosa, 2019; Lundstrom et al., 2025; Seitz et al., 2014). Numerous studies have reported that a mixture of endurance, power and resistance training has an impact on the performance of the long-distance runners (Lesinski et al., 2020; Lum & Barbosa, 2019; Seitz et al., 2014; Thompson et al., 2023). It is suggested that the long-distance runners need to develop endurance, strength, speed and power in order to improve their performance. The training increased strength and power in the lower limbs and trunk that may improve the running efficiency and maintain speed throughout the race. A high level of power is also required to maintain the high pace required during the final phase of the race.

Conclusion

The athletic training has a positive impact on the anthropometric, physiological, and physical fitness variables of long-distance runners. Changes in body fat percentage, lean muscle mass, VO2max, heart rate variability, and blood lactate levels showed the physiological adaptations resulting from endurance training. Improvements in strength, speed, and flexibility help to understand their contribution to enhanced running economy. Mixed periodization training with endurance, strength, power and speed may improve the distance running performance. The findings highlight the significance of specialized training programs in improving the performance of long-distance runners by enhancing both physiological and biomechanical efficiency. Regular monitoring of the performance determinants may predict the performance of the athletes and suggest the coaches modify their training schedule accordingly. This research provides valuable insights for athletes, coaches, and sports scientists in designing effective training regimens to maximize endurance and competitive success.

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The author is agree to share the published data in a relevant public data repository.

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