World Academy of Science, Engineering and Technology
International Journal of Sport and Health Sciences
Vol:17, No:10, 2023

Investigation of Various Physical and Physiological Properties of Elite Male Ethiopian Distance Runners

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***Abstract*—**The purpose of this study was to investigate the key physical and physiological characteristics of 16 elite male Ethiopian national team distance runners, who have an average age of 28.1 ± 4.3 years, a height of 175.0 ± 5.6 cm, a weight of 59.1 ± 3.9 kg, a BMI of 19.6 ± 1.5, and training age of 10.1 ± 5.1 yrs. The average weekly distance is 196.3 ± 13.8 km, the average 10,000 m time is 27:14 ± 0.5 min sec, the average half marathon time is 59:30 ± 0.6 min sec, the average marathon time is 2:04:20 ± 2.7 hr min ss. In addition, the average Cooper test (12-minute run test) is 4525.4 ± 139.7 meters, and the average VO_2 max is 90.8 ± 3.1 ml/kg/m. All athletes have a high profile and compete on the international label, and according to the World Athletics athletes' ranking system in 2021, 56.3% of the 16 participants were platinum label status, while the remaining 43.7% were gold label status-completed an incremental treadmill test for the assessment of VO_2peak, submaximal running, lactate threshold and test during which they ran continuously at 21 km/h. The laboratory determined VO_2peak was 91.4 ± 1.7 mL/kg/min with anaerobic threshold of 74.2 ± 1.6 mL/min/kg and VO_2 max 81%. The speed at the Anaerobic Threshold (AT) is 15.9 ± 0.6 kmh and the altitude is 4.0%. The Respiratory Compensation Point (RCP) was reached at 88.7 ± 1.1 mL/min/kg and 97% of VO_2 max. On RCP, the speed is 17.6 ± 0.4 km/h and the altitude/slope are 5.5%, and the speed at Maximum effort is 19.5 ± 1.5 and the elevation is 6.0%. The data also suggest that Ethiopian distance top athletes have considerably higher VO_2 max values than those found in earlier research.

***Keywords*—**Long-distance running, Ethiopians, VO_2 max, World Athletics, Anthropometric.

I. Introduction

IN 1960, Abebe Bikila, 28 years old and unheralded, stunned the world by winning the Olympic marathon in the Rome Summer Olympic Games. He drew international notice not just for becoming the first African to win an Olympic gold medal, but also for running the race barefoot. He won his second gold medal at the 1964 Tokyo Olympics. He was the first athlete to successfully defend an Olympic marathon title after winning back-to-back Olympic marathons. He ran in world record time in both victories. Mamo Wolde, another Ethiopian marathon winner, competed in the 1968 Summer Olympic Games in Mexico. Since then, Ethiopia has dominated long-distance running contests. Miruth Yifter, known as "the shifter," rose to prominence in the 1970s and 1980s, winning both the 5,000 m and 10,000 m races in the 1980 Moscow Olympics. A flurry of world and Olympic champions appeared after 1990. During this period, Derartu Tulu, Gete Wame, Fatuma Roba, and Haile Gebrselassie began to win the world and Olympic titles. Fatuma Roba won the women's marathon in the 1996 Atlanta Olympics, while Derartu Tulu became the first black woman to win the 10,000 m. In 1992, she earned her first Olympic medal at the Barcelona Olympic Games. Then, in Sydney in 2000, she won her second 10,000 m Olympic gold medal. She also won a bronze medal at the 2004 Olympic Games in Athens. In Edmonton, Canada, Derartu Tulu, a 10,000 m specialist, won the IAAF world athletics championships in 2001. She also won silver in the 1995 IAAF World Athletics Championships in Gotenborg. During this time, the legendary Haile Gebrselassie rose to prominence and began to dominate distance competitions ranging from the 3000 m to the marathon. In the 5,000 m and 10,000 m, he won eight world championships and two Olympic crowns, setting 27 world records in the process.

After Haile Gebrselassie, a double and multiple world and Olympic champion, Kenenisa Bekele dominated the 5,000 m and 10,000 m for more than a decade, and he had never been beaten in the 10,000 m for ten years. He won 26 gold, three silver, and two bronze medals for his country on an international level. In both the 5000 m and 10,000 m, he held the world record. He is also the first athlete in history to win 11 gold medals at the World Cross Country Championships. Furthermore, he is presently the second fastest marathoner (2:01:41), having missed the world marathon record just by 2 seconds in 2019. Ethiopian female athletes have also won many World and Olympic titles, including Derartu Tulu, a two-time Olympic and one-time world winner. Tirunesh Dibaba is a three-time Olympic gold medalist, five-time world champion, four-time world cross-country champion, and two-time African champion gold medalist, with a total of 14 gold, 4 silver, and three bronze medals for her country on the international stage. Meseret Defar has won medals at the highest levels of international competition, including gold medals at the Olympic and World Championships in the 5000 m. She won the Olympic Games twice, the World Championships twice, the World Indoor Championships four times, the World Junior Championships twice, and the African Championships once. At the international level, she won 11 gold, 8 silver, and 3 bronze medals for Ethiopia. Ethiopian athletes such as Silesh Sihin, Almaz Ayana, Genzebe Dibaba, Asefa Mezgebu, Gezahegn Abera, Meselech Melkamu, Worknesh Kidane, Birhane Adere, Tariku Bekele, Gebre Egziabher Gebremariam and others have won gold, silver, and bronze medals at Olympic and world championships.

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Ethiopians are currently the fastest athletes in long-distance events of sports, including the 5,000 m, 10,000 m, half marathon, and marathon. For example, many races were canceled or postponed once COVID-19 began. However, on the 4th of October 2020, the London Marathon organizers organized the 40th Virgin Money London Marathon, which was exclusively open to top participants. In this race, five male and two female Ethiopian athletes participated. Surprisingly, the male Ethiopian athletes dominated over their longtime rivals from Kenya, and all Ethiopian athletes finished the race in the top 6 and the females finished in the top 3. Among the top 6 athletes, the second-placed athlete was from Kenya, but the rest are Ethiopian (1st, 3rd, 4th, 5th & 6th). This shows that Ethiopia is dominating the long-distance races even during difficult times.

Ethiopia and Kenya are multi-cultural and diverse countries with a diverse ethnic population, and many experts have determined that successful Ethiopian and Kenyan athletes came out from the same geographical location, region, and tribe [1]-[3]. Before the 2000s, most Ethiopian athletes representing Ethiopia in international competitions were from the same geographical location and ethnic group, i.e., Oromia, Arsi region. World-class distance athletes began to emerge from other regions, including Amhara and Tigrai, according to this research. Since 2012, ethnic Amhara athletes, like ethnic Oromo athletes, have dominated Ethiopian long distance athletics, and the country has been represented in international competition by athletes from every part of the country. In this study, the female profile of long-distance athletes in Ethiopia is examined. Some athletes are successful in track events and marathon events i.e., first start in track events and then change disciplines to marathons as they get older, and they are successful in both track events and road races [4], [5].

Many factors have been identified that influence success in long-distance running. The observation of significant relationships between VO_2 max [6]-[9], the proportion of slow-twitch fibers, the proportion of VO_2 max that can be utilized, and running economy has linked these and several other factors to their success [10], [11]. The physiological characteristics and abilities of the elite athlete develop from a combination of genetic predisposition and strenuous physical training [12], [13]. While we believe that these physiological factors are some of the most important determinants of athletic success, running events from the middle to long distances are dominated by East African black runners [7], [14]. East African (Ethiopia, Kenya, and Eritrea) Ethiopian distance runners may have a genotypic or phenotypic advantage [15]. Some researchers have looked for phenotypic differences between black and white endurance athletes from South Africa, Kenya, and Eritrea [16], [17]. Studies indicated that black runners had a higher percentage of their maximal oxygen consumption (VO_2 max) during a simulated treadmill marathon [16], [18]. A greater percentage of black runners had higher VO2 max values at a 10-km race pace than white runners, indicating that black endurance runners had lower blood lactate concentrations during submaximal exercise testing and a relatively high muscular lactic acid tolerance [19]-[21].

II. Methodology

A. Subjects

The study was carried out on 16 elite male distance athletes, who have an average age of 28.1 ± 4.3 years, height of 175.0 ± 5.6 cm, weight of 59.1 ± 3.9 kg, BMI of 20.1 ± 1.1, and training age of 10.1 ± 5.1 yrs. According to the athlete's training journal, the athlete covers 196.3 ± 13.8 kilometers every week. According to World Athletics (WA) athlete profile statistics, their personal bests for 10,000 meters, half marathon, and marathon are 27:14 ± 0.5 min: sec, 59:30 ± 0.6 min: sec, and 2:03:39 ± 0.02 hr: min: sec, respectively. In addition, the average Cooper test (12-minute run test) is 4526.4 ± 139.7 meters, and the average VO_2 max is determined from the 12-minute run result of 90.8 ± 3.1 ml/kg/m. The ethics committee at Gazi University gave their approval to the project. All the subjects were healthy and free from injury, and fill out a voluntary participation form, which was used to receive their written consent before participating in this study. The context of the study was briefed to participants, with all details.

At the time of the study, all athletes were mainly participating in half marathons and marathons, and national team athletes who have been representing Ethiopia in international competitions like African Championships, WA World Championships, World Cross Country Championships, and Olympic Games, and in platinum and gold label road races. All of them are medalists and top 20 athletes in the WA ranking system in 2021/2022. They were from different ethnic groups (Amhara, Oromo, Tigray, and others) throughout the nation. We can say all of them were high-altitude natives and have always lived in the high central plateau of the country (altitude varying from 2000 m to 3300 m), all of them live in Addis Ababa, the capital (altitude near 2500 m), and train up to 3300 m, Entoto. Altitude training includes long and road workouts in Sebeta (2356 m) and Sendafa (2514 m); interval and track workouts on the Adis Ababa Stadium's track, Ethiopian Sports Academy's track (2355 m), and Kenenisa Bekele's track in Sululta (2780 m); and slow and recovery training in Entoto (3300 m), Megenagna forest (2700 m), and Sendaf (2514 m).

B. Experimental Protocol

According to the guidelines of the institutional ethics committee of Gazi University, a written agreement was obtained from each subject, and the study was authorized by the Gazi university ethics committee. Athletes were informed about all the tests and the possible risks and discomfort involved. Each athlete signed a written informed consent before testing. Before the measurements were done, all the participants were warned about alcohol consumption and not exhausting themselves with heavy training a day before the study. There were no illnesses or injuries during the test, and the athletes trained at least more than 186 kilometers per week. On the same day, body composition, VO_2 max, and the Pulmonary Function Test (PFT) were all measured. First and foremost, the athletes' body composition was assessed without eating anything. The athletes were then encouraged to eat breakfast to continue the PFT, but they had to wait two hours before they could begin. The athletes were advised to measure their VO_2 max after the PFT was completed. In the 2021-2022 seasons, all athletes had Gold or Platinum status with WA. Their daily, weekly, and monthly training data were validated with each runner's coach, and during the time they attended different training facilities and competed internationally, performance results were noted from each athlete's records (WA Athlete Profile). The athletes were chosen in the top range based on the WA score. Since they were all top elite athletes, the personal bests (PB) for each athlete for the 10,000 m, 10k, 15k, 21k, and 42k races were gathered from their profiles in the WA data record. In this study, we estimated the athletes' 12-minute runs or Cooper Tests based on the races they completed on the track, and we obtained their results straight from the races.

C. Data Collection Tools

The respiratory function and respiratory muscle strength of the athletes were evaluated with a digital spirometer (Pony FX Cosmed, Italy). Digital standing scales with the model number TANITA MC-980 were used to measure the runners' anthropometric measurements, including height, weight, BMI, and body composition. The h/p cosmos Saturn Treadmill, Germany VO2 max (ml/min/Kg) was employed to test for athletes' VO2 max and other CPET parameters. The data collection devices, both h/p cosmos and Tanita Mc-980 body composition analyzer, were employed in Turkey Olympic Preparation Center (TOHM) in Ankara around 800 m altitude to determine CPET and PFT.

D. Data Collection

Before the PFT and CPET measurements were done, all the participants were required to avoid alcohol consumption and not exhaust themselves with heavy training a day before the study. Subjects undergo the following measurements, respectively: Height and weight measurement, body composition analysis, evaluation of breathing parameters (PFT), and finally CPET.

1. Anthropometric Data

Model TANITA MC-980 Body Composition Analyzer digital standing scales were used to determine results to the nearest 0.1 scales which were functioning in the universities, and Olympic Preparation Centers sports centers. This is the latest clinically accurate Multi-frequency BIA Technology that most researchers use. The MC 980 body composition analyzer sets a new performance standard in body composition analyzer with 8 electrodes to use 6 frequencies to allow high accuracy to measure each arm, leg, and trunk area. The flexible integrated Microsoft software enables easy download of the stored data via USB for comfortable data management and research analysis. The system is simple to use, and the Windows operating system's flexibility allows for complete data management and analysis for consultancy progress tracking. It is easy to use accessible easy-to-use touch screen making the MC 980 a reliable body composition analyzer. BMI was calculated as weight/height^2, with body mass in kilograms (kg) and height in meters (m). From their training diaries, the athletes' training characteristics, including the daily, weekly, monthly, and mesocycle of their training quantity, were noted. The information was double-checked with each runner's coach. Subjects were asked to explain the normal training week over the preceding 3 to 4 months, as well as other characteristics such as the altitude where they live and train (typically 2400-3300 mm in Ethiopia), previous training experience, and the number of hours of sleep. Using conventional equipment, the runners' body mass, height, and body mass index (BMI) were recorded, however, the TANITA Body Composition Analyzer Machine calculated itself automatically. The athletes' skinfold thickness was assessed at six different locations: the triceps, subscapula, supra-iliac, belly, anterior thigh, and supraspinal (Holtain, Crymych, UK). The elite professional runners wear only sports equipment and walk barefoot, and then stand on the TANITA MC 980 Body Composition Analyzer machine.

2. Respiratory Function Tests

Purpose of the Test: PFT is aimed to reveal the respiratory system problems that may exist by evaluating the respiratory parameters of the athletes.

a. Conceptual Framework

A PFT is a physiological test that shows the volume and flow of inhaled and exhaled air within a defined time function. Just as the blood pressure measurement is important in determining the general cardiovascular status, spirometry is indispensable in the evaluation of the general respiratory status [1], [22]. Compared to the general population, athletes show many different physiological characteristics. Athletes with better cardiovascular function, greater stroke volume, and high maximal cardiac output develop different physiological adaptations in the respiratory system. Many studies are comparing the respiratory functions of athletes and non-athlete and determining a significant difference between the groups [23], [24]. The resulting adaptations also vary according to the type of sport [25], [26].

b. PFT Data Collection

Athletes were informed before the tests. Before the tests, the athletes were asked to avoid eating for at least two hours, and they were allowed to rest for at least 15 minutes between each test. The tests were performed in a comfortable sitting position. During the tests, the athlete's nose was closed with a latch, and the athletes were asked to close the mouthpiece with their lips so that there was no gap at the edges of the mouth to prevent air from escaping from the spirometer mouthpiece. The tests were performed by performing respiratory maneuvers over the spirometer mouthpiece. Before the tests, a few trial tests were made to understand the application and adapt it to the device. Each test was applied three times and the best measurement score was used [21], [25].

c. Application of PFT Tests

Forced vital capacity maneuvers and maximal minute ventilation tests were applied to evaluate the respiratory functions of the athletes.

During the forced vital capacity maneuver, the athlete was first asked to take a deep breath, when the athlete reached the point where he/she could no longer breathe, to expel all the air in his lungs quickly, forcefully, and for a long time, and then to take a deep breath again. As a result of the test; forced vital capacity (FVC), forced expiratory volume in 1 second (FEV1), FEV1/FVC, peak expiratory flow (PEF), and forced mid-expiratory flow rate (FEF25-75) values were obtained.

During the maximal minute ventilation (MVV) test, the athlete was asked to breathe deeply, quickly, and forcefully for 12 seconds. At the end of the test, the athlete was asked to hold his breath for a few seconds so that the maneuver performed would not cause respiratory alkalosis, and the MVV value was obtained.

Maximum inspiratory pressure (MIP) and maximum expiratory pressure (MEP) tests were applied to evaluate the strength of respiratory muscles. For the MIP test, the athlete must first completely evacuate the air in his or her lungs; followed by deep, rapid, and vigorous full breathing. For the MEP test, he/she was first asked to fill his lungs with air, and then to exhale quickly and strongly [39].

3. CPET Determining VO2 max

The h/p cosmos Saturn Treadmill, Germany VO2 max (ml/min/kg) was employed to test for athletes. All subjects completed a continuous graded exercise test on a treadmill (h/p cosmos Saturn Treadmill, Germany) to determine their maximal oxygen consumption (VO2 max) and ventilator threshold (VT). Heart Rate, gas exchange, and ventilation were also measured with this device. This CPET test machine is nice for stability, validity, and reliability. The quality of this treadmill is also extraordinary, and it is a very useful tool for this study. This treadmill machine can analyze and interpret data by itself. Measurements were carried out in the Physiology Laboratories of the universities and the Olympic Preparation Centre. Weight, height, and BMI measurements, as well as a complete resting PFT, were conducted before the activity challenge (h/p Cosmos, Germany). The day before testing, runners were advised to get plenty of rest and engage in an extremely little exercise. Before the running tests, all athletes received intensive treadmill training, including exposure to both low- and high-speed running. On a treadmill (h/p cosmos Saturn, Germany), the CPET was carried out utilizing the sub-maximal and maximal incremental exercise test procedure [27]. The treadmill's elevation remained constant at 0.5% during the test, and the exercise protocol consisted of 1.5-min stages with workload increments of 1 km/h (speed) until the subject attained a speed of 14 or 15 km/h, depending on the runner's best 10 k run time (about 70% of VO_2 peak). To ensure steady state conditions, this work rate (speed) was maintained for 5 minutes (verified by unchanged HR and VO_2 for at least two consecutive minutes). The 1-min stages procedure with speed increments of 1 km/h was then resumed after the constant-sub-maximal stage (keeping the slope constant) until the patient attained his maximum acceptable exertion (typical total CPET time was 17-18 min). Runners were considered to have reached their peak performance when at least two of the following conditions were met: 1) A plateau in 2 in the test's final two phases; 2) HR within 10 beats/min of age-predicted maximum heart rate; 3) End-tidal partial pressure for carbon dioxide (PETCO2) down sloping throughout the last two minutes of the test; and 4) Respiratory exchange ratio (RER) ≥ 1.15 (220-age). According to the linear relationship between oxygen consumption and speed throughout the incremental test, a plateau in 2 was defined as less than half the expected rise in oxygen consumption for the workload. When these requirements were not met, the athletes were required to retake the test and received verbal coaching throughout to improve their results.

a. Data Analysis

Standard descriptive statistics such as mean and standard deviation were used to present participant characteristics for all variables. Standard descriptive statistics (mean, s, and range) were used to present the characteristics of the subjects for all directly measured and derived variables. All analyses were carried out using SPSS version 28.0.01

IV. Results

The physical, physiological, and performance characteristics, as well as the athletes' training profiles, are presented in Table I. The physical characteristics, Cooper test (12 minutes run test), fat Percentage (%BF), athlete label status, rank position, WA score, and PBs were all described. Athletes run more than 196.3 ± 13.8 k/week. Multiple pace calculators were used to determining the average speed (km/hr) of each distance athlete. In this study, we used the athletes' best times from each event from their international races. The athletes' training ages were taken after they were registered as professional athletes with WA.

PBs of the respective mean (± SD) 10 k, 15k, half marathon and marathon run time of the ET athletes were 12:56 (2.35 pace) ± 0.1, 27:17 (2:43 pace) ± 0.1, 41.50 (2.47 pace) ± 0.4, 59:30 (2.48 pace) ± 0.6, 2:04:20 (2.57 pace) ± 2.7, respectively. We also calculated their Cooper test by analyzing the results of their performances in international competitions like the World Championship, Olympic Games, and Diamond League races (see Table I).

In this study, PFT and CPET were measured and given in tables and graphs. We measured the athletes' maximum oxygen uptake (VO2 max) and CPET variables on a h/p cosmos Saturn Treadmill, Germany VO2 max (ml/min/Kg) in the lab (see Table II). In Table II and Fig. 1 PFT variables were presented.

Training Characteristics

Typically, most athletes compete in long-distance events first training and competing in track and cross-country races before moving on to half marathon and marathon races. As shown in Table I, the average training age of the participant (10.1 ± 5.1 years) and athletes' weekly training distance were 196.3 ± 13.8 km. Each runner's training data were taken from their training log and noted. The accuracy of the data was confirmed by each runner's coach. Most athletes work out twice daily—once in the morning and once in the afternoon—and we added up each session plan for 6 or 7 days of training per week to calculate the weakly training volume. As a result, it is simple for us to determine the weekly training distance. Ethiopian Athletes frequently train at high altitudes at speeds and long runs of more than 200 kilometers per week. Their training includes interval training such as 10 * 1 km or 30 * 1 min fast runs with a minute of jogging in between sets. Long runs are a critical part of an athlete's weekly training schedule [28]. The distances of these long runs can range from 25 km to 40 km. They also regularly complete 30 km and even 40 km training runs that begin slowly but end like a race pace.

TABLE I
THE PHYSICAL CHARACTERISTICS AND TRAINING PROFILES OF ETHIOPIAN MALE RUNNERS OVER 10K, 15K, HALF MARATHON, AND MARATHON DISTANCES (n=16)

	Mean	Sd
Age, yrs.	28.1	4.3
Hight, m	172.3	4.4
Mass, kg	59.4	4.5
BMI, kg/m^2	20.1	1.1
Fat Percentage (%BF)	5.8	4.6
Skinfold Thickness (6 sites)	28.8	1.4
Training age, yrs.	10.1	5.1
Weekly Distance. Miles	196.3	13.8
5,000m PB time, min: sec	12.56 (2:35 pace)	0.1
10k PB time, min: sec	27:14 (2:43 pace)	0.5
10k Average Speed (km/hr)	21.935	0.5
15k PB time, min:sec	41.50 (2.47 pace)	0.4
15k Average Speed (km/hr)	21.510	0.4
HM PB time,min:sec	59.30 (2.49 pace)	0.6
HM Average Speed (km/hr)	21,290	0.9
Marathon PB time, hr:min: sec	2:04:20 (2.57 pace)	2.7
M Average Speed (km/hr)	21,05	2.7
12 Minutes Run Test	4526.4	139.7
Calculated VO2 max from Cooper Test	89.9	1.8
RRRS 2021/2022	P&G	-
WARS 2021/2022	1264.2	25.5
WARP 2021/2022	5.7	3.0

BF = Body Fat, HM = Half Marathon, M = Marathon, WARS = World Athletics Result Score, WARP = World Athletics Ranking Position, P = Platinum Label, G = Gold Label, WR = World Ranking, RRRS = Road Race Running Status, RT = Run Test.

Anthropometry

The BMI, height, and weight of the subjects were all measured, together with 6 skinfold measurements (triceps, subscapular, supra-iliac, abdominal, front thigh, and median calf) using standard equipment (Holtain, Crymych, UK), using anatomical reference points as described elsewhere [29]. The ages of athletes are 28.1 ± 4.3, their heights were 172.3 ± 4.4, their weights were 59.4 ± 4.5, and with BMIs of 20.1 ± 1.1 (Table I). Athletes' skinfold thickness in 6 sites were 28.8 ± 1.4 mm. Table I shows the physical and performance characteristics of the groups, as well as their training profiles.

Athletes' Profile and Label Status of Athletes at WA

Athletes' Profile, PB, Label Status, and 2021/2022 world ranking position of athletes at WA [30] were described in Table I. The athletes in this study run 5,000 m to marathon on the road and the track, but their results on the track are better than their performance on the road while they run 5.000 m and 10,000 m on the track or 5k and 10k on the roads. Athletes' mean (SD) 5k, 10k, 15k, 21k, and 42k run times were 12:56 ± 00:01 min: sec, 27:14 ± 00:05 min: sec, 41.50 ± 00:4 mm: sec, 59:30 ± 00.06 min: sec, 2:04:20 ± 00:02:07 hr: min: sec. All athletes have high label status, which consists of platinum and gold label athletes and the athletes' average World, Athletics Scoring (WAS) is 1264.2 ± 25.5. In terms of World Athletics Ranking Position (WARP), athletes ranked in the top 12. The RRRS, WARS, and WARP are determined by the athletes' performance in international events, as determined by WA. According to WA road race running status (RRRS), athletes were gold label and Platinum label status.

According to the WA Scoring Table of athletics, 1400 points is the maximum point for all events. Therefore, the athletes' score (see Table I) is out of 1400 m [31]. But it has different scoring rules based on sex and type of events. These athletes are track and road race athletes. The ranking system is based on two important aspects of all athletics performances: athletes' measurable results score and their placement score during competitions. The athletes' performance score for each competition is calculated by combining these criteria. The Performance Score is generated by combining the Outcome and Placing Scores. As a result, WA has assigned them the top ranking position based on their performance. Road Race Running Label status of the athletes is also given by WA every year. According to WA, there are 4 labels: Platinum, Gold, Silver, and Bronze. An athlete's Status is determined by how he/she ranks in the event group(s) of the WA World Rankings relevant to the race applying for the Label. Such event groups are how elite athletes can obtain their Gold/Silver/Bronze Status. Most of the athletes who were part of this study are Platinum and Gold Label.

Kenenisa Bekele of Ethiopia was the world record holder in the 5,000 m (12:37:35) in 2004 and the 10,000 m (26:17:53) in 2005 for men. According to WA score points, Bekele has 1294 points in the 5000 m and 1295 points in the 10,000 m out of 1400. Bekele's PB in the marathon is 2:01:41 just 2 seconds different from the world record-holder of Kipchoge and his score is 1302 [15]. For the women, Ethiopia's Letesenbet Gidey has four world records in the 5,000 m (14:06), 10,000 m (29:01), 15k (44:20), and 21 km (1:02.52), with results scores of 1269, 1303, 1274, and 1281, respectively. World Athletics has taken on the task of developing a worldwide ranking system in which competitors receive points based on their performance and placement in competitions of several levels. All athletes who compete in global athletics-certified races have their RRRS, WARS, and WARP values established by world athletics. Thus, information about the athletes who took part in this study was obtained from the world athletics website [31].

Cooper Result/ 12-Minute Run Result

Ethiopian male athletes covered 4526.4 ± 139.7 meters in the 12 minutes run test. We have already determined the athletes' VO2 max values from a treadmill test in the lab (see Table II). In the cooper test in this study, the athletes were already professional athletes, and we have already had their 12 minutes run results in WA athletes' results and PBs from WA athletes' data [32]. For instance, we could find the results of the WA athletes' 5000-meter personal records. As a result, we were able to compute the distance they run in 12 minutes from their PB of 5000 meters, and we recorded their results in Table I. We could determine the athletes' 12-minute run distance using the 5000-meter race results in addition to seeing a video of an international competition put on by world athletics. As a result, we used the general formula VO2 Max= (Distance covered in 12 minutes - 504.9)/44.73 to calculate the VO2 Cooper test rather than the 400-meter track test: For instance, in 2004 at Hengelo, Netherlands, Kenenisa Bekele raced the 5000 m in 12:37.35 [32]. Therefore, Bekele completed 4780 meters in 12 minutes, and his VO2 max is equal to (95.6 ml/kg/min) = (4780-504.9)/44.73. The average distance covered by runners in this study was 4526.4 meters. As a result, the runners' average VO2 max was calculated as follows: (4526.4 - 504.9) / 44.73 = 89.9 0.8 ml/kg/min.

Cooper's (1968) test assessment of normative data stated that running more than 2700 meters for men and more than 2000 meters for women runners in 12 minutes is considered to be good [33], [34]. The Cooper Test (Cooper 1968) was used to check an athlete's aerobic endurance progress and determine their maximum oxygen consumption [35]-[37]. We estimate an athlete's VO2 max as follows: (distance covered in meters - 504.9)/44.73 [48]. For example, Kenenisa Bekele covers 4800 m in 12 minutes and his VO2 max estimate will be 96.0 ml/kg/min. According to the athletes' performance results in WA, Ethiopian runners covered an incredible distance in 12 minutes, which was 4526.4 ± 139.7 meters. The 12 minutes run the athletes' cover in their competition suggested that Ethiopian elite athletes had a high VO2 max (mL/kg/min) at all speeds.

The athletes' VO2 max was also determined by a h/p cosmos Saturn Treadmill. The VO2 max test results in both methods were very close. According to previous research, the treadmill test can be used to estimate the athletes' VO2 max which is ideal for endurance sports [34], [38].

TABLE II
THE RUNNERS' RESTING PULMONARY FUNCTIONS TEST RESULT

Parameter	Measurement	Normal	between	expected	%Expected	Z score
FVC	L	4.05 ± 0.4	2,94 - 4,95	3,96 ± 0.02	102.1 ±	0.15
FEV1	L	3.57 ± 0.5	2,50 - 4,18	4,25 ± 0.02	84.0 ± 1.4	-1,06
FEV1/FVC%		88,3 ± 6.8	69,8 - 93,4	81,6 ± 5.6	108.3 ± 9.0	0,93
PEF	L/s	4,36 ± 0.07	7,14 - 11,12	9,13 ± 1.2	47.8 ± 1.4	-4,77
FEF25-75%	L/s	2,65 ± 0.1	2,92 - 6,34	4,63 ± 0.04	57 ± 4.2	-1,90
MEF25%	L/s	1,50 ± 0.1	0,96 - 3,52	2,24 ± 0.3	67 ± 2.8	-0,95
MEF50%	L/s	3,09 ± 0.3	2,88 - 7,23	5,06 ± 1.5	61 ± 3.2	-1,49
MEF75%	L/S	3.2 ± 0.1	5,02-10.65	8,06 ± 0.04	40.0 ± 0.7	-1.57
MVV	L/min	23.6 ± 1.2	---	136.7		
MEP cm H2O	-	122	>96	153	79.7	-1.08
MIP cm H2O	-	92	>58	110	83.6	-0.55
FET100%	S	5,3 ± 0.3	---	-	-	
PEFT	Ms	323 ± 106.0	---	-	-	
VEXT	mL	215.5 ± 37.	---	-	-	

FVC = Force vital capacity; FEV1 = Force expiratory volume in one second; %pred. = Percent of predicted value. FVC, FEV1, FEV1/FVC, and FEF25-75 were pulmonary measurements.

Pulmonary function normal ranges vary from athlete to athlete and person to person. It is generally assumed that an athlete would breathe better than a non-athlete [39]. How much air you are inhaling and exhaling relies on your pulmonary function, which is influenced by your age, height, gender, and race [26]. The results are also compared to any previous test results you may have had, even though in this situation we do not have the subject's prior pulmonary function test results. In general, additional testing may be required if the PFT measures are abnormal or if the results have changed.

The VO2 max of Ethiopian athletes competing in distance races varies from person to person and athlete to athlete. In both male and female athletes, the Ethiopian athletes' VO2 max (ml/kg/min) was substantially higher than the other groups' values.

V. DISCUSSION AND CONCLUSION

As shown on the Fig. 2 and Table III, the average peak exercise respiratory change rate (RQ) is 1.13; the estimated heart rate (HR) is 99%, and the maximum Perceived Strain Rate for dyspnea for leg pain ll indicate an increase [49], [50]. Maximal oxygen uptake is 90.9 ± 1.7 mL/min/kg, which is normal. According to the American College of Sports Medicine (ACSM) guidelines [49], exercise capacity was found to be Superior (99° %). AT of 74.2 ± 1.6 mL/min/kg and VO2 max 81%. The level for AT state is 4.0% incline on thread mill, and the submaximal point was reached at 88.7 ±

1.1 mL/min/kg and 97% of VO2 max. On RCP, the speed is 17.6 ± 0.4 km/h and the altitude/slope is 5.5%, the speed at maximum effort is 19.5 ± 1.5 and the elevation is 6.0%.

TABLE III
MEAN (± SD) MEASURED PHYSIOLOGICAL VARIABLES OF ATHLETES DURING AT, RCP, SUBMAXIMAL AND MAXIMUM (PEAK) TREADMILL TEST

Protocol	Measurement	Warm up	Anaerobic Threshold	Submaximal	Maximum
T	S		1:35 - 2:10	17:55 - 1:05	7:19 - 1:45
Speed	Kmh	6,00	14 - 16	17.6 ± 0.4	19.5 ± 1.5
Grade	%	0,0	4,0	5,5	6,0
Metabolic Variables					
VO2	mL/min	1730.2 ± 88.1	3714.2 ± 105.1	4433.4 ± 125.6	4601.4 ± 112.0
VO2/Kg	mL/min/Kg	34.6 ± 1.2	74.2 ± 1.6	88.7 ± 1.1	90.8 ± 1.7
METS	------	9.9 ± 1.0	21.2 ± 0.3	25.3 ± 1.2	26.6 ± 0.9
RQ	------	0.85 ± 0.08	0.90 ± 0.04	1.05 ± 0.03	1.10 ± 0.07
Ventilation Variables					
VE_ergo	L/min	47.4 ± 3.2	89.1 ± 11.1	120.3 ± 7.6	128.9 ± 10.1
BR	%		33.6 ± 10.3	10.5 ± 9.2	4.5 ± 7.3
VT	L(BTPS)	1.17 ± 0.12	1.64 ± 0.13	1.90 ± 0.97	1.98 ± 0.11
Rf	1/min	40.6 ± 5.3	54.4 ± 2.7	63.2 ± 3.3	65.2 ± 1.2
Cardiovascular Variables					
HR	Bpm	108.3 ± 3.3	155 ± 6.5	183 ± 1.3	188 ± 1.1
HRR	Bpm	7.5 ± 4.2	-------	------	-------
HRR_1_min	Bpm	44.3 ± 7.5			24.7± 2.4
VO2/HR	mL/beatpm	15.9 ± 1.1	23.9 ± 1.5	24.2 ± 2.2	
Gas Exchange change Varaiables					
VO2@AT mL/min	3714.2 ±105.1				
PETCO2 mmHg		37 ± 4.2	41.8 ± 4.7	44 ± 1.2	45 ± 1.6
PetO2mmHg		3,95 ± 95	91 ± 5.3	4.2 ± 93	94 ± 3.1
VE/VO2 ---			23.0 ± 3.2	26.1 ± 3.4	27.7 ± 3.5
VE/VCO2 ---			25.5 ± 4.1	24.9 ± 3.1	24.8 ± 2.4

Note: VO2 = oxygen uptake; VO2 max = Maximum oxygen uptake; METs = metabolic equivalents; RER/RQ = Respiratory Exchange Ratio/Respiratory Quotient; VE = pulmonary ventilation/minute ventilation; BR = breathing reserve; VT = Ventilatory Threshold; RR/f = Respiratory Rate/frequency HR = Maximum Heart Rate; HRR = Heart Rate Recovery; HRR_1_minute = Heart Rate Recovery 1 minute after peak exercise; RHR = Resting Heart Rate; BPS/D = Systolic/Diastolic Blood Pressure; VO2/HR = O2 pulse, VO2@AT = Oxygen Uptake at Anaerobic Threshold, VCO2 = carbon dioxide output; PETCO2 = end-tidal partial pressure for carbon dioxide; PETO2 = end-tidal partial pressure for oxygen; VE/VO2 = Ventilatory equivalents for oxygen; VE/VCO2 = ventilatory equivalent for CO2; BF = breathing frequency; RC = Respiratory Compensation; PEAKVO2: oxygen consumption at peak exertion; VO2 AT: oxygen consumption at anaerobic threshold.

Metabolic variables: VO2 (mL/min), VO2 Max (ml/kg/min) METs and RQ; Ventilatory Variables: VE_ergo (L/min), BR (%), VT L(btps) and RF (1/min); Cardiovascular Variables: HRmax (pm), HRR_1_min (bpm), RHR (bpm), BPS/D (mmHg) and VO2/HRmax (L/bpm); Gas Exchange: PETCO2 (mmHg), PETO2 (mmHg), VE/VO2 and VE/VCO2.

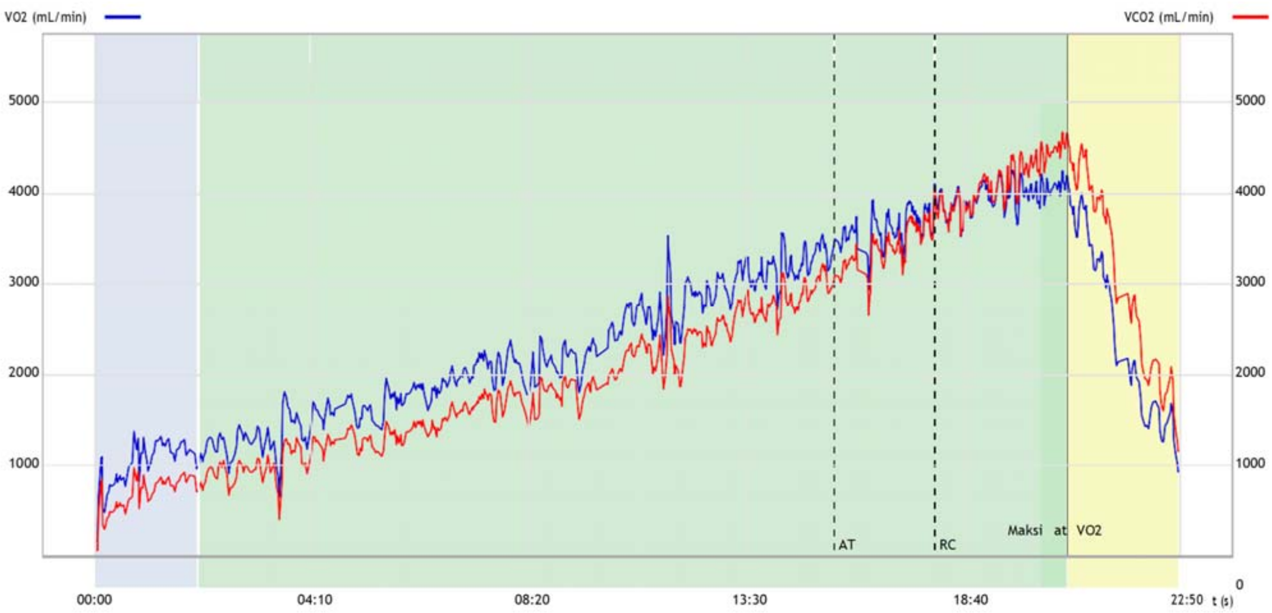

Fig. 1 The metabolic variables of the athletes at AT, RC, and Maximum (VO2 peak) state

Elite male runners typically have a VO2 max of 70-85 mL/kg/min [40]. The elite Ethiopian distance athletes' exercise capacity (VO2 max mL/min/kg) is higher than it was in the earlier study [40], as illustrated in Fig. 2. The higher the values of VO2 max, the better the performance for athletes, even though it is not the only predictor in distance running. In addition to VO2 max, anaerobic threshold (AT) and running economy (RE) are used to determine performance in distance running competitions, particularly half marathon and marathon races [11], [14], [40].

As the data show, the athletes' VO2 max during AT, submaximal, and maximal states is quite high. Training for a longer period of time has been shown to increase vAT in marathoners, including world record holders [41]. Some researches [40], [42] discovered increased vAT in distance runners as a result of further training at vAT intensities. Several studies have shown that vAT has risen as a result of additional training at rates faster than the vAT pace [14], [17], [19], [28], [40], [42]. According to the scientific literature, men's and women's VO2 max for world-class distance runners ranged from 70 to 87 ml/kg/min and 60 to 78.7 ml/kg/min, respectively [40], [41].

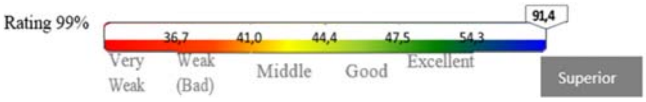

Fig. 2 Exercise Capacity (VO2/kg - mL/min/kg) of the Participants

5,000m PB time, mn: sec 12:56 ±0. 1	Number of Participants (N=7)		Sex Male	age 28.1± 4. 3	Height (cm) 172.3±4. 4	Mass (kg) 59. 4±4. 5
10k /10,000m PB time, min: sec 27:14±0.1	*Weekly Training* 196.3±13.8	Fat Percentage 5. 8±4. 6	BMI (kg/m2) 20.1±1.1	Cigarette No	Training age 10.1±5.1	Smoking / Day
15k PB time, mn: sec 41:50±0. 4	Half marathon PB time, mn: sec 59:30 ±0.6		Marathon PB time, min: sec 2:04:20 ±2. 7			
Ethnicity African ancestry Ethiopian	Expected value settings ERS93/Zapletal (Lung Function Test)					

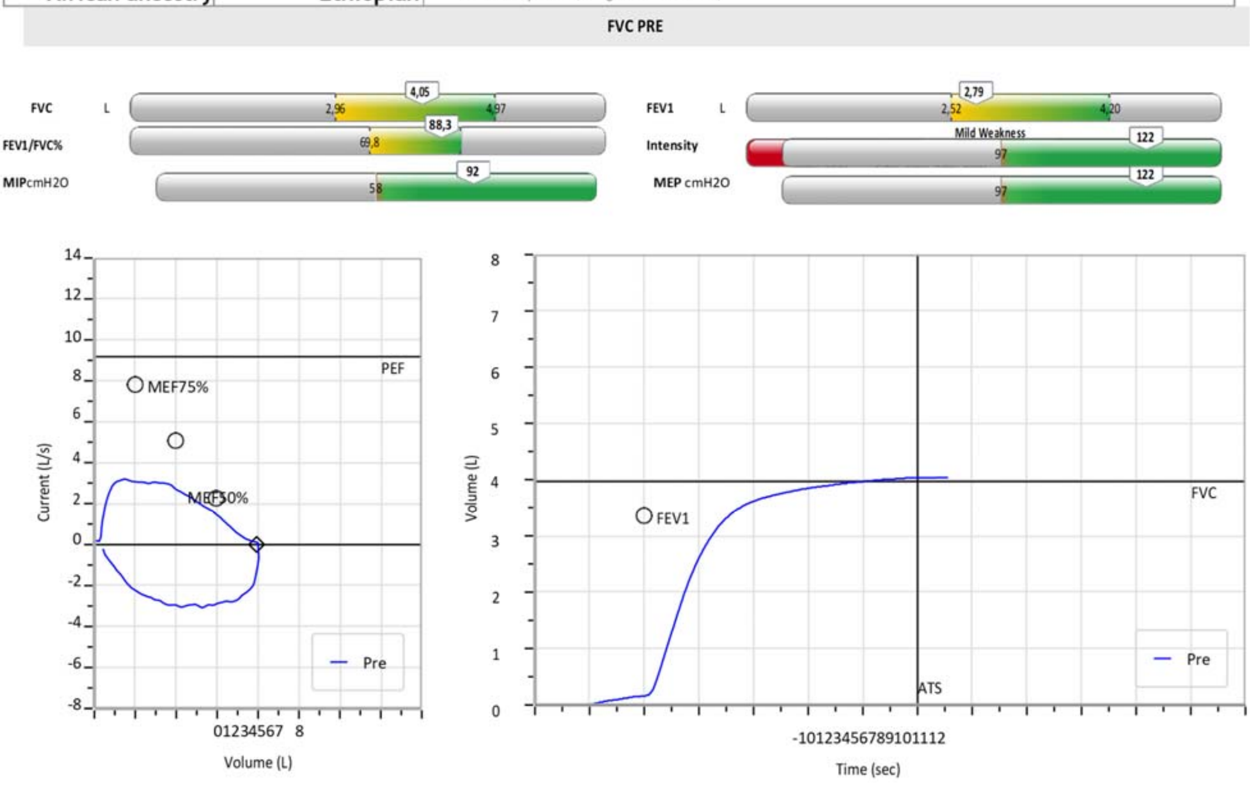

Fig. 3 Respiratory Parameter results of the athletes

PFT normal ranges vary from athlete to athlete and person to person. It is generally assumed that an athlete would breathe better than a non-athlete. The results in Tables II and Fig. 2 show the respiratory test parameters of Ethiopian elite distance athletes, and the PFT results for the male Ethiopian athletes in this study were as follows: FVC L 4.05 ± 0.4, FVC% pred 102.0 ± 1.3, FEV1,1/sec 3.57 ± 0.5, FEV1,% pred 84.0 ± 1.4, PEF L/S 3.36 ± 0.1, PEF% pre 47.8 ± 1.4, FEV1/FVC,% 88.3 ± 7.2, PEF L/S is 3.36 ± 0.1. PEF %pre is 47.8 ± 1.4. The measured values of FVC and FEV1 in Ethiopian athletes were

4.05 ± 0.4 and 3.57 ± 0.5, respectively, which is normal but less than the FVC and FEV1 parameters in elite athletes in [39], which were 4.37 ± 1.05 L and 3.90 ± 0.88 L, respectively, basketball, water polo, and rowing have substantially different characteristics (FEV1 was greater, followed by VC, and FVC), whereas boxing, kayak; rugby, handball, taekwondo, and tennis had lower PEF [39]. The athletes' FVC and FEV1 scores in the above study are greater than the Ethiopian top distance athletes in this investigation.

The participants in the current study were highly profiled elite distance Ethiopian 16 runners whose average are 10k (< 27:30), 15k (< 43 min), half marathon (< 60 min), and marathon (< 2:07:00 hr: min: sec) respectively. As demonstrated in the present studies, black East African runners still outperform white Caucasian runners even at this level of performance [23], [41], [43].

Even though other combinations could result in elite performance in endurance competitions, it seems that individuals with exceptionally high VO2 max values and excellent running economy are rarely observed together [11], [13], [42]. The mean VO2 max of the athletes was 88–89 mL/kg/min with a range of 88 to 91.4 mL/kg/min (Fig. 1). These values are different from previously reported VO2 max values for highly trained distance runners [38], [40] indicating that better race results in recent years cannot be solely attributable to greater VO2 max levels. The VO2 max was measured in the current investigation with a 1% treadmill grade after a multistage treadmill protocol. The maximum value for VO2 max that may have been obtained if a technique with a gradual rise in treadmill gradient had been used may have been understated by the reported VO2peak. The VO2peak given here would more properly represent the greatest value for VO2 that could be obtained during competition on a level surface. However, any such difference is likely to have been modest (3%; [40]). This study shows that a 5% treadmill gradient at RC and a 5.5/6% at VO2 peak state produce high values of VO2 max. This makes sense when we contrast our findings with those of the earlier study in the publication mentioned above.

The first significant conclusion of this study is that despite having lower VO2 ml/in at AT, RC, and maximum treadmill test, lower VT, and lower VE-ergo than the previous related studies, each of the ET runners was nevertheless able to outperform any other athletes with higher VO2 max at all stages. Additionally, Ethiopians shared similar RER (RQ) and METs values. These discoveries and others like them have already been reported [2], [21], [38].

The athletes' anthropometric measurements, including their stature, body mass, BMI, body composition, and thigh and calf lengths and girths, were comparable to those found in earlier cohorts [40], [44]. Some of these traits may be connected to running economy and performance, according to some theories [40]. The athletes were relatively homogeneous in terms of their physical and physiological characteristics, so even though there were no significant correlations between anthropometric variables and running economy in the current study, this does not mean that those factors are not significant influences on running economy. Dotan et al. [24] found a moderate connection between BMI and marathon running performance. Lower limb skinfold thickness was likewise linked to running time in long-distance races, according to [45]. In terms of body composition, Brandon and Boileau [46] claim that having more fat-free mass makes runners more efficient. Wilson et al. [43] also investigated the link between somatotype and physical performance in running competitions. Smaller, lighter, and slimmer body stature results in superior long-distance running performance [41], [47].

VI. Limitations

Although professional athletes were employed in this study, there are a few constraints that should be addressed in order to learn more about Ethiopian distance runners' physical and physiological measurable parameters. The participants were in the competition period during the test. Most of them were prepared to run a half marathon or a marathon abroad, and other athletes had just returned from a race. Some of the athletes may not have been at their best when assessed due to differences in their condition and training label. As a result, depending on a few variables, the stated findings may change. The athletes' schedules made it difficult to give them enough time to become familiar with the treadmill and the gas exchange monitoring device. Although there were no variations between treadmill and track readings, it is plausible that some athletes had never run on a treadmill before and that this had an impact on the VO2 measures made in the lab. The athletes were all inexperienced with the procedure and had a lot of difficulties performing the PFT (also known as a spirometry test). Since they did not know how to breathe in and out, the participants tried 3 or 4 times to obtain a figure inside the standard limit. Additionally, several athletes had slight hyperventilation due to a lack of complete acclimation to the facemask used to measure gas exchange and some nervousness, which increased RER and hindered our ability to assess the running economy in terms of energy expenditure.

VII. Conclusion

Ethiopian distance athletes are very popular in distance running events in international competitions from 5k to marathon. Elite performance is believed to be the product of both physical and physiological characteristics in the field of distance athletics field. But it's still unclear to what extent champions are created or born. The goal of this study was to show physical and physiological variables and characterize the contributions that specific physical, training, and physiological (spirometry and exercise-related) characteristics have made to the achievement of a high-level distance performance. The findings also imply that Ethiopian distance elite athletes' high VO2 max values are much greater than those in the corresponding studies conducted previously.

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