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ORIGINAL ARTICLE

Impact of short term training on morphological, physical fitness and physiological variables of middle distance runners

Soumyadip Ghosh. *Department of Physiology. Midnapore College (Autonomous). Midnapore, India.*
Sayan Jyoti Bera. *Department of Physiology. Midnapore College (Autonomous). Midnapore, India.*
Kingshuk Ghosh. *Department of Allied Health Science. Manav Rachana International Institute of Research and Studies. Faridabad, India.*
Pritee Singha. *Department of Allied Health Science. Manav Rachana International Institute of Research and Studies. Faridabad, India.*
Atanu Jana. *Department of Allied Health Science. Manav Rachana International Institute of Research and Studies. Faridabad, India.*
Indranil Manna . *Department of Physiology. Midnapore College (Autonomous). Midnapore, India.*

ABSTRACT

Purpose: The present study was designed to investigate the effects of short term training on morphological, physical fitness and physiological determinants of middle distance runners. Method: Total of 97 male volunteers (age: 18-20 yrs.) (40- sedentary control, and 57- middle distance runners) were included randomly, and 17 middle distance runners were excluded. The rest were divided into (a) Sedentary Control Group (SCG, n = 40) and (b) Middle Distance Runners Group (MDR, n = 40). The volunteers of MDR followed a training schedule of 2 hrs/d, 5days/wk., for 6 wks.; no training was given in SCG. Results: A significant ($p < .05$) increase in strength (of grip, back, leg, upper body strength, abdominal), anaerobic power, flexibility, VO_{2max}, FEV_1, FVC, PEFR; and decrease ($p < .05$) in body mass, body fat and sprint time, heart rate (during rest, sub-maximal exercise and recovery) among the volunteers of MDR after 6 weeks of training. This study showed positive correlation between standing broad jump and height (r = +0.51, $p < .05$); and between speed and leg strength (r = +0.52, $p < .05$). Conclusion: Training have a positive impact on morphological, physical fitness and physiological variables of middle distance runners. Further research would provide conclusive results that can be extrapolated to general population.
Keywords: Performance analysis of sport, Body fat, Strength, Power, VO_{2max}, Training, Middle distance runners.

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Corresponding author. *Department of Physiology. Midnapore College (Autonomous). Midnapore-721101, West Bengal, India.*
E-mail: dr.indranilmanna@gmail.com
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INTRODUCTION

The middle distance running are popular worldwide and covers a distance of 800 meter to 1500 meter. The duration of mid-range runs ranges from two minutes to eight minutes (Mooses et al., 2013). The physiological demands of middle distance runners are different from those of short distance and long distance runners. The success in middle distance running is dependent on both aerobic and anaerobic determinants which allow the athlete to maintain a rapid velocity during a race (Mooses et al., 2013; Berryman et al., 2018).

The body composition has a significant contribution of performance of the middle distance runners (Mooses et al., 2013). It has been observed that the shorter events, particularly 800 meters; there is a tendency towards greater mesomorphy among the athletes (Mooses et al., 2013). The larger fat-free mass may enable runners to perform efficiently (Esco et al., 2018; Stefani, 2006). The strength, anaerobic power, speed, flexibility are the important variables which may limit the performance of the middle distance runners (Nikolaidis et al., 2018). The VO_{2max} and aerobic endurance are crucial factors in middle distance running performance (Legaz-Arrese et al., 2007; Helgerud et al., 2007; Galbraith, 2021). Training plays an important role in improvement of fitness variables of the athletes (Mcardle et al., 2015; Bompa & Buzzichelli, 2021). Middle-distance running requires a balance in different fitness variables, which include endurance, power, strength and technique (Mooses et al., 2013). Heart rate plays a significant role for assessment of training load and may be used as a tool for monitoring of training of the athletes (McArdle et al., 2015). The performance determinants of the middle distance runners must be evaluated at regular intervals in order to achieve better performance. On the basis of the above the present study has been designed to find out the effects of short term training on morphological, physical fitness and physiological variables of middle distance runners.

MATERIALS AND METHODS

Subjects

Ninety seven healthy male volunteers (age: 18-20 yrs.) (forty- sedentary control, and fifty seven- middle distance runners) were included randomly from Midnapore, W.B., India. The sample size was determined by G*Power software and the total sample size were found fifty four (Faul et al., 2009; Kang, 2021). In this study ninety seven volunteers were taken to avoid drop out of the volunteers. All the volunteers were undergoing a medical checkup performed by physicians, and based on their decision seventeen middle distance runners were excluded from this study. The rest were divided into (a) Sedentary Control Group (SCG, n = 40) and (b) Middle Distance Runners (MDR, n = 40).

Training and experimental design

General and specific training related to middle distance running was given by the qualified coaches to the volunteers of middle distance runners group, whereas the volunteers of sedentary control group did not receive any training. Training includes speed training, strength and power training, flexibility training, interval training, endurance training etc. and were given following the schedule (2 hrs/day, 05 days/week for 06 weeks) (Bompa & Buzzichelli, 2021). The selected morphological, physical fitness and physiological variables were measured at the beginning of the training (baseline data, 0 week) and at the end of training programme (06 weeks). Statistical analysis was performed to find out the significant differences among the variables.

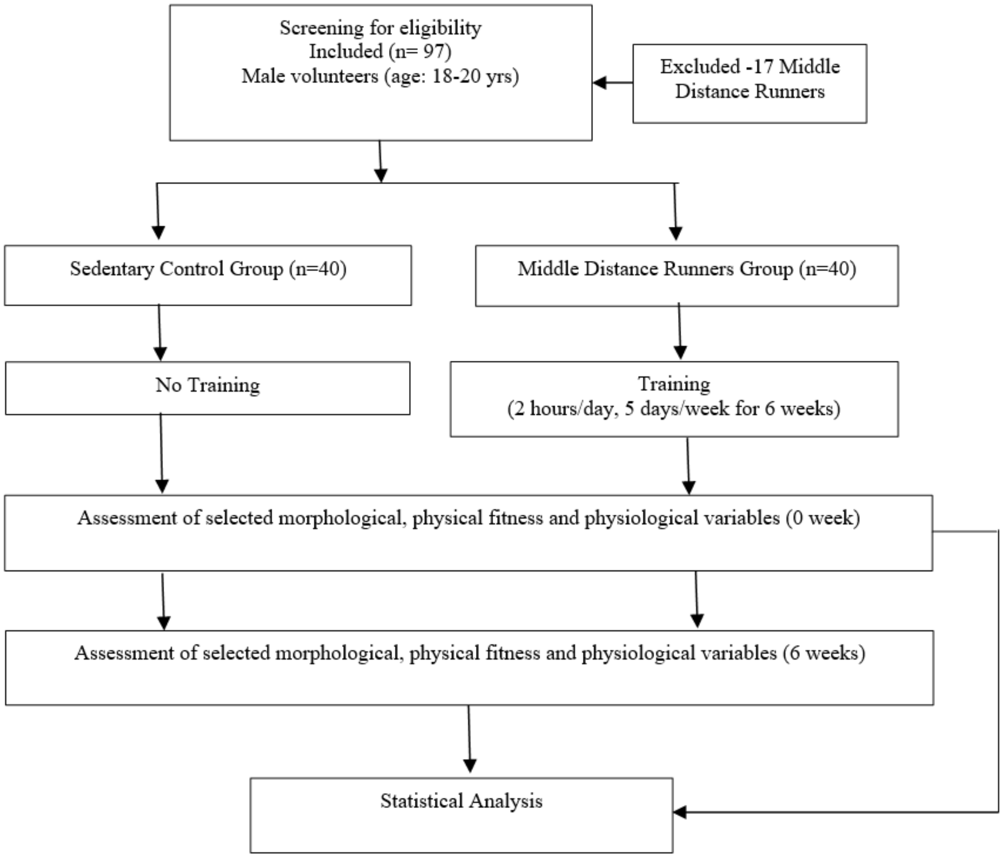

Figure 1. The experimental design of the study.

Table 1. Training plan for middle distance runner.

Phases			**6 Weeks plan**		
Phases of Training			Baseline	Preparatory Phase	
Sub-phases			Zero level baseline	General Preparation (Physical Preparation)	Specific Preparation (Technical and tactical Preparation)
Periodization	Strength		-	Anatomical adaptation	Maximal Strength
	Endurance		-	Aerobic	Anaerobic
	Speed		-	Specific high	
	Skills		-	Foundation	Advanced
Macro Cycles			0 weeks	1-3 weeks	3-6 weeks
Training Factors	Volume	100%	-	80-90%	
	Intensity	90%	-	70-80%	
	Peaking	80%	-	70-75%	
	Physical Preparation	70%	-	50-55%	40-45%
	Technical Preparation	60%	-	40-45%	40-45%
	Tactical Preparation	50%	-	10%	10%
	Psychological Preparation	40%	-		10%

Ethical considerations
The subjects were informed about the possible complications of the study and a written informed consent was taken from them. All volunteers were asked to maintain their normal diet and stay away from alcohol and smoking. The Institutional Ethical Committee (Human Studies) approved this study.

Measurement of morphological variables
Measurement of height (stature) and body mass
The height (stature) was recorded by the stadiometer (Seca 220, UK) and expressed in centimetres (cm) (Jonson & Nelson, 1996). The body mass was measured by using electronic weighing machine (Seca Alpha 770, UK) and expressed in kilogram (kg) (Jonson & Nelson, 1996). The body mass index (BMI) and body surface area (BSA) was calculated using the standard equations from the values of height and body mass (Jonson & Nelson, 1996).

Determination of subcutaneous fat
The skin fold thickness was taken from biceps, triceps, sub-scapular and suprailiac skin fold sites by using skin fold calliper (Cescorf, Brazil) for determination of body density (Durnin & Womersley 1974). The body density score was used for assessment of percent body fat (Siri, 1956). The total fat mass and lean body mass (LBM) was calculated by using standard equation (Jonson & Nelson, 1996).

Determination of waist-hip ratio
The waist and hip circumference was measured with a non-stretchable tape and the waist-hip ratio was determined (Jonson & Nelson, 1996).

Measurements of physical fitness variables
Measurement of hand grip strength
The hand grip strength was measured using the hand grip dynamometer (Baseline, USA) in both the hands. The subject was asked to hold the dynamometer using palm and the handle rest on fingers. The arm was at the right angle with elbow parallel to the ground. After that the subject was asked to squeeze the dynamometer with maximum strength and maintained it for 5 seconds, the measurement was recorded in kilogram (kg) (Lee & Gong, 2020).

Measurements of back and leg strength
The back and leg strength was measured using the back and leg dynamometer (Baseline, USA) (Coldwells et al., 1994). The subject was asked to stand on the base of dynamometer keeping both feet apart and hold the centre of the bar mounted at the end of the chain with the palm facing upwards to the head. Then without bending and jerking the athlete pulled the bar with maximum force for 5 seconds. For measurement of leg strength same procedure was followed. The knees of the subject were bent at approximately 110°. The subject pulled the chain as hard as possible while straighten the legs and arms. The back and leg strength was recorded in kilogram (kg).

Measurement of upper body strength (push up test)
The subject was asked to maintain a position and his toes touches the floor, the body and legs maintaining a line. The subject performed push up as fast as possible for one minute. The number of the push-ups in one minute was counted (Jonson & Nelson, 1996).

Measurement of abdominal strength (sit up test)
The abdominal muscles strength of the subjects was measured by sit up test. The subject performed sit up as fast as possible for one minute. The number of the sit ups in one minute was counted (Jonson & Nelson, 1996).

Determination of anaerobic power
The running based anaerobic sprint test (RAST) was performed to assess anaerobic power of the subject (Andrade et al., 2015). The subject had undertaken six 35 meter sprints with 10 seconds recovery between each sprint, for this a non-slip ground surface 35 meters was marked with cones. The subject warmed up for 10 minutes, then the subject was asked to take a stand at the starting position and start running to the second cone when whistle was heard by him. The time taken by the subject to cover 35 meter was recorded. The subject was taken rest for 10 seconds and came back 35 meters to the first cone, and the time taken was recorded. The test was repeated 3 times and time taken for six sprints was recorded for determination of anaerobic power following standard equations.

Measurement of leg muscle power (vertical jump)
The vertical jump test was conducted following standard procedure (Jonson & Nelson, 1996). The subject was asked to stand side on to a wall and raise his hand up and the highest point the figure touched was marked. The subject was asked to stand away from the wall and leaps vertically as high as possible and touched the wall at the highest point of the jump, and measurement was taken.

Measurement of explosive power of legs (standing board jump)
The subject was asked to stand on a line with feet slightly apart. The subject performed the jump with maximum effort and landing both feet without falling backwards. The distance from the line to the nearest point of contact was record (Jonson & Nelson, 1996).

Measurement of speed
The speed was measured by 30 meter sprint test (Jonson & Nelson, 1996). The subject ran for a specified distance of 30 meter from the standing start. The time taken for completing 30 meter sprint was noted.

Assessment of flexibility
The flexibility of the volunteer was assessed by modified sit and reach test using sit and reach box (Baseline, USA) (Jonson & Nelson, 1996). The subject was asked to seat, stretching the leg ahead and keeping the knees flat against the floor and try to touch the feet. The fingertip of both hands of the subject was placed on the ruler on the box after adjusting the zero mark on the ruler. Placing the hands side by side the subject was asked to lean forward slowly as far as possible maintaining fingertips at the same level and keeping the legs flat, and the measurement was taken in cm.

Measurements of physiological variables

Determination of maximum aerobic capacity (VO_{2max})
The Yo-Yo Intermittent Recovery Test 1 (YYR1) was used for determination of maximum oxygen uptake (VO_{2max}) of the subject (Bangsbo et al., 2008). The subject was asked to run for 20 m distance, for this a track was created for 20 m and 5 m for recovery. The subject ran on the track maintaining a rhythm and with the advancement of duration the speed was increased. The test was continued until subject was exhausted. The specific lap and shuttle was noted for determination of VO_{2max} using standard equation.

Measurement of heart rate and blood pressure
The subject was asked to take rest in a seating position for 15 min. The resting heart rate and blood pressure was measured by using digital sphygmomanometer (Omron, Japan) (McArdle et al., 2015). The pulse pressure and mean pressure were calculated. The heart rate was also recorded during sub-maximal exercise, maximal exercise and recovery following the Yo-Yo intermittent recovery test 1 (YYIR1) (McArdle et al., 2015; Bangsbo et al., 2008).

Determination of lung functions
The lung functions of the subject including force vital capacity (FVC), force expiratory volume in 1st sec (FEV_1) and peak expiratory flow rate (PEFR) were measured by using a digital spirometer (CareFusion, Japan) (Gallucci et al., 2019).

Measurement of blood lactate
The subject was asked to sit quietly for 15 min, and 2 ml of 12 hour fasting blood sample was taken from the fingertip for measurement of resting blood lactate. For the measurement of peak lactate, blood sample was taken 3 min after the completion of running based anaerobic sprint test (RAST). The blood lactate analysis was done using portable blood lactate analyser (Lactate Scout 4, EKF Diagnostics, USA) (Bosquet et al., 2001).

Statistical analysis
The computerised software package SPSS-20 for Windows (IBM, USA) was used for statistical analysis. Descriptive statistics were performed for selected morphological, physical fitness and physiological variables. To find out the within group and between group difference in selected variables Paired sample t-test was performed. In each case the significant level was chosen at .05 levels (Banerjee, 2018).

RESULTS

Impact of short term training on morphological variables of middle distance runners
In the present study, a significant ($p < .05$) reduction in body mass, percent body fat and total fat mass was noted after six weeks of training among the volunteers of middle distance runners group. No significant difference was noted in height, BMI, BSA, LBM and WHR among the volunteers following the training programme. The volunteers of middle distance runners group had possessed lower ($p < .05$) body mass and body fat than the control group volunteers (Table 2).

Table 2. Impact of short term training programme on morphological variables of middle distance runners.

Parameter	Sedentary Control Group (SCG, n = 40)		Middle Distance Runners (MDR, n = 40)	
	0 Wk.	6 Wk.	0 Wk.	6 Wk.
Height (cm)	171.4 ± 7.0	171.6 ± 7.0	171.5 ± 7.0	171.5 ± 7.1
Weight (Kg)	59.7 ± 4.6	60.5 ± 4.2	58.7 ± 4.6	$56.0^{*\#}$ ± 4.7
BMI (kg/m^2)	20.3 ± 1.2	20.6 ± 1.2	20.4 ± 1.2	20.0 ± 1.3
BSA (m^2)	1.70 ± 0.11	1.71 ± 0.13	1.70 ± 0.11	1.69 ± 0.12
Body fat (%)	13.7 ± 1.8	13.8 ± 1.6	13.8 ± 1.8	$12.6^{*\#}$ ± 1.6
Fat mass (kg)	8.2 ± 1.7	8.2 ± 1.7	8.3 ± 1.6	7.3^{*} ± 1.8
LBM (kg)	50.9 ± 3.8	50.9 ± 3.8	51.0 ± 3.7	50.4 ± 3.5
WHR	0.85 ± 0.08	0.86 ± 0.08	0.84 ± 0.07	0.84 ± 0.08

*Data presented as mean ± SD, n = 40, paired sample t-test was performed; when compared to '0 week' and '6 week- *p < .05; when compared to CG and EG- #p < .05; SD = Standard deviation, BMI = Body mass index, BSA = Body surface area, LBM = lean body mass, WHR - Waist Hip ratio.*

Impact of short term training on physical fitness variables of middle distance runners

A significant ($p < .05$) increase in strength (of grip, back, leg strength, upper body, abdominal muscles), highest power output, lowest power output, average power output, anaerobic capacity, fatigue index and flexibility; and a decrease ($p < .05$) in 30 meter sprint time among the volunteers of middle distance runners group after six weeks of training. No significant difference was noted in leg muscle power and explosive power of legs among the volunteers following the training programme. Further, the volunteers of middle distance runners group had higher ($p < .05$) strength (of grip, back, leg strength, upper body, abdominal muscles), highest power output, lowest power output, average power output, anaerobic capacity, fatigue index and flexibility when compared to volunteers of sedentary control group (Table 3). The positive correlations were obtained in (a) standing broad jump vs height (r = 0.51, $p < .05$); (b) speed vs leg strength (r = 0.52, $p < .05$).

Table 3. Impact of short term training programme on physical fitness variables of middle distance runners.

Parameter	Sedentary Control Group (SCG, n = 40)		Middle Distance Runners (MDR, n = 40)	
	0 Wk.	6 Wk.	0 Wk.	6 Wk.
GSTR (kg)	34.4 ± 3.6	34.7 ± 3.5	34.9 ± 3.7	36.9 $^{*\#}$ ± 3.4
GSTL (kg)	32.7 ± 3.2	31.6 ± 3.4	33.5 ± 3.1	35.2 $^{*\#}$ ± 3.2
Back strength (kg)	101.3 ± 7.8	102.1 ± 8.2	100.8 ± 7.8	104.9* ± 7.5
Leg strength (kg)	112.5 ± 11.7	113.4 ± 11.8	112.3 ± 11.1	119.8$^{*\#}$ ± 11.4
Push up test (no/min)	25.7 ± 3.3	25.4 ± 3.4	26.2 ± 3.1	28.9$^{*\#}$ ± 3.2
Sit up (no/min)	24.8 ± 3.0	24.6 ± 3.4	24.4 ± 3.2	26.3*± 3.1
30m sprint test (sec)	4.6 ± 0.4	4.6 ± 0.4	4.6 ± 0.3	4.4$^{*\#}$ ± 0.3
Standing broad jump (m)	2.8 ± 0.5	2.8 ± 0.4	2.8 ± 0.5	2.9 ± 0.5
Vertical jump (m)	0.46 ± 0.08	0.46 ± 0.07	0.47 ± 0.07	0.48 ± 0.06
HPO (watt)	771.6 ± 64.4	774.3 ± 62.4	779.4 ± 68.5	816.4$^{*\#}$ ± 69.3
LPO (watt)	356.4 ± 32.4	368.3 ± 35.3	364.7 ± 42.3	398.2$^{*\#}$ ± 41.5
APO (watt)	565.2 ± 51.3	572.4 ± 59.7	573.1 ± 52.4	607.4$^{*\#}$ ± 53.3
AC (watt)	3391.1 ± 102.2	3434.2 ± 112.6	3438.8 ± 114.6	3644.3$^{*\#}$ ± 108.8
Fatigue Index (watt/second)	8.5 ± 1.8	8.4 ± 1.7	8.5 ± 1.9	9.6$^{*\#}$ ± 1.8
Flexibility (cm)	33.5 ± 4.2	33.7 ± 4.5	32.7 ± 4.1	35.9* ± 4.2

*Data presented as mean ± SD, n = 40, paired sample t-test was performed; when compared to '0 week' and '6 week- *p < .05; when compared to CG and EG- #p < .05; SD = Standard deviation, GSTRH = Grip strength of right hand, GSTLH = Grip strength of left hand, HPO = Highest power output, LPO = Lowest power output, APO = Average power output, AC = Anaerobic capacity.*

Impact of short term training on physiological variables of middle distance runners

In the present study, a significant ($p < .05$) increase in maximum aerobic capacity (VO_{2max}), force expiratory volume in 1st sec (FEV_1), force vital capacity (FVC), peak expiratory flow rate (PEFR); and decrease ($p < .05$) in heart rate (during rest, sub-maximal exercise, and recovery) was noted after six weeks of training among the volunteers of middle distance runners group. No significant difference was noted in systolic blood pressure (SBP), diastolic blood pressure (DBP), pulse pressure (PP), mean pressure (MP), maximum heart rate (HR_{max}), resting blood lactate (BL_{rest}), peak blood lactate (BL_{peak}) among the volunteers of middle distance runners group following the training programme. In addition, the volunteers of middle distance runners group had higher ($p < .05$) VO_{2max} and FVC; and lower ($p < .05$) heart rate (during rest, sub-maximal exercise, and recovery) tan the volunteers of sedentary control group (Table 4).

Table 4. Impact of short term training programme on physiological variables of middle distance runners.

Parameter	Sedentary Control Group (SCG, n = 40)		Middle Distance Runners (MDR, n = 40)	
	0 Wk.	6 Wk.	0 Wk.	6 Wk.
SBP (mmHg)	115.0 ± 6.2	117.0 ± 6.1	116.5 ± 5.2	114.0 ± 6.0
DBP (mmHg)	68.2 ± 6.9	69.5 ± 7.0	68.6 ± 7.0	67.2 ± 6.5
PP (mmHg)	46.8 ± 6.5	47.5 ± 6.8	48.9 ± 5.3	46.8 ± 6.0
MP (mmHg)	83.5 ± 5.5	84.5 ± 5.4	83.9 ± 5.9	82.6 ± 5.2
HR_{rest} (bpm)	65.2 ± 3.3	65.8 ± 4.2	64.7± 3.2	62.9 $^{*\#}$ ± 3.3
$HR_{submax1}$ (bpm)	125.7 ± 4.1	126.6 ± 4.0	126.7 ± 4.1	122.8$^{*\#}$ ± 4.2
$HR_{submax2}$ (bpm)	137.5 ± 4.8	139.2 ± 4.5	138.5 ± 4.7	135.5$^{*\#}$ ± 4.8
HR_{max} (bpm)	195.4 ± 7.7	196.5 ± 7.6	196.3 ± 7.5	194.2 ± 7.8
HR_{rec1} (bpm)	168.5 ± 6.5	166.2 ± 6.6	167.4 ± 6.4	161.5$^{*\#}$ ± 6.1
HR_{rec2} (bpm)	134.3 ± 5.1	132.3 ± 5.2	132.3 ± 5.5	125.4$^{*\#}$ ± 5.4
HR_{rec3} (bpm)	108.5 ± 5.2	106.2 ± 5.4	109.5 ± 5.1	104.3* ± 5.2
VO_{2max} (ml/kg/min)	51.8 ± 5.4	51.3 ± 5.3	52.7 ± 5.9	55.8 $^{*\#}$ ± 5.7
FEV_1 (l)	3.6 ± 0.3	3.6 ± 0.3	3.6 ± 0.3	3.8 * ± 0.3
FVC (l)	3.7 ± 0.3	3.7 ± 0.4	3.7 ± 0.3	3.9 * ± 0.3
FEV_1/FVC	96.8 ± 1.5	96.9 ± 1.5	97.1 ± 1.4	97.8$^{\#}$ ± 1.4
PEFR (l/min)	460.2 ± 33.5	461.8 ± 34.5	457.6 ± 32.1	478.2* ± 30.3
BL_{rest} (mmol/l)	2.5 ± 0.8	2.5 ± 0.7	2.4 ± 0.7	2.1 ± 0.9
BL_{peak} (mmol/l)	18.3 ± 2.7	19.1 ± 2.4	18.7 ± 2.7	19.3 ± 2.5

*Data presented as mean ± SD, n = 40,paired sample t-test was performed; when compare to '0 week' and '6 week- *p < .05; when compare to CG and EG- #p < .05; SD = Standard deviation, SBP = Systolic blood pressure, DBP = Diastolic blood pressure, PP = Pulse pressure, MP = Mean pressure, HR_{rest} = Resting heart rate, $HR_{submax1}$ = Sub maximal heart rate 1st load, $HR_{submax2}$ = Sub maximal heart rate 2nd load, HR_{max} = Maximum heart rate, HR_{rec1} = Recovery heart rate in 1st min, HR_{rec2} = Recovery heart rate in 2nd min, HR_{rec3} = Recovery heart rate in 3rd min, VO_{2max} = Maximum aerobic capacity, FEV_1 = Force expiratory volume in 1st sec, FVC = Force vital capacity, PEFR = Peak expiratory flow rate. BL_{rest} = Resting blood lactate, BL_{peak} = Peak blood lactate.*

DISCUSSION

The morphological variables include body mass, height, body fat, lean body mass and circumferences are used for predictions of body composition of the athletes (Mooses et al., 2013; Knechtle, 2014; Molla, 2017). Theses variables are associated with the performance of middle distance runners (Munoz et al., 2020). In the present study, a significant decline in body mass, percent body fat and total fat mass was noted after six weeks of training among the volunteers of middle distance runners group. These changes in body mass, subcutaneous fat and total fat mass might be due to athletic training programme. The control group volunteers did not receive any training, therefore, higher body mass and percent body fat was noted in this group than the middle distance runners. It has been reported that the sports training, specifically aerobic training leads to greater utilization of fat as fuel which may reduce body fat (Esco et al., 2018; Stefani, 2006). The previous studies indicated that body fat plays a crucial role in endurance running, as excess body fat increases the body mass of the athlete and causes difficulty to perform skilful activities during the athletic event (Esco et al., 2018; Knechtle, 2014; Molla, 2017).

Middle distance running involves high intensity activities which required high levels of physical fitness. The athletes execute running skills throughout the race which require high levels of strength, power, speed and flexibility (Berryman et al., 2018; Nikolaidis et al., 2018; Galbraith, 2021). It can be stated that in international races, athletes took approximately 50 seconds for the first lap of an 800 meter run, which may need similar duration for 400m performance. Therefore, high level of strength, power and speed is desirable for the runners (Berryman et al., 2018; Nikolaidis et al., 2018; Guariglia et al., 2011). The present study showed a significant increase in strength (of grip, back, leg strength, upper body, abdominal muscles), highest power output, lowest power output, average power output, anaerobic capacity, fatigue index and flexibility; and decrease in 30 meter sprint time among the middle distance runners after six weeks of training. It can be stated that the increase in strength (of grip, back, leg strength, upper body, abdominal muscles), highest power output, lowest power output, average power output, anaerobic capacity, fatigue index and flexibility; and decrease in 30 meter sprint time among the middle distance runners might be due to the effects of training. The control group volunteers did not receive any training, therefore, lower strength (of grip, back, leg strength, upper body, abdominal muscles), highest power output, lowest power output, average power output, anaerobic capacity, fatigue index and flexibility was note among these volunteers than the middle distance runners. This study showed a positive correlation between standing broad jump and height. This suggested that tall athletes has longer stride length and thus requires less time to reach the distance (Trowell et al., 2022; Blagrove et al., 2018). In addition, a positive correlation has been found between speed and leg strength. This indicted that higher strength helps to achieve maximum speed and maintain the speed throughout the race (Trowell et al., 2022; Blagrove et al., 2018). Some recent studies have reported that resistance training and weight training may increase the strength of the muscles (Trowell et al., 2022; Lum & Barbosa, 2019) . It is suggested that the enhanced anaerobic capacity by the ATP – creatine phosphate energy system is responsible for improvement of anaerobic power of the athletes (Trowell et al., 2022; Lum & Barbosa, 2019; Driss & Vandewalle, 2013) It has been stated that training increased muscle strength and power in limbs and trunk, which may improve the running efficiency and maintain speed throughout the race (Nikolaidis et al., 2018; Beattie et al., 2017). High level of power helps to maintain the high pace required for racing, it can increase the sprint speed and power in the final phase of the race ((Trowell et al., 2022; Blagrove et al., 2018).

Physiological factors including VO_{2max}, lung functions, heart rate, blood lactate levels etc. may limit the performance of middle distance runners (Rabadan et al., 2011; Thompson, 2017). Success in middle distance running is dependent on contribution from both aerobic and anaerobic components which allows a runner to maintain a rapid velocity during a race, thus contributions of the two energy systems are essential (Thompson, 2017; Wiriawan & Kes, 2020). In the present study, a significant increase in VO_{2max}, FEV_1, FVC, PEFR; and decrease in heart rate (during rest, sub-maximal exercise and recovery) was noted after six weeks of training among the middle distance runners. These changes might be because of training. Earlier studies reported that aerobic training has significant role in improvement in VO_{2max} and pulmonary functions of the athletes (Thompson, 2017; Wiriawan & Kes, 2020). The increase in VO_{2max} might be due to increase in cardiac output, increase oxygen delivery to the exercising muscle and increase in utilization of oxygen for aerobic metabolism (Thompson, 2017; Wiriawan & Kes, 2020). Regular exercise might increase the strength of the respiratory muscles, thus making them more efficient, this might be the reason that the FEV_1, FVC and PEFR increased after training (Galbraith, 2021; McArdle et al., 2015). The quick acceleration and deceleration is related to recovery process (Galbraith, 2021; McArdle et al., 2015). The faster recovery helps the athletes to perform repeated activities (Galbraith, 2021; McArdle et al., 2015). It has been noted that the resting heart rate and the recovery heart rate of the athletes reduced after the training. It has been found that the parasympathetic activation leads to quick recovery after the exercise (Plews et al., 2017). Previous studies have reported that endurance training is responsible for reduction in resting and sub-maximal heart rate, but maximum heart rate slightly decrease or remain constant (Borresen & Lambert, 2008). Similar investigations have reported that exercise training at a variety of intensities increases VO_{2max} (Milanovic et al., 2015; Scribbans et al., 2016). No significant difference was noted in systolic blood pressure (SBP), diastolic blood pressure (DBP), pulse pressure (PP), mean pressure (MP), maximum heart rate (HR_{max}), resting blood lactate (BL_{rest}), peak blood lactate (BL_{peak}) among the volunteers of middle distance runners group following the training programme. This might be because of limited time for the training. The control group volunteers did not receive any training, thus lower VO_{2max} and FVC; and higher heart rate (during rest, sub-maximal exercise and recovery) was note in theses volunteers than the middle distance runners. It can be suggested that a well-developed VO_{2max} and lung functions improve the performance of the athletes.

CONCLUSION

Training was found to have a positive impact on morphological, physical fitness and physiological variables of middle distance runners. The specific training is required for improvement in each fitness components required for the success in middle distance running. The findings of the proposed study may help the athletes, coaches and scientific community to modify training programme in order to improve performance of the athlete. The findings of present study may be used as a frame of reference for the future investigations. Further research in this field would provide conclusive results that can be extrapolated to general population.

AUTHOR CONTRIBUTIONS

Study design, IM.; Data collection, SG, KG, SJB, PS, AJ; Statistical analysis, SG, SJB; Data interpretation, IM; Manuscript preparation, SG, SJB; Literature search, PS, AJ.

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DISCLOSURE STATEMENT

No potential conflict of interest was reported by the authors.

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