

The Maximal Oxygen Uptake of Sri Lankan Athletes

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Abstract : The maximum oxygen uptake (VO_2 max) which is regarded as the best criterion of cardio-respiratory fitness, was measured using sub-maximal workloads in 214 Sri Lankan athletes chosen from the national pools. The steady state heart rate (Fh) was determined electrocardiographically at the end of the sixth minute of a stepping exercise and the VO_2 max was predicted using the Astrand Ryhming Nomogram. The aerobic capacity (physical fitness) of the Swimmers, Footballers, Gymnasts, Hockey Players, Netball Players and the Rugby players was inferior to accepted international standards. Among the Athletes, the Army endurance runners and sprinters had an oxygen uptake of international standards, although the All Ceylon Athletes who were non-service personnel showed a significantly lower uptake. It was further found that the average duration of training of army athletes was almost double that of other athletes when their respective training schedules were analysed.

1. Introduction

It seems strange that Asians who constitute half of the world population have only a 2% chance of winning prizes at the Olympic games. There are several reasons for this anomaly, and diet, body build, training schedules, state aid, physical fitness are all contributory factors. But there is no doubt that the use of sophisticated research techniques to assess and improve physical fitness is a major factor which enables the developed countries to sweep the board at international athletic meets.

Although much work has been done in other countries regarding the physical assessment of their athletes, very little work has been done in Sri Lanka, regarding the assessment of physical fitness of Sri Lankan athletes.

Cullumbine⁴ measured the fitness index in 7000 Ceylonese subjects using post-exercise pulse rates. This method is, however, inaccurate⁷ and these recovery tests are seldom used now for assessing physical fitness. Other than for this work of Cullumbine and of Koch⁵ who assessed the vital capacity of University students, there has been no significant research done in this field for the past three decades.

Although many tests of physical fitness have been proposed, it is now recognised that the maximal oxygen uptake is the absolute criterion of cardio-respiratory fitness.^{2,9} The objective of this project was to determine the physical fitness of Sri Lankan athletes using the maximal oxygen uptake as an index of physical fitness, to compare them with international standards and to suggest methods of improving the physical fitness of these athletes.

2. Materials and Methods

The maximal oxygen uptake was predicted from the heart rate using the nomogram proposed by Astrand and Ryhming³ which was constructed on the postulate that the oxygen consumption and pulse rate are linearly related. A correction factor was applied for age as suggested by Astrand.¹

The workload used was a submaximal one which involved the climbing of steps (40 cm high for males and 33 cm high for females) at the rate of 20 ascents per minute for males and 15 ascents per minute for females, the rate being controlled by a metronome. Care was taken to see that the athletes stood erect at each ascent and placed both heels on the ground with each descent. The heart rate was recorded electrocardiographically throughout the duration of the exercise, which lasted six minutes.

As the pulse rate shows a pronounced circadian rhythm,⁶ the tests were carried out between 7 a.m. and 10 a.m. in a room where the temperature varied between 26°C and 28°C and the relative humidity varied between 60% and 70%.

The athletes chosen were from the national training pools and consisted of those who had or were representing the country in their respective sports or those who had taken part in the Ceylon Nationals. They were tested at the peak of their training schedules, a day or two prior to a meet.

The athletes were tested on an empty stomach, bare-bodied and bare-footed, clad only in physical training shorts and were advised to avoid unusually strenuous exertion the day prior to testing and to completely abstain from any strenuous activity on the day of testing.

They were rested supine on a bed for half an hour after which their resting pulse rates, systolic and diastolic blood pressures were recorded.

They were then asked to perform the stepping exercise without a preliminary warm-up period. The heart rate was calculated from the ECG, by measuring the distance between 7 R—waves (i.e. six intervals). Two consecutive heart rate recordings after the fifth minute which differed by no more than ± 5 beats was the criterion used to define the steady state.

The sports these athletes participated in were athletics (track and field), swimming, hockey, football, gymnastics, netball and rugby. They were all between 15 and 35 years of age.

3. Results

The physical fitness of the participants is calculated separately for each event.

3.1. Swimming

A total of seven males and seven females were examined. They were Ceylon's best swimmers and were examined just prior to the Indo-Ceylon meet. The details of their physical characteristics are shown in Table 1 (males) and Table 2 (females). In the swimming events, as bodyweight is supported, it is customary to express maximal oxygen uptake in litres per minute rather than in ml/kg/min.

TABLE 1. Swimming — Males (N = 7)

	Range	Mean	S.D.
Age (yrs)	13 — 24	16.4	3.6
Body Wt. (kg)	49 — 73	59.4	8.8
Rest. Ht. Rate/min	57 — 84	65.4	11.0
6th min Ht. Rate/min.	130.4—166.7	148.9	14.1
R.S.B.P. (mm Hg)	110 —130	120	7.1
R.D.B.P. (mm Hg)	68 — 85	75.9	6.1
VO ₂ Max (L/min)	2.1— 3.8	2.8	0.55

TABLE 2. Swimming — Females (N = 7)

	Range	Mean.	S.D.
Age (yrs)	13 — 16	14.1	1.2
Body Wt. (kg)	39 — 64.5	50.6	7.9
Rest. Ht. Rate/min	51 — 82.0	74	11.6
6th min. Ht. Rate/min	128.6—173.6	157.9	15.8
R.S.B.P. (mm Hg)	104 —130	114.3	8.4
R.D.B.P. (mm Hg)	68 — 84	72.3	5.8
VO ₂ Max (L/min)	1.6— 3.4	2.2	0.68

As all of them were students, their training was restricted to 1½ hours of swimming in the evenings. There were no body building or ground exercises included in their training schedules.

3.2. Hockey

36 hockey players from the national hockey pool were examined. There were 17 males and 19 females. The results of the 17 male players are shown in Table 3, while those of the female players are shown in Table 4.

TABLE 3. Hockey — Males (N = 17)

	Range	Mean	S.D.
Age (yrs)	17 — 21	18.3	0.99
Body Wt. (kg)	45 — 63	52.9	6.03
Rest. Ht. Rate/min	48 — 83	62.5	8.1
6th min Ht. Rate/min	129.6—154.4	142.5	7.3
R.S.B.P. (mm Hg)	100 —128	114.1	8.3
R.D.B.P. (mm Hg)	64 — 90	73	5.6
VO ₂ Max (ml/kg/min)	43.7 — 63.7	52.5	5.9

TABLE 4. Hockey — Females (N = 19)

	Range	Mean	S.D.
Age (yrs)	15 — 30	19.4	4.03
Body Wt. (kg)	36 — 61	46.7	5.5
Rest. Ht. Rate/min	58 — 96	77.0	12.7
6th min Ht. Rate/min	133.3—168.8	154.9	8.8
R.S.B.P. (mm Hg)	94 —146	111.8	10.3
R.D.B.P. (mm Hg)	52 — 84	71.6	8.9
VO ₂ Max (ml/kg/min)	32.8 — 55.7	44.0	6.3

The average duration of training of these male players was 2½ hours per day of which two hours was spent in playing hockey and acquiring its skills, while half an hour was spent in running and doing exercises. The females trained for 1½ hours each day, of which one hour was spent in playing hockey while ¼ hour was spent each in running and doing exercises.

Except for four players, they were all students, many of them from Jaffna schools.

3.3. Football

12 Navy football players who had reached the semi-finals of the Ceylon Football Association cup were investigated at the end of the football season. The details of their measurements are shown in Table 5. The average duration of training per day was 3 hours, of which two hours were spent in playing football while ½ an hour was spent in running and doing exercises.

TABLE 5. Football (N = 12)

	Range	Mean	S.D.
Age (yrs)	22 — 34	26.3	3.8
Body Wt. (kg)	50 — 68.5	60.3	4.9
Rest. Ht. Rate/min	50 — 64	58.5	4.1
6th min Ht. Rate/min	117.6—157.9	140.6	12.8
R.S.B.P. (mm Hg)	90 —124	103.5	9.7
R.D.B.P. (mm Hg)	50 — 76	67.3	8.7
VO ₂ Max (ml/kg/min)	41.1— 76.7	53.4	11.2

3.4. Gymnastics

13 male gymnasts from the pool were examined prior to the Indo-Ceylon meet (Table 6). The average duration of training per day was 3 hours, of which two hours were spent in running and doing body-building exercises.

TABLE 6. Gymnastics (N = 13)

	Range	Mean	S.D.
Age (yrs)	17 — 25	20	2.4
Body Wt. (kg)	40 — 65	52	6.5
Rest. Ht. Rate/min	52 — 72	61.8	6.1
6th min. Ht. Rate/ min	130.4—166.7	148.6	9.8
R.S.B.P. (mm Hg)	96 —137	115.3	11.4
R.D.B.P. (mm Hg)	60 — 80	69.8	6.2
VO ₂ Max (ml/kg/min)	37.9— 61.1	48.5	6.8

3.5. Netball

Twenty-five girls who formed the pool for the Sri Lanka netball team were examined (Table 7) just prior to their international match against Seychelles. Their average duration of training per day was two hours, of which about quarter of an hour was spent in doing exercises.

TABLE 7. Netball (N = 25)

	Range	Mean	S.D.
Age (yrs)	15 — 35	23.2	5.4
Body Wt. (kg)	40 — 60	48.6	5.4
Rest. Ht. Rate/min	48 — 84	67.9	8.2
6th min. Ht. Rate/min	136.4—184.9	160.2	11.6
R.S.B.P. (mm Hg)	90 —126	109.3	10.4
R.D.B.P. (mm Hg)	50 — 80	69.9	5.7
VO ₂ Max (ml/kg/min)	29.1— 60.5	40.2	8.0

3.6. Rugger

A total of 17 rugby players were examined. Of these, 9 players represented Sri Lanka in the International seven-a-side rugby tournament in Hong Kong. The remaining 8 players represented a leading Colombo rugby club—the Colombo Hockey and Football Club (C.H. and F.C.).

3.6.1. Seven-a-Side-Rugger

Their physical assessment is shown in Table 8. The average duration of training was 1½ hours per day. These players were mainly executives and staff officers.

TABLE 8. Rugger—Seven a side (N = 9)

	Range	Mean	S.D.
Age (yrs)	21 — 27	23.4	1.7
Body Wt. (kg)	56 — 76	64.6	7.2
Rest. Ht. Rate/min	54 — 82	61.1	8.7
6th min Ht. Rate/min	121 — 161.5	139.2	14.3
R.S.B.P. (mm Hg)	100 — 125	112.8	7.4
R.D.B.P. (mm Hg)	68 — 75	71.9	3.8
VO ₂ Max (ml/kg/min)	38.9 — 70	54.1	11.2

3.6.2. Club Rugger

The physical characteristics of these 8 players is shown in Table 9. The average duration of training per day was 1½ hours. Four of these players were employed while the other four came from upper middle-class families.

TABLE 9. Rugger — Club rugger (N = 8)

	Range	Mean	S.D.
Age (yrs)	18 — 29	21.5	4.2
Body Wt. (kg)	52 — 73.5	61.5	8.8
Rest. Ht. Rate/min	62 — 72	67.5	10.5
6th min. Ht. Rate/min	136.4 — 163.1	151	10.3
R.S.B.P. (mm Hg)	90 — 116	101.3	10.2
R.D.B.P. (mm Hg)	60 — 78	67.3	7.2
VO ₂ Max (ml/kg/min)	37.8 — 55	44.3	6.0

3.7. Athletes

A total of ninety-seven athletes were examined. These included 86 male athletes and 11 female athletes. Of these 97 athletes, 8 had participated in field events like the Javelin, Discus and Puttshot. Out of the 89 athletes who participated in track events, 67 (58 males and 9 females) were sprinters who had as their favoured event the 100m, 200m, 400m, 800m flat or hurdles.

22 athletes (20 males and 2 females) were long distance runners, who specialized in either the 1500m, 3000m, 5000m, 10,000m or the marathon road race—26 miles. Many had represented Sri Lanka in international meets, some held Ceylon records, others were winners of the Amateur Automobile Association (AAA) meet, the Junior Nationals, the Ceylon schools or the army meet.

The sprinters, army athletes, public school athletes, female athletes, long distance runners, and those athletes who participated in field events are considered separately.

3.7.1. Field Events

A total of 8 athletes fell into this group. They were males. Their characteristics are shown in Table 10.

TABLE 10. Male Athletes — Field events (N = 8)

	Range	Mean	S.D.
Age (yrs)	21 — 30	23.5	2.8
Body Wt. (kg)	59.6— 80	68.3	8.1
Rest. Ht. Rate/min	54 — 71	61.4	6.1
6th min. Ht. Rate/min	123.1—159.6	142.9	11.9
R.S.B.P. (mm Hg)	95 —112	107.1	5.4
R.D.B.P. (mm Hg)	60 — 96	70	11.7
VO ₂ Max (ml/kg/min)	38.8— 68.8	49.8	10.2

Their average duration of training per day was one and a quarter hours of which $\frac{1}{4}$ hour was spent doing weight-lifting exercises.

3.7.2. Female Athletes

There were 11 female athletes, 2 long distance runners and 8 sprinters. Their details are shown in Table 11. Their average duration of training per day was $1\frac{1}{2}$ hours in the evenings.

TABLE 11. Female Athletes (N = 11)

	Range	Mean	S.D.
Age (yrs)	16 — 29	24.3	4.1
Body Wt. (kg)	40 — 67.5	49.4	8.6
Rest. Ht. Rate/min	56 — 82	67.5	9.6
6th min. Ht. Rate/min	128.6—158	151	13.2
R.S.B.P. (mm Hg)	95 —116	106.5	7.0
R.D.B.P. (mm Hg)	60 — 90	73.3	7.6
VO ₂ Max (ml/kg/min)	33.3— 63.2	44.4	10.4

3.7.3. Army Sprinters

Twenty of the top sprinters from the army athletic pool were examined. They had all won their events either at the Army meet or at the Nationals. The results of their examination are shown in Table 12. The average duration of training per day was $2\frac{1}{2}$ hours.

TABLE 12. Army sprinters (N = 20)

	Range	Mean	S.D.
Age (yrs)	20 — 27	22.8	2.1
Body Wt. (kg)	51 — 66	58.4	4.3
Rest. Ht. Rate/min	52 — 72	56.6	5.8
6th min Ht. Rate/min	111.1—150	133.3	11.7
R.S.B.P. (mm Hg)	90 —120	110.3	8.7
R.D.B.P. (mm Hg)	50 — 80	66.4	7.7
VO ₂ Max (ml/kg/min)	45.8— 90.4	60.4	13.3

3.7.4. National Sprinters

A total of 17 sprinters were examined (Table 13). All of them were placed either in the Nationalised Services, AAA or Mercantile athletic meets, and some had represented Sri Lanka in the Indo-Ceylon Athletic meet.

TABLE 13. National sprinters (N = 17)

	Range	Mean	S.D.
Age (yrs)	19 — 31	24.4	3.4
Body Wt. (kg)	44 — 66	56.2	6.2
Rest. Ht. Rate/min	46 — 80	58.7	9.9
6th min Ht. Rate/min	120 — 162.2	143.7	11.1
R.S.B.P. (mm Hg)	85 — 118	102.9	9.3
R.D.B.P. (mm Hg)	60 — 76	68.7	4.8
VO ₂ Max (ml/kg/min)	38.5— 62.1	48.8	6.9

The average duration of training of these athletes was only 1½ hours each day.

3.7.5. Public School Sprinters

21 students who had won or who had been placed in the Public School or the Junior Nationals were examined. (Table 14).

TABLE 14. Public School sprinters (N = 21)

	Range	Mean	S.D.
Age (yrs)	15.4	18.5	2.1
Body Wt. (kg)	42.5— 60	49.7	4.2
Rest. Ht. Rate/min	48 — 80	62.8	9.1
6th min Ht. Rate/min	126.9—190.6	153.6	14.4
R.S.B.P. (mm Hg)	90 — 130	105.7	10.1
R.D.B.P. (mm Hg)	60 — 78	68.4	4.5
VO ₂ Max (ml/kg/min)	29.8— 67.8	46.5	0.6

The average duration of training per day of these schoolboys was 1½ hours.

3.7.6. Army Long Distance Runners

13 long distance runners who had won or had been placed in the 1500, 5000, 10,000 metres or marathon road race were investigated (Table 15).

The average duration of training per day was 3 hours.

TABLE 15. Army Long Distance runners (N = 13)

	Range	Mean	S.D.
Age (yrs)	22 — 29	25.2	2.2
Body Wt. (kg)	43 — 58.5	51.1	4.0
Rest. Ht. Rate/min	41 — 70	54.7	9.8
6th min Ht. Rate/min	95.5—152	121.4	19.7
R.S.B.P. (mm Hg)	100 —130	111.7	9.0
R.D.B.P. (mm Hg)	50 — 85	67.7	10.1
VO ₂ Max (ml/kg/min)	50 — 96.2	74.9	18.9

3.7.7. Long Distance Runners—Non-Service Personnel

7 long distance runners who were non-service personnel but who had been placed in one of the events at the Nationals were examined. Their results are shown in Table 16. The average duration of training per day was two hours.

TABLE 16. Long Distance runners — non-service personnel (N = 7)

	Range	Mean	S.D.
Age (yrs)	17 — 25	20.6	3.0
Body Wt. (kg)	45 — 63.5	52.6	6.5
Rest. Ht. Rate/min	47 — 90	62.4	13.9
6th min Ht. Rate/min	117.2—170.7	143.7	23.2
R.S.B.P. (mm Hg)	94 —130	106.9	12.2
R.D.B.P. (mm Hg)	60 — 80	69.9	6.4
VO ₂ Max (ml/kg/min)	34.7— 78.9	55.1	18.0

4. Discussion

The assessment of physical fitness of Sri Lankan athletes using maximal oxygen uptake as an index of physical fitness has not been performed earlier.

It has been shown by direct measurements of maximal oxygen uptake that the best physically trained athletes in endurance events have a maximal oxygen uptake in the region of 70 ml to 75 ml/kg/min for males and between 50 ml to 60 ml/kg/min for females. A maximal oxygen uptake of less than 42 ml/kg/min for a healthy young adult is a sign of poor physical fitness.⁸

Low resting heart rates and low sixth minute heart rates during submaximal exercise are also recognized criteria of physical fitness.

The physical fitness of the participants is calculated separately for each event.

4.1. Swimming

A total of seven males and seven females were examined. They were Ceylon's best swimmers and were examined just prior to the Indo-Ceylon meet. The details of their physical characteristics are shown in Table 1 (males) and Table 2 (females).

In the swimming events, as body weight is supported, it is customary to express maximal oxygen uptake in litres per minute rather than in ml/kg/min.

Their duration of training of $1\frac{3}{4}$ hours per day is inadequate. There were no body-building or ground exercises included in their training schedules.

4.2. Hockey

36 hockey players from the national hockey pool were examined. There were 17 males and 19 females. The results of the 17 male players are shown in Table 3, while those of the female players are shown in Table 4.

The average duration of training of these male players was $2\frac{1}{2}$ hours per day of which two hours was spent in playing hockey and acquiring its skills while half an hour was spent in running and doing exercises. The females trained for $1\frac{1}{2}$ hours each day of which one hour was spent in playing hockey while $\frac{1}{4}$ hour was spent each in running and doing exercises.

The uptake of these hockey players was fairly satisfactory compared to international standards and none of the male players had an uptake below 40 ml/kg/min. This could probably be attributed to their rigid training schedules and strict supervision by the coaches.

4.3. Football

12 Navy football players who had reached the semi-finals of the Ceylon Football Association (F.A.) cup were investigated at the end of the football season. The details in their measurements are shown in Table 5.

The average duration of training per day was 3 hours, of which two hours was spent in playing football while $\frac{1}{2}$ hour was spent in running and doing exercises. In spite of a three hour training schedule, their mean maximum oxygen uptake was low (53.4 ± 11.2 ml/kg/min) though none were below the unfit mark of 40 ml/kg/min.

4.4. Gymnastics

13 male gymnasts from the pool were examined prior to the Indo-Ceylon meet (Table 6). The average duration of training per day was 3 hours, of which two hours were spent in running and doing body-building exercises.

Although their duration of training was long, their uptakes were relatively low indicating a low endurance fitness. Two of them had uptakes below 40 ml/kg/min.

4.5. Netball

Twenty-five girls who formed the pool for the Sri Lanka netball team were examined (Table 7) just prior to their international match against Seychelles. Their average duration of training per day was two hours.

The mean age of these players (23.2 ± 5.4 years) was greater than those in other events and many of them were working mothers who had very little time for serious training.

4.6. Rugger

A total of 17 rugby players were examined. Of these, 9 players represented Sri Lanka in the International Seven-a-Side rugby tournament in Hong Kong. The remaining 8 players represented a leading Colombo rugby club—the C.H. and F.C.

4.6.1. Seven-a-side Rugger

Their physical assessment is shown in Table 8. The average duration of training was only $1\frac{1}{4}$ hours per day.

There were no schoolboys in this event and all players were employed, six of them being executives.

Although they constituted the best rugger players in the country, their mean maximum oxygen uptake was low (54.1 ± 11.2 ml/kg/min). This rugger team was unplaced in the international meet and their lack of physical fitness may account for their poor performance.

4.6.2. Club Rugger

The physical characteristics of these 8 players is shown in Table 9. Their average duration of training per day was $1\frac{1}{4}$ hours.

These players had a mean oxygen uptake of 44.3 ± 6.0 ml/kg/min which was far inferior to that of the seven-a-side players.

4.7. Athletes

A total of ninety-seven athletes were examined. These included 86 male athletes and 11 female athletes. Of these 97 athletes, 8 had participated in field events like the Javelin, Discus and Puttshot. Out of the 89 athletes who participated in track events, 67 (58 males and 9 females) were sprinters who had as their favoured event the 100m, 200m, 400m, 800m flat or hurdles.

22 athletes (20 males and 2 females) were long distance runners, who specialized in either the 1500m, 3000m, 5000m, 10,000m or the marathon road race—26 miles.

Many had represented Sri Lanka in international meets, some held Ceylon records, others were winners of the AAA meet, the Junior Nationals, the Ceylon Schools or the army meet.

The sprinters, army athletes, public school athletes, female athletes, long distance runners and those athletes who participated in field events are considered separately.

4.7.1. *Field Events*

A total of 8 male athletes fell into this group, their characteristics are shown in Table 10. Their average duration of training per day was $1\frac{1}{4}$ hours of which $\frac{1}{4}$ hour was spent doing weight-lifting exercises.

These athletes were among the heaviest examined (mean wt 68.3 ± 8.1 kg), their bigger muscle mass probably accounting for the reason why they had a higher mean oxygen uptake than the sprinters.

4.7.2. *Female Athletes*

There were 11 female athletes, 2 long distance runners and 8 sprinters. Their details are shown in Table 11. Their average duration of training per day was $1\frac{1}{2}$ hours in the evenings.

Two of these athletes were outstanding and had oxygen uptakes of 62.8 and 63.2 ml/kg/min. They were two of Ceylon's best female athletes who had represented Ceylon in several international athletic meets.

4.7.3. *National Sprinters*

A total of 17 sprinters were examined (Table 13). Their oxygen uptake was low mean $48.8 \text{ ml} \pm 6.9 \text{ ml/kg/min}$.

Their average duration of training was only $1\frac{1}{2}$ hours each day.

4.7.4. *Public School Sprinters*

21 students who had won or who had been placed in the Public Schools or the Junior nationals were examined (Table 14).

Their average duration of training per day was $1\frac{1}{2}$ hours.

4.7.5. *Army Sprinters*

Twenty of the top sprinters from the army athletic pool were examined. They had all won their events either at the army meet or at the Nationals. The results of their examination are shown in Table 12.

The mean oxygen uptake of these sprinters was 60.4 ml/kg/min—a relatively high value for Ceylonese athletes, significantly higher than the national and public school sprinters. Seven of these had an uptake of over 60 ml/kg/min and none were below the 40 ml/kg/min mark.

Their duration of training per day was almost double that of the other sprinters.

4.7.6. *National Long Distance Runners*

Seven long distance runners who were non-service personnel but who had been placed in one of the events at the nationals were examined. Their results are shown in Table 16. The average duration of training per day was two hours.

Their mean oxygen uptake ($55.1 \text{ ml} \pm 18.0 \text{ ml/kg/min}$) was lower than that of the army sprinters. Three of them had an uptake below 40 ml/kg/min indicating the poor physical endurance of these national runners.

4.7.7. *Army Long Distance Runners*

13 long distance runners who had won or had been placed in the 1500m, 5000m, 10,000m or marathon road race were investigated (Table 15). The average duration of training per day was 3 hours.

These athletes had the lowest resting heart rates in this series (mean 54.7 ± 9.8 per minute), five were below 50/min. Their mean sixth minute heart rates were also the lowest (121.4 ± 19.7 per minute) in this series. These are good indices of physical fitness. They had the highest mean oxygen uptake (74.9 ± 18.9 per minute) of all athletes examined. Nine had an uptake of over 60 ml/kg/min and none were below 40 ml/kg/min.

These army endurance runners also had the lowest mean body weight (51.1 ± 4.0 kg) of all the male athletes examined. It is well known that among athletes the lowest bodyweight is among endurance runners.

Their duration of training was at least three hours each day, which was double that of their non-service counterparts.

These results show the superiority of the army sprinters and army long distance runners over their non-service counterparts and stresses the importance of endurance training for the improvement of physical fitness of athletes.

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