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Fitness Profile in Male Boxers of Kolkata, India

Sohini Basu, Anindita Singha Roy, Amit Bandyopadhyay
Sports and Exercise Physiology Laboratory, Department of Physiology, University of Calcutta, University Colleges of Science and Technology, Calcutta, India

Abstract. Forty light weight and forty medium weight Indian male boxers (age: 19–24 yrs) were selected for the study to evaluate their fitness profile parameters and to compare the data with their sedentary control group (n=40, age: 21–25 yrs) and their national and overseas counterparts. Boxer groups had significantly higher ($p<0.05$) values of absolute and relative VO_{2max}, flexibility, VJT scores, body density, % lean body mass (LBM) and significantly lower ($p<0.05$) values of pre-exercise heart rate, diastolic blood pressure, high intensity effort (HIE), agility, fat mass and %fat compared to their sedentary counterparts. The light weight boxers (LWB) showed significant differences in body weight, BMI, BSA and LBM when compared against the sedentary control group. Significant intra-group variation for LWB and middle weight Boxers (MWB) were seen in case of body weight, BMI, BSA, BD, FM, % fat, % LBM, absolute VO_{2max} and VJT scores. Correlation statistic revealed significant relationship of motor fitness parameters, absolute VO_{2max} and relative VO_{2max} with physical parameters and different components of body composition in all the three groups and accordingly the group specific regression equations have been computed for the prediction of different fitness parameter from the concerned morphological parameter. It can be concluded from the study that boxing training improved the fitness profile in LWB and MWB. LWB and MWB had significant intra–group difference in some fitness parameters probably due to the difference in their training modules. Present database will act as a reference to promote and improve boxing training among eastern Indian boxers and the regression norms would help to predict the fitness profile parameters in the studied population.
Key words: *boxing, fitness, VO_{2max}, agility, lean body mass.*

Introduction

Boxing is an intermittent sport characterized by short duration, high intensity bursts of activity involving the interplay of anaerobic (70%-80%) and aerobic (20%-30%) energy systems (1-3). It is classified into light (<54 kg), medium (<64 kg) and medium heavy (<75 kg) weight categories. The primary aim of conditioning for boxing is to delay the onset of fatigue by increasing tolerance of lactic acid build–up, escalating the ATP and CP, for improving the efficiency of oxygen usage, and to better the recovery between intense bursts of activities (4). The duration of competitive and amateur boxing is 11 min and it is structured on rounds with 1 min rest period which is often not enough to settle down the accumulated blood lactate (4). The work and rest ratio of the game is 3:1.

The performance of boxers depends on speed and coordination of movements, accuracy of movements during blows, force of blows and psychomotor abilities (4-5). Thus, the boxers develop speed, strength, endurance, agility, flexibility and the complex expression of coordination abilities during the course of the training (5-7).

Studies on elite Italian amateur boxers and on senior and junior England international amateur boxers, suggested that success in boxing performance depends not only on high individual anaerobic threshold and aerobic power but also on upper-body muscular strength as indicated by hand-grip strength (4). Boxing training depicted beneficial effects on various physiological and biochemical markers of fitness profile in elite Egyptian boxers (8). Elite Lithuanian boxers developed their explosive strength, speed, strength and speed exercises following boxing training (9).

Few selective fitness profile parameters of Indian national level boxers is available (2) but detailed data of fitness profile in Indian boxers, especially from Eastern region of India are unavailable.

The present study was therefore aimed to evaluate and compare the selective fitness profile parameters in light weight and medium weight male boxers of Kolkata, India. The study was further aimed to compare the data with their sedentary control group as well as with their national and international counterparts.

Material and Method

Study design. Subjects visited the laboratory for a total of 3 occasions with at least seven days' gap between the consecutive visits. Subjects were explained, demonstrated and familiarized with the experimental protocol on the first day of visit (Familiarization Trial) to allay their apprehension. Data were collected during the two Experimental Trial sessions which were conducted on the second and third days of visit, respectively. Body height, body weight, skinfold measurements, agility, flexibility and high intensity effort (HIE) were measured in the second visit, i.e., in the first Experimental Trial while pre-exercise heart rate, blood pressure, vertical jump test (VJT) and VO_{2max} were measured on the third day of visit, i.e., in the second Experimental Trial. The study was approved by the Human Ethical Committee, Department of Physiology, University of Calcutta and written informed consent was obtained from all the subjects.

Selection of Subjects. Male Boxers (experimental group or EG, n = 80) were selected from eminent boxing academies of Kolkata, India and their sedentary male counterparts (Control Group or CG, n=40) were recruited from the post graduate section of the University of Calcutta. All the subjects were non-smokers and belonged to same age group (20–25 years) with similar socio-economic background. The Boxer participants were divided into two groups depending upon the weight categories, the light weight Boxer group (LWB; <54 kg; n=40) and the medium weight Boxer group (MWB; <64 kg; n=40).

Each subject filled up one questionnaire to record their personal demographic data, health status and consent to participate in the study. Postgraduate students who were engaged in regular exercise or participated in any physical conditioning programme and individuals having history of any major diseases and undergoing treatment for the same were excluded from participation in the study.

Preparation of Subjects. Age of each subject was calculated in nearest year from the date of birth as obtained from their Photo ID issued by the Government of India. Subjects were instructed to have a light breakfast 2–3 hours before the trial. They came to the laboratory at 9 am and took rest for half an hour.

Measurements of body height and body mass were done with the subject standing barefoot and wearing minimum clothing on a weighing machine built-in with height measuring rod (Avery India Ltd, India) having an accuracy of ±0.50 cm and ±0.1 kg, respectively. Pre–exercise heart rate and blood pressure were also measured. Body surface area (BSA) and body mass index (BMI) were calculated from the following equations:

$$BSA\ (m^2) = (\text{Body mass in kg})^{0.425} \times (\text{Body height in cm})^{0.725} \times 0.007184 \quad (10)$$

$$BMI\ (kg/m^2) = (\text{Body mass in kg}) / (\text{Height in m})^2 \quad (11)$$

Determination of body composition. Skinfolds were measured with the help of Holtain Skinfold caliper (Holtain Ltd., UK) with constant tension to determine the different components of body composition by using the following equations:

$$\text{Body Density or BD (gm/cc)} = 1.10938 - 0.0008267(X_1) + 0.0000016(X_1)^2 - 0.00002574(X_2) \quad (12)$$

[Where: X_1= Sum of chest, abdominal and mid thigh skinfolds and X_2= Age in nearest years]

% Body fat or %fat= (495/BD) – 450 (13)

Subsequently total body fat, percentage of lean body mass and lean body mass was calculated using the following equations:

Total Body Fat or FM (kg) = (%fat / 100) x Body weight (kg)
%Lean Body Mass or %LBM (%) = 100 – %fat
Lean Body Mass or LBM (kg) = Body Mass (kg) – FM (kg)

Determination of maximum oxygen uptake or VO_{2max}. Cardiorespiratory fitness was measured in terms of VO_{2max} by incremental bicycle exercise followed by analysis of expired gas in Scholander micro-gas analyzer (14).

Determination of high-intensity effort (HIE). High-intensity effort (HIE) was determined by a 60-yard dash test (14). This test constitutes a shuttle run test of progressing distances.

Three marker cones were placed in three yard lines which were set at a distance of 5 yards apart. Participants began from one end, ran 5 yards and came back to the start line, then rushed immediately to the 10 yards mark and returned to the start line and finally rushed again to the 15 yards mark and returned to finish at the start line. 60 yards of total distance was thus accomplished by the participants who were instructed to touch the line with their finger tips at each turn, for a total of five touches in every step. The entire running time was recorded with the help of a stopwatch.

Determination of flexibility. Modified sit and reach test was employed to evaluate the flexibility (14). Subjects sat barefoot on the floor with legs stretched out straight ahead. The soles of the feet were placed flat against a wooden box while keeping both the knees locked and pressed flat to the floor. Hands were placed on top of each other or side by side with the palms facing downwards, the subjects bend to reach forward along the measuring line as far as possible, ensuring that the hands remained at the same level, not one reaching further forward than the other. The distance was recorded at the moment the subjects reached out the maximum possible distant point on the measuring line (scale). Subject was restricted from performing any jerky movement of the arm or shoulder while performing the test.

Measurement of Agility. Participants were asked to complete a shuttle run as fast as possible between two parallel lines which were set 30 feet apart. Two wooden blocks were placed behind the line opposite to the start line. Participants started the run from the start line to the other line and picked up one block and returned to place it behind the start line, and then again ran to pick up the second block and returned to place it back across the start line. The total time taken to complete this entire shuttle run test was recorded (14).

Determination of vertical jump test (VJT) score. Explosive strength of the leg muscles was assessed by VJT (15). Subject stood erect next to a wall with the arm extended fully over the head and reached the topmost position with completely extended fingers smeared in color with palm facing the wall. The feet were kept flat on the floor. At this posture, the spot marked with the most extended tip of the finger was noted. Then, the subject performed a spot jump as high as possible touching the wall at the maximum height of the jump. This spot was then marked as well and the difference between the marks was recorded as the vertical jump height.

Statistical Analysis. The data are presented as Mean ± SD. One way analysis of variance (ANOVA) was employed to test the significance of difference among the mean values of the measured variables among different groups. Following the detection of a significant main effect, Bonferroni's post–hoc analysis was performed to locate where the specific mean differences were laid. The level of significance was set at $p<0.05$. Pearson's product moment correlation coefficient (r) was computed to find out the relationship between physical parameters and different fitness profile parameters. Simple regression analysis was adopted to compute the prediction norms for physical fitness parameters from various anthropometric parameters and different components of body composition. Statistical package for social sciences (SPSS) Version16 was used for the entire statistical treatment of the data.

Results

The physical characteristics, physiological parameters and body composition of all the studied groups were presented in table 1 and table 2, respectively.

Table 1. Physical characteristics and physiological parameters of the studied population.

Group	Age (yrs)	Body Height (cm)	Body Weight (kg)	BMI ($kg.m^{-2}$)	BSA (m^2)	Heart rate (bpm)	Blood Pressure (mmHg) Systolic	Diastolic
Control (n=40)	22.73 ±0.88	167.18 ±4.41	60.24 ±9.17	21.52 ±2.83	1.65 ±0.12	78.60 ±5.88	117.75 ± 6.18	76.60 ± 6.10
LWB (n=40)	21.30 ±1.57	165.80 ±2.19	52.11 ±1.47 *	18.96 ±0.60 *	1.55 ±0.03*	68.83 ±5.87*	115.25 ± 5.50	65.70 ± 3.61*
MWB (n=40)	21.55 ±1.28	167.09 ±3.82	58.55 ±3.14#	20.99 ±1.53#	1.64 ±0.05#	69.95 ±5.63*	113.55 ± 6.04*	66.33 ± 4.97*

*Data were expressed as mean ±SD, bpm = beats per min, BMI=Body Mass Index, BSA=Body Surface Area, BP=Blood Pressure, SP=Systolic Pressure, DP=Diastolic Pressure, LWB= light weight Boxer, MWB= medium weight Boxer (*Significant at p<0.05 when compared with the sedentary control group; #Significant at p<0.05 when compared between LWB vs. MWB)*

Table 2. Body composition of the studied population

Group	**Sum of Skinfold** (mm)	**BD** ($gm.cc^{-1}$)	**FM** (kg)	**%Fat** (%)	**LBM** (kg)	**%LBM** (%)
Control (n=40)	37.85±6.18	1.07±0.004	6.48±1.84	10.65±1.87	53.76±7.73	89.35± 1.87
LWB (n=40)	24.30±2.59*	1.09±0.003*	1.33± 0.55*	2.54± 1.05*	50.78±1.55*	97.46± 1.05*
MWB (n=40)	32.20±3.18*#	1.08±0.002*#	5.16±0.69*#	8.81±0.98*#	53.38±2.81	91.19±0.98*#

Data were expressed as mean ±SD, BD=Body Density, FM=Fat Mass, LBM=Lean Body Mass, LWB= light weight Boxer, MWB= medium weight Boxer (*Significant at p<0.05 when compared with the sedentary control group; #Significant at p<0.05 when compared between LWB vs. MWB)

Age and body height did not show any significant inter-group variation but body weight and BMI were significantly higher and BSA was significantly lower in the LWB group in comparison to the CG. The body weight, BMI and BSA were also significantly higher in MWB group when compared to the LWB group. Pre exercise heart rate was significantly lower in LWB and MWB groups when compared to the CG. Systolic and diastolic blood pressures were significantly lower in the MWB when compared against the CG. However, systolic blood pressure of LWB did not show any significant variation although the diastolic blood pressure was significantly lower than the CG.

ANOVA depicted significant inter–group difference in the mean values of different skinfold measurements and these have been presented in figure 1. BD and %LBM were significantly higher in both the Boxer groups while sum of skinfolds, FM and %Fat were significantly lower in the LWB and MWB groups when compared to the CG. LBM was significantly lower in LWB compared to the CG. LWB and MWB had significant inter–group variation in sum of skinfolds, BD, FM, % Fat and % LBM. BD and %LBM were significantly lower contrary to the higher values of sum of skinfolds, FM and %Fat in MWB compared to the LWB. The aerobic capacity, HIE score and motor fitness parameters of EGs and CG were presented in table 3. Aerobic capacity expressed as absolute VO_{2max} revealed significantly higher value in both boxer groups compared to the CG. Absolute VO_{2max} was also found to be significantly higher in case of the MWB compared to the LWB. Aerobic capacity in terms of relative VO_{2max} was significantly higher in both the LWB and MWB compared to the CG. High intensity effort was significantly better in both the groups of Boxers in comparison to the CG. Flexibility, agility and VJT scores were also significantly higher in EGs. VJT was also found to be significantly higher in LWB when compared to the MWB. Results of the correlation statistic were presented in table 4 and 5.

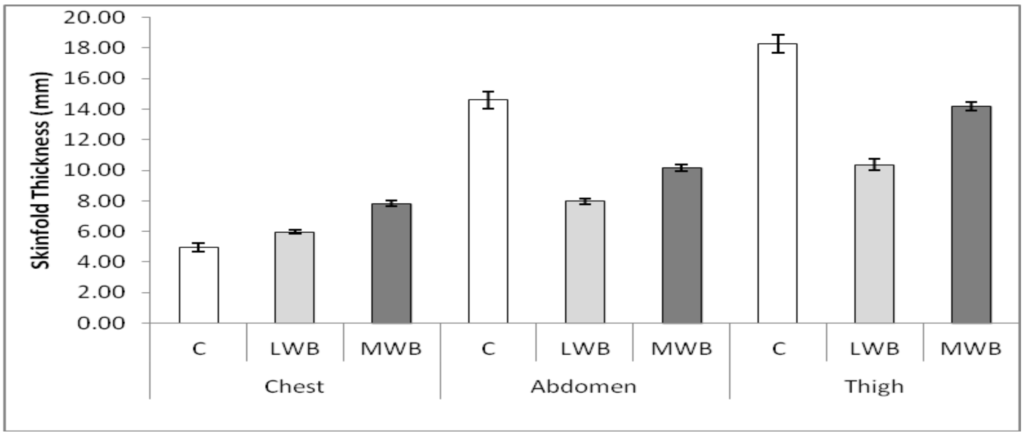

Figure 1. Skinfold thickness (chest,abdomen and thigh) of the studied population
☆Significant at p<0.05 when compared with the sedentary control group; ✦ Significant at p<0.05 when compared between LWB vs MWB

Table 3. Aerobic capacity, high intensity effort and motor fitness of the studied population.

Group	VO_{2max} (L. min^{-1})	(ml.kg^{-1}.min^{-1})	**HIE** (sec)	**Agility** (sec)	**Flexibility** (cm)	**VJT** (cm)
Control (n=40)	2.59±0.45	43.04±3.76	10.08±0.63	12.92±0.69	5.33±3.15	25.73±4.28
LWB (n=40)	3.01±0.24*	57.77±3.75 *	7.39±0.47 *	10.16±0.48 *	23.15±4.17 *	39.65±3.89 *
MWB (n=40)	3.50±0.43*#	59.73±4.81* #	7.48±0.60 *	10.30±0.64 *	24.38±6.90 *	36.33±3.17* #

Data were expressed as mean ±SD, HIE=High Intensity Effort, VJT=Vertical Jump Test, LWB= light weight Boxer, MWB= medium weight Boxer (Significant at p<0.05 when compared with the sedentary control group (# Significant at p<0.05 when compared between LWB vs. MWB)*

Table 4. Values of correlation coefficients between physical parameters, body composition measurements and VO_{2max} in the studied groups

Parameter	VO_{2max} L.min^{-1}			ml.kg^{-1}.min^{-1}		
	Control (n=40)	**LWB** (n=40)	**MWB** (n=40)	**Control** (n=40)	**LWB** (n=40)	**MWB** (n=40)
Age (yrs)	0.12	0.08	-0.14	0.04	0.10	-0.04
Body height (cm)	0.28	0.35*	-0.13	-0.21	0.26	-0.18
Body weight (kg)	0.87***	0.61 ***	0.83***	0.02	0.31	0.57***
BMI (kg.m^{-2})	0.86***	0.26	0.72***	0.11	0.06	0.54***
BSA (m^2)	0.82***	0.61 ***	0.61***	-0.03	0.36*	0.36*
BD (gm.cc^1)	-0.35*	0.16	-0.19	-0.03	0.17	-0.16
FM (kg)	0.73***	-0.13	0.51***	0.03	-0.16	0.37*
% Fat (%)	0.35*	-0.16	0.19	0.03	-0.17	0.16
LBM (kg)	0.86***	0.63 ***	0.81***	0.02	0.35*	0.55***
% LBM (%)	-0.35*	0.16	-0.19	-0.03	0.17	-0.16

*BMI=Body Mass Index, BSA=Body Surface Area, BD=Body Density, FM=Fat Mass, LBM=Lean Body Mass, LWB= light weight Boxer, MWB= medium weight Boxer (*p<0.05, **p<0.01 & ***p<0.001)*

Table 5. Values of correlation coefficients between body composition measurements and motor ability measurements in sedentary and boxer groups

Parameter	**Agility** (sec)			**Flexibility** (cm)			**VJT** (cm)		
	Control (n=40)	**LWB** (n=40)	**MWB** (n=40)	**Control** (n=40)	**LWB** (n=40)	**MWB** (n=40)	**Control** (n=40)	**LWB** (n=40)	**MWB** (n=40)
Age (yrs)	0.05	0.14	-0.36*	0.02	0.26	0.19	-0.09	0.01	-0.01
Body height (m)	-0.15	-0.31	0.12	0.14	0.55***	-0.04	-0.26	-0.28	-0.18
Body weight (kg)	0.29	-0.01	0.10	0.34*	0.23	-0.01	-0.25	-0.59 ***	-0.03
BMI (kg.m^{-2})	0.39*	0.25	-0.01	0.33*	-0.26	0.03	-0.17	-0.29	0.09
BSA (m^2)	0.22	-0.17	0.16	0.34*	0.45**	-0.04	-0.28	-0.56 ***	-0.14
FM (kg)	0.09	0.08	-0.04	0.37*	0.03	0.09	-0.04	-0.30	-0.05
%fat (%)	-0.01	0.09	-0.09	0.31	0.01	0.11	0.15	-0.26	-0.05
LBM (kg)	0.32*	-0.04	0.12	0.31	0.20	-0.04	-0.28	-0.45**	-0.02
%LBM (%)	0.01	-0.09	0.09	-0.31	-0.01	-0.11	-0.15	0.26	0.05

*LWB= light weight Boxer, MWB= medium weight Boxer (*p<0.05, **p<0.01 & ***p<0.001)*

Regression norms for the prediction of different fitness profile parameters from physical parameters and different components of body composition in all the studied groups were presented in table 6.

Table 6. Regression equations for prediction of VO_{2max} (absolute & relative), agility, VJT and flexibility in light weight Boxers, medium weight boxers and control group sedentary subjects

Parameter	Group	Regression Equation	r	SEE (Unit)
VO_{2max} ($L.min^{-1}$)	C	VO_{2max} =0.04 BW+0.01	0.87	0.22 $L.min^{-1}$
	C	VO_{2max} =0.14 BMI-0.35	0.86	0.23 $L.min^{-1}$
	C	VO_{2max} =3.07 BSA-2.49	0.82	0.26 $L.min^{-1}$
	C	VO_{2max} = -35.82 BD+41.09	-0.35	0.43 $L.min^{-1}$
	C	VO_{2max} =0.18 FM+1.44	0.73	0.31 $L.min^{-1}$
	C	VO_{2max} =0.08 PF+1.70	0.35	0.43 $L.min^{-1}$
	C	VO_{2max} = 0.05LBM-0.11	0.86	0.23 $L.min^{-1}$
	C	$VO2_{max}$ = -0.08 PLBM+10.08	-0.35	0.43 $L.min^{-1}$
	LWB	VO_{2max} =0.04 BH-3.42	0.35	0.23 $L.min^{-1}$
	LWB	VO_{2max} = 0.10BW-2.26	0.61	0.19 $L.min^{-1}$
	LWB	VO_{2max} = 5.38BSA-5.33	0.61	0.19 $L.min^{-1}$
	LWB	VO_{2max} = 0.10LBM-1.96	0.63	0.19 $L.min^{-1}$
	MWB	VO_{2max} =0.11 BW-3.11	0.83	0.24 $L.min^{-1}$
	MWB	VO_{2max} = 0.21BMI-0.89	0.72	0.30 $L.min^{-1}$
	MWB	VO_{2max} = 5.68BSA-5.79	0.61	0.34 $L.min^{-1}$
	MWB	VO_{2max} = 0.31FM+1.89	0.51	0.37 $L.min^{-1}$
	MWB	VO_{2max} = 0.12LBM-3.02	0.81	0.25 $L.min^{-1}$
VO_{2max} ($ml.kg^{-1}.min^{-1}$)	LWB	VO_{2max} =48.80BSA-17.83	0.36	3.55 $ml.kg^{-1}.min^{-1}$
	LWB	VO_{2max} = 0.86LBM+14.32	0.35	3.56 $ml.kg^{-1}.min^{-1}$
	MWB	VO_{2max} = 0.88BW+8.48	0.57	4.00 $ml.kg^{-1}.min^{-1}$
	MWB	VO_{2max} = 1.79BMI+22.13	0.54	4.09 $ml.kg^{-1}.min^{-1}$
	MWB	VO_{2max} = 38.53BSA-3.31	0.36	4.54 $ml.kg^{-1}.min^{-1}$
	MWB	VO_{2max} =2.59 FM+46.35	0.37	4.53 $ml.kg^{-1}.min^{-1}$
	MWB	VO_{2max} = 0.94LBM+9.68	0.55	4.08 $ml.kg^{-1}.min^{-1}$
Agility (sec)	C	Agility =0.10BMI+10.87	0.39	0.65 sec
	C	Agility =0.03LBM+11.39	0.32	0.67 sec
	MWB	Agility = -0.18Age+14.13	-0.36	0.61 sec
VJT (cm)	LWB	VJT = -1.56BW+120.77	-0.59	3.18 cm
	LWB	VJT = -78.66BSA+161.50	-0.56	3.28 cm
	LWB	VJT = -1.13LBM+97.19	-0.45	3.51 cm
Flexibility (cm)	C	Flexibility =0.12BW-1.66	0.34	3.00 cm
	C	Flexibility =0.37BMI-2.53	0.33	3.02 cm
	C	Flexibility =8.79BSA-9.21	0.34	3.00cm
	C	Flexibility =0.63FM+1.28	0.37	2.97 cm
	LWB	Flexibility =1.05BH-150.93	0.55	3.53 cm
	LWB	Flexibility =68.84BSA-83.50	0.45	3.77 cm

LWB = Light Weight Boxer group, MWB= Medium Weight Boxer group C = Control group, BW = body weight, BH= body height, BMI = body mass index, BSA = body surface area, FM = fat mass, PF = percent fat, LBM = lean body mass, PLBM = percent lean body mass.

Discussion

The essential objective of the present study was to assess and compare the various fitness profile parameters of trained boxers of two different weight categories viz. LWB and MWB and to compare the data with the age–matched healthy sedentary control group.

The other prime objective of the study was to investigate the relationship of fitness profile parameters with anthropometric measurements and different components of body composition in all the studied groups.

It was seen that the body weight, BMI, BSA, BD, %fat, FM and %LBM of both the categories of boxers differed markedly from the sedentary male counterparts. Gross size of an individual may be quantified on the basis of two major structural components viz. FM and LBM by means of estimation of body composition (12,13). %fat values obtained in the Boxer groups were much lower than the %fat value reported in North Indian LWB (12.2±1.1%) and MWB (11.6±0.9%) (2).

Existence of significantly higher value of LBM in sedentary group was due to the existence of significantly higher value of body weight in the sedentary group. The body composition in case of an athlete offers a better view for determining the desirable weight instead of using the standard height–weight–age table of normal population because of existence of high proportions of muscular content. (16,17).

Significant difference in pre exercise heart rate was noted in the present study and the value was significantly ($p<0.05$) higher in case of the sedentary control group in comparison to the experimental boxer groups. Lower resting HR has long been known as an indicator of better aerobic capacity (17) as also reflected in the present study with the finding of higher VO_{2max} score in athlete groups in comparison to the sedentary control subjects. The HR values of both the boxer groups were found to be slightly lower when compared against the Indian National boxers [LWB (71±9 beats.min^{-1}) and MWB (76±5 beats.min^{-1})] (2).

Physical activity has a high impact on well-being enhancement in athletic activities (18). Thus in keeping with the data recorded in the present study it can be said that boxing exercise accounts for improved cardiovascular well-being in trained athletes. Existence of the significantly lower values of pre-exercise HR in boxers might be attributed to the fact that long-term physical training influences cardiac rhythm by inducing sinus bradycardia in resting conditions, and a slower rise in heart rate at any level of submaximal oxygen uptake due to a swing of the sympatho-vagal balance towards parasympathetic dominance (19,20).

The VO_{2max} values obtained in the Boxer groups of the current study were higher than the Indian amateur boxers (1) but were almost similar with the Indian elite boxers (21). Higher value of VO_{2max} was also reported in senior national Boxers of England and Egypt (3,8). LWB of the present study had comparatively lower values of relative VO_{2max} (expressed in ml.kg^{-1}.min^{-1}) than the MWB and this finding corroborated with the study of Khanna et al., (2).

Literatures revealed that VO_{2max} was significantly higher in the boxers in comparison to the sedentary control group suggesting that like all other training regimens the boxing training also improved the cardiorespiratory fitness (1,2,4,8). Egyptian elite boxers started boxing training with a pre-training relative and absolute VO_{2max} values of 58.2 ml.kg^{-1}.min^{-1} and 4.65 l.min^{-1} respectively but after 8 weeks of boxing training program the relative and absolute VO_{2max} values were subsequently elevated to 64.6 ml/kg/min and 5.23 l.min^{-1} respectively (8).

VO_{2max} value of 8 Senior Italian middle weight (75kg) amateur boxers (57.5±6.9 ml.kg^{-1}.min^{-1}) was lower than the MWB of the present study (4). Differences in VO_{2max} between the groups might be in conformity with the type of training undertaken and the mean body weight of the boxers mentioned in each study. This hypothesis corroborated with the study of Ghosh et al. (1) that postulated lower values of VO_{2max} in Indian senior international amateur Boxers belonging to the heavier weight categories. Significantly lower value (49.8 ± 3.29 ml.kg^{-1}.min^{-1}) of relative VO_{2max} was noted in junior boxers (1).

The present study revealed that the light weight boxers and medium weight boxers possess better HIE or anaerobic capacity compared to their sedentary control counterparts.

The anaerobic capacity in Indian boxers showed significantly higher values in case of senior boxers as compared to junior boxers (2).

The study also revealed significantly better agility score in LWB and MWB compared to the sedentary control counterparts. Agility or coordinative abilities are understood as relatively stabilized and generalized patterns of motor control and regulation process (22). Agility, an essential component of motor fitness, improved in Boxers, indicating that their control over the movement of the body in cooperation with the body's sensory functions was much better than the sedentary control counterparts.

Moreover, significantly higher flexibility indicative of lower back muscle and hamstring muscle strength along with higher explosive power were observed in both the light weight class and medium weight class boxers compared to the control group. Comparison of the flexibility in boxers is restricted due to unavailability of data in this particular population.

Vertical jump score of athletes could be predicted by %fat which is related to the work performed during vertical jump (23). Previous researches suggested that a reduction of body fat by proper dietary planning would help to develop leg power (15, 24). LWB of the present study had significantly higher value of VJT score than the MWB. However, the VJT score that determines the explosive strength of the leg muscles was significantly higher in both the boxer groups than the sedentary control group. Boxing is a combat sport that involves forceful and explosive (e.g. punches, movements, changing pace etc) activities not only during the event but also during the training.

The power outputs during such activities are related to the strength of the muscles involved in the movements and that was perhaps the underlying cause for the boxers to have significantly higher VJT score. Trapezium muscle has been reported as the most active muscle in all fight actions (17) and it might also diminish the risk of injury (17). Skill for successful boxing includes abilities such as leg mobility, reaction time, strength and speed which produce power of movement while executing different types of punch (4). Thus the leg and back strength affect the boxing performance significantly. Participation in high level of strength training might also be largely responsible for higher flexibility and explosive power in the Boxers.

The value of correlation coefficient (r) of relative VO_{2max} and absolute VO_{2max} with the physical parameters were presented in Table 4.

Body weight, BMI and BSA had significant correlations with the absolute VO_{2max} in the sedentary CG. Body height, body weight and BSA revealed significant correlations with absolute VO_{2max}, while BSA was significantly correlated with relative VO_{2max} in the LWB. Body weight, BMI and BSA depicted significant correlations with absolute VO_{2max} and relative VO_{2max} in the MWB.

Correlation coefficient (r) values of relative VO_{2max} and absolute VO_{2max} with different components of body composition were also presented in Table 4.

Fat mass, % Fat, LBM and %LBM had significant correlations with the absolute VO_{2max} in the sedentary control group as also reported in earlier study (25). FM expressed significant correlation with the absolute VO_{2max} as well as relative VO_{2max} in case of the MWB. LBM showed significant correlation with both the absolute VO_{2max} and relative VO_{2max} in both the LWB and MWB. The findings corroborated with the earlier study which concluded that LBM always exerted facilitating action towards maximal oxygen uptake. (25)

The value of correlation coefficient (r) between different motor ability parameters and different components of body composition were presented in Table 5. Agility showed significant correlation with BMI and LBM in sedentary CG, with age for the MWB. Flexibility possessed significant correlations with body weight, BMI, BSA and fat mass in the sedentary CG while in the LWB group flexibility had significant correlation only with BSA parameter.

Body weight, BSA and LBM showed significant correlations with VJT score in the LWB. Studies relevant to the present investigation also revealed by means of one way ANOVA significant ($p<0.001$) difference in body mass, total body fat (TF), % Fat, lean body mass (LBM) and VJT score in boxers, swimmers as well as sedentary groups. (15)

Higher values of correlation coefficients were found in the boxer groups in comparison to the sedentary CG. Such closer association of fitness profile parameters and morphological parameters in the trained groups might be due to their participation in regular training regimens as also reported in earlier studies.

Depending on these significant correlations, simple regression equations were computed to predict the values of $VO_{2max,}$ and different parameters of motor fitness from physical parameters in both the groups of athletes as well as in the sedentary CG. The standard errors of estimates (SEE) were higher in the sedentary CG probably because of the lower values of correlation coefficients in that group in comparison to the experimental groups (LWB and MWB).

Conclusion

The study depicted that boxing training improved the general physical fitness profile in light and medium weight categories of Boxers as reflected from their significantly higher values of $VO_{2max,}$ HIE, agility, flexibility, VJT score, BD and %LBM as well as significantly lower values of pre exercise heart rate, diastolic blood pressure, %fat and FM.

The light weight Boxers and medium weight Boxers showed prominent intra–group differences in body weight, BMI, BSA, absolute VO_{2max}, VJT scores, BD, FM, %fat, and %LBM probably because of difference in their training pattern that was intimately related with the specific requirement of their respective weight category. Present study established that boxing exercise is capable of improving aerobic capacity that efficiently improved the Boxers' VO_{2max}. Different components of body composition and physical parameters were significantly correlated with VO_{2max} and motor fitness parameters although group variation existed in certain cases. Regression equations were computed for prediction of different fitness profile parameters in the studied groups. The present data will not only serve as a useful database of fitness profile parameters in eastern Indian Boxers but also will guide to promote and improve boxing training among them.

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Corresponding author
Amit Bandyopadhyay
Sports and Exercise Physiology Laboratory
Department of Physiology, University of Calcutta
University Colleges of Science and Technology
92, A. P. C. Road, Kolkata: 700009, India.
E-mail address: *bamit74@yahoo.co.in*

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