ORIGINAL RESEARCH

# The Relationship Between Anthropometric Variables and Race Performance

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**Introduction:** The key elements of success in a given sports competition have become an area of interest for researchers. The reason for the success of Ethiopian runners was not proved scientifically. This study aimed at documenting the anthropometric parameters of 10,000 meter runners and to find out the association between such parameters and performances.

**Methods:** A descriptive field study was conducted. 32 elite 10,000 meter runners participated. The data were collected while the athletics team was preparing for the world athletics championship. The procedure was repeated three times for each individual. Statistical analysis was performed using SPSS version 18. All the data were presented as mean ± S.D. The Pearson product-moment test was used to determine the correlation between the variables and finishing time. The level of significance for all statistical tests was set at $p < 0.05$.

**Results:** The experience of male and female athletes showed a negative association with finishing time. However, there was no statistically significant correlation between the age and running time in both sexes. A significant positive association of body weight to running time was observed in both sexes. Body height correlates positively to running time in males ($p<0.05$), but not in females. The length of the arm, the forearm, the leg in both sexes and length of the thigh in women had no significant association with finishing time. A smaller arm and calf circumferences have a positive effect on the performance of both sexes. Smaller thigh circumference showed a positive association with the performance of men.

**Conclusion:** The age of the runners did not correlate with their performance. The anthropometric variables displayed significantly higher values in men than in women. Experienced athletes performed better in both sexes. Anthropometric parameters may be useful for selection, prediction, improving running performance besides for preventing injuries and health risk assessment.

**Keywords:** anthropometry, experience, limb circumference limb length, running time

## Introduction

In the highly dynamic era of sports competitions, looking for the key elements of success in a given sport has become a major area of interest. Many speculations have been said about the American dominance of basketball,[1] the Northern European dominance of skiing and the East African dominance of middle and long-distance running.[2,3]

Studies have tried to find out the possible factors that could clarify the success and dominance of East Africa's long-distance athletes.[4] Most of them are mainly attributed to factors such as social, psychological, genetic, environmental, structural and physiological adaptations.[5] The case of East African domination in middle and long-distance athletic running has paid more attention than any other group, and

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their overwhelming success in such distances has kept warm debates, for example, Scott et al[4] states that genetic endowments, and physiological characteristics, play a role in the determination of athletic success. In addition, attributes such as environmental conditions, exposure to running a long way to school each day, potentially give psychological advantages for the athletes.[5–7]

There are different suggested factors that explain the success and dominance of East Africa's long-distance athletes. The first is their social situation.[3] Scholars argued that the East African youngsters', due to their economic, cultural, demographic and political situations, they undertake aerobic activities daily, in their way to and from school as well as in other day-to-day routines during early ages could bring higher physiological advantages in running.[4,8]

Another factor for the East African long-distance runners' domination w believed to be a positive "mindset" of East African athletes using the opportunity to get themselves and their families out from poverty might drive them to put their utmost effort and perform their best. This also motivates them and their juniors to become better.[9,10] On the other hand, it has widely been believed that birth and living at high altitude can potentially produce great athletes.[8] However, a great range of athletic potentials has been observed between areas of similar altitude.[5] The most controversial and widely speculated factor assumed to determine the success of East African long-distance runners is the anatomical and physiological adaptation which in turn is determined by a gene-environment combination.[11]

Anthropometric characteristics play a crucial role in the performance of runners.[12] Some of the variables that can commonly affect performance are body weight, body height, limb length, and circumference of limbs.[2,5,12]

Although some, not all, physical characteristics seemed to favor athletes of East African long-distance runners, the best successful athletes are limited to specific ethnic and regional origins,[3,4] for example, The Kalenjin tribes from Kenyans hold 40% of the top honors for distance running.[3] The Arsi and Shewa regions in Ethiopia hold 73% of marathon runners and 43% of 5000 meters & 10,000 meter runners of the country.[4]

The reason for the success of east Africans, especially the success of Ethiopian athletes was not proved scientifically. Therefore, researchers in this area are should find out the real contributing factors for the success of Ethiopian athletes. Therefore, it motivated the researchers to conduct this study.

Studies indicated that anthropometric variables have a crucial effect on running performance as investigated in different research centers and tournaments of different countries.[12,13] However, there is no scientifically established anthropometric profile of Ethiopian runners in relation to their performance in various running categories. This study aimed at documenting the anthropometric parameters of Ethiopian world-class 10,000 meter runners and finding out the association between these parameters and their performance thereby filling a gap to the previous studies.

## Materials and Methods

Prior to the actual data collection process, two data collectors took training and practiced each measurement procedure for ten days on the available runners at Ethiopian national stadium. The training and the practice were supported by the national team physician and the coach. Pilot measurements were taken before the main measurements. The data were collected while the Ethiopian athletics team was preparing for 16th IAAF (International Association of Athletics Federation) world athletics championship, which was held in August 2017, in London.

After the researchers obtained written informed consent from each participant, a descriptive field study was conducted at Ethiopian National Stadium, the training field. There were 45 runners who had qualified the minimum performance based on a standard time set by IAAF, they were training every day, once a day. From these runners, we took 32 runners of 10,000 meters (16 males & 16 females). The participants were those who were voluntary to participate, those who have evidence of the best finishing time (minima) based on the IAAF standard, which was 28:12:00/min: sec. for men and 32:20:00 min: sec. for women. Participants who were injured at the time of data collection and those who were not willing to participate were excluded from the study.

Before conducting the study, ethical clearance for the study was obtained from Addis Ababa University Medical Faculty Institutional Review Board. Information about socio-demographic characteristics such as age, sex, running experience, was obtained from the participants using questionnaires. Anthropometric characteristics that were measured include body weight, body height, limb length, the circumference of limbs. Anthropometrics of symmetrical structures were taken on the right side of the body.

The data obtained were checked for clarity, consistency, and completeness. Statistical analysis was performed using SPSS version 18. All the data were presented as mean ± S.D. The Pearson product-moment test was used to determine the correlation between the variables and finishing time. In addition, partial correlation test was also used to determine the

partial effect of the associated variables on the finishing time by controlling their covariant(s). Then, a stepwise multiple linear regression analysis was applied to identify performance predictor variables from the set of already associated variables obtained from the correlation results. The level of significance for all statistical tests was set at p < 0.05.

Except for the finishing time, every measurement was taken; the descriptions of procedures were adapted from Nhanes III: National health survey; Anthropometry.[14] The procedure was repeated three times for each individual and the average was taken as a value for the measurement. The procedure which was employed is given as follows:

(A) The time to finish the distance was taken, using the stopwatch when the athletes arrived at the finishing line (min: sec.). The stopwatch was calibrated every day before taking the measurements.

(B) The weight of the athlete is measured barefooted using a standardized scale, and the measurement was taken and recorded to the nearest 0.1 kg.

(C) The body height was measured using a stadiometer (height board), and the value was taken to the nearest 0.1 cm.

(D) Length and circumference of limbs were recorded using a calibrated measuring tape.

## Length and Circumference of the Upper Limbs

The length of the arm was taken from the uppermost edge of the posterior border of the acromion process to the oleocranon process. Then, the measurement was taken and recorded to the nearest 0.1 cm. The Circumference of the arm was measured from the halfway distance of the arm of the above procedure with the right arm hanging freely to the side using a measuring tape. The measurement was taken to the nearest 0.1 cm.

The forearm (antebrachial) length was taken after arm length from the oleocranon process of the ulna to the line joining the styloid process of radius & ulna in a flexed position. Then, the measurement was taken and recorded to the nearest 0.1 cm.

## Length and Circumference of the Lower Limbs

Thigh-length was taken from the upper border of the greater trochanter to the level of the lateral meniscus of

the knee. Then, the measurement was taken and recorded to the nearest 0.1 cm.

The length of the leg was taken from the proximal end of the medial border of the tibia to the lower border of the medial malleolus of the leg. The measurement was taken to the nearest 0.1 cm. Circumferences of the thigh and calf were measured at the midpoints of the thigh and leg length measurements. The measurements were taken to the nearest 0.1cm.

## Results
### Socio-Demographic Characteristics
The distribution of sex, age, finishing time, and running experience of runners are presented in Table 1 below. The mean time to finish the 10,000-meter distance was 27:11 ±0:62/min: sec. for men and 31:07 ±1:07/min: sec. for women. The mean years of running experience for male and female athletes were found to be 5.0 ± 2.42/years and 4.44±1.9/years respectively, and their corresponding mean age was also found to be 24.1 ± 2.22/years for men and 22.37±2.24/years for women, respectively.

### Anthropometric Profiles
#### Length and Circumferences of the Limbs
The mean arm, forearm, thigh, and leg lengths were 29.0 ±3.53/cm, 27.6±4.3/cm, 46.8±4.58/cm, 38.6±1.28/cm for men, and 22.9±3.2/cm, 26.3±2.58/cm, 37.9±1.62/cm, 36.2 ±2.30/cm for women, respectively. Whereas, the mean arm, thigh and calf circumference of male runners were 28.95 ±3.54/cm 46.8±4.58/cm and 31.97±4.36/cm, respectively. Correspondingly, for women, the measurements were 22.9 ±3.25/cm, 36.9±4.12/cm and 23.3±6.45/cm (Table 2).

#### Correlation Between Finishing Time and Anthropometric Variables of the Runners
A significant positive correlation was observed between arm and calf circumference of men and women with the running time (p>0.05; Table 3). However, thigh circumference was

**Table 1** Socio-Demographic Characteristic of Male and Female Athletes

| Variables | Results | |
|---|---|---|
| Sex | Male (n=16) | Female (n=16) |
| Age (years) | 24.1±2.22 | 22.37±2.24 |
| Finishing time/min: sec | 27:11±0:62 | 31:07±1:07 |
| Training experience (years) | 5.0±2.42 | 4.44±1.9 |

**Note:** Results are expressed as mean ± standard deviation

**Table 2** Anthropometric Profiles of Male and Female Athletes

| Variables | Results | |
|---|---|---|
| | **Male** | **Female** |
| Body weight/kg | 57.4±3.94 | 47.27±3.47 |
| Body height/cm | 172.7±3.9 | 163.19±3.23 |
| **Limb Length/cm** | | |
| Arm | 29.0±3.53 | 24.5±1.22 |
| Forearm | 27.6±4.3 | 26.3±2.58 |
| Thigh | 40.8±0.9 | 37.9±1.62 |
| Leg | 38.6±1.28 | 36.2±2.30 |
| **Limb Circumference/cm** | | |
| Arm | 28.95±3.54 | 22.9±3.25 |
| Thigh | 46.9±4.58 | 36.9±4.12 |
| Calf | 31.97±4.36 | 23.3±6.45 |

**Note:** Results are expressed as mean ± standard deviation.

**Table 3** Correlation Between Finishing Time and Anthropometric Variables of Athletes

| Variable | Results | | | |
|---|---|---|---|---|
| | **Male (n=16)** | | **Female (n=16)** | |
| | **r** | **p-value** | **r** | **p-value** |
| Experience | −0.602 | 0.014* | −0.519 | 0.039* |
| Age | 0.042 | 0.877 | −0.117 | 0.665 |
| Body weight, kg | 0.585 | 0.017* | 0.517 | 0.040* |
| Body height, cm | 0.729 | 0.002* | 0.208 | 0.439 |
| **Length, cm** | | | | |
| Arm | 0.366 | 0.163 | 0.451 | 0.080 |
| Forearm | 0.364 | 0.166 | 0.462 | 0.072 |
| Thigh | 0.584 | 0.018* | −0.03 | 0.921 |
| Leg | 0.270 | 0.312 | −0.27 | 0.304 |
| **Circumference, cm** | | | | |
| Arm | 0.590 | 0.016* | 0.539 | 0.031* |
| Thigh | 0.620 | 0.010* | 0.234 | 0.383 |
| Calf | 0.498 | 0.050* | 0.506 | 0.046* |

**Note:** p<0.05 was considered significant (*); r = correlation coefficient

positively correlated with the finishing time of male runners only (p<0.05).

### Regression Analysis of the Predictor Variables on the Finishing Time

Multicollinearity tests were done between each predictor variable for the presence of correlations between them using variance inflation factor (VIF). The results confirmed that VIF output is less than 5, which is in line with the recommended cut off points for correlation between independent factors.[15] The influence/strength of the association between anthropometric variables and the finishing time of athletes was clarified using multiple regression analysis. In doing so, variables such as running experience, body weight, body height, thigh length, arm circumference, thigh circumference, and calf circumference were taken as predictor variables in the regression model. However, the body height of male athletes appeared to have a significant positive prediction effect on finishing time (negative to performance (p<0.05; Table 3). The scatter diagram with a regression line and prediction interval shown in Figure 1 indicates that an increase in body height of male runners has an effect on running time.

A scatter diagram with a regression line and prediction interval in Figure 2 shows that an increase in arm circumference positively associated with the running time of female athletes respectively.

## Discussion

For this study, the subjects were world-class runners fulfilling the requirements of 28:12.00/min: sec set by IAAF for men and 32:20.00 min: sec for women. The biological differences between men and women refer that men are stronger, faster and hence more dominant in sports including 10,000 meters running discipline.[16,17] However; other studies[18,19] have suggested that sex differences in records and performances of runners may disappear when differences are going to be diminished in the future.

In the present study, the running experience of male and female athletes showed a negative association with finishing time (p<0.05; Table 3); the less experience an athlete had, the longer time he/she took to finish the 10,000-meter distance. In addition, a significant partial correlation was seen between experience and finishing time of both sexes when the effect of age was controlled as a covariant (Table 4, p < 0.05).

However, there was no statistically significant correlation observed between the age and finishing time of runners in both male and female athletes (p > 0.05; Table 3).

The association between experience and better performance may be linked to better adjustment of runners that could improve the economy of movement. Another effect of experience associated with ease of psychological factors that act upon athletes. This might be due to the familiarization of athletes to running related extrinsic as well as intrinsic factors that may determine the economy of running and a reaction to any stimulus. This agrees with the
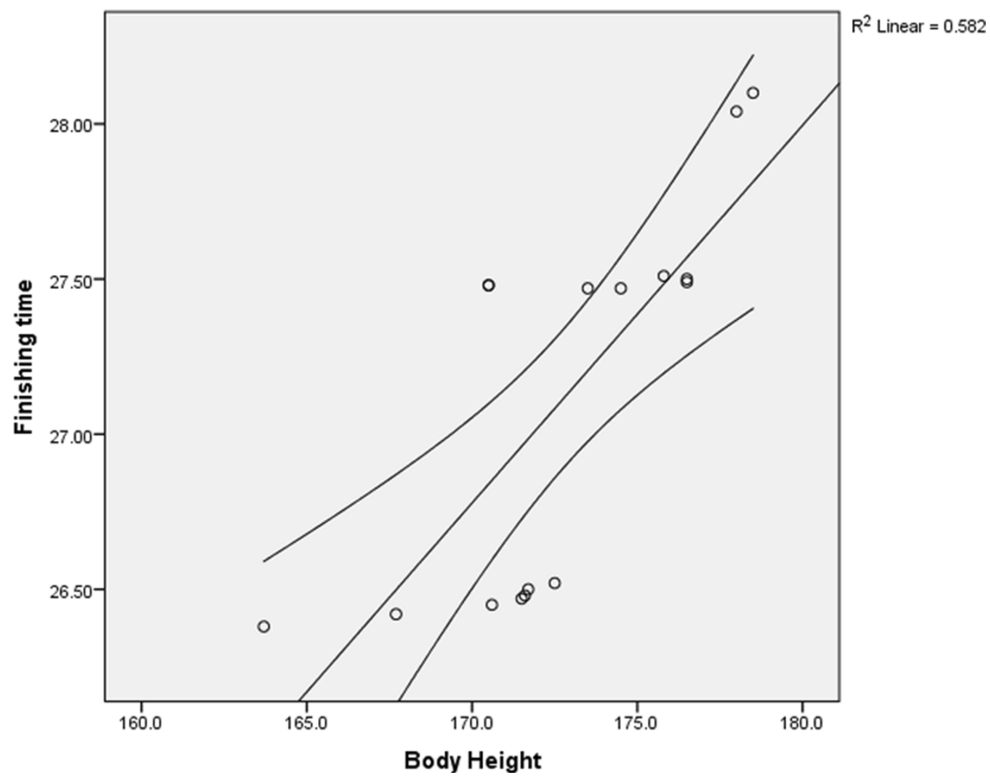
**Figure 1** Scatter diagram of finishing time and body height of male runners showing the linear regression line and prediction interval.
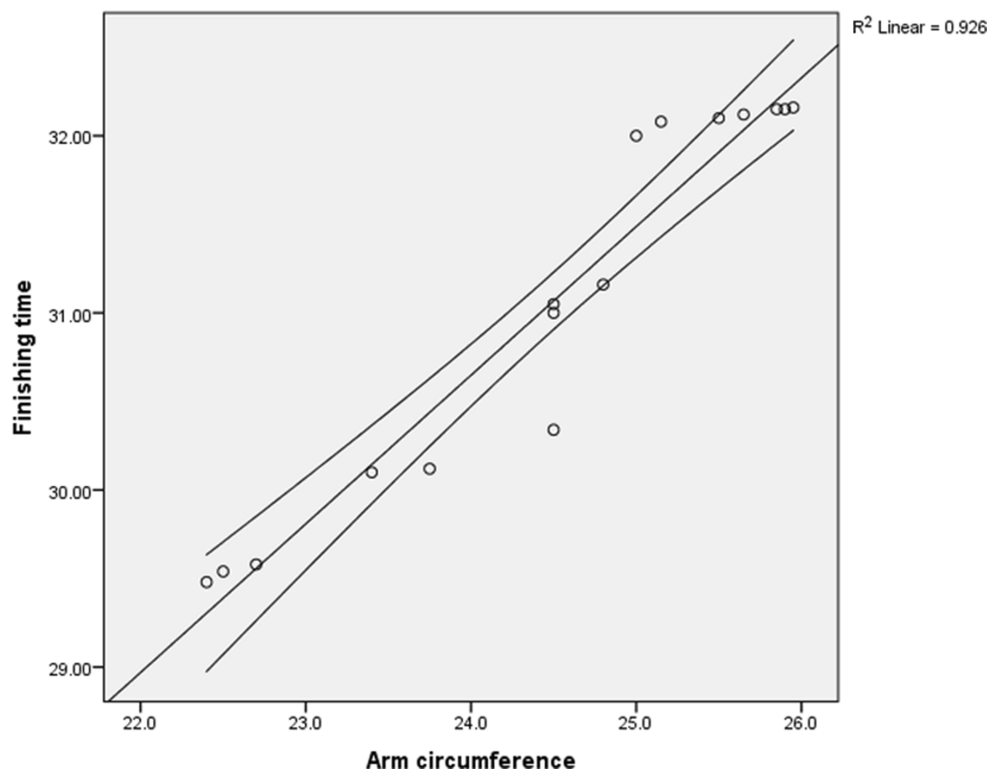


**Figure 2** Scatter diagram of finishing time and arm circumference of female runners showing the linear regression line and the prediction interval.

report of a study by Conley et al, Charkoudian and Joyner[20,21] who found out that highly experienced and trained distance runners perform better than inexperienced runners did.

A number of studies have drawn attention to age-related changes in the musculoskeletal system and other organ systems that lead to a decline in performance with age.[22,23] The age of runners in the present study did not correlate with their performance (p>0.05; Table 3). The absence of a significant age-performance association may suggest that a narrow range of age in athletes of the present study could not allow the effect of age to be seen on performance.

A significant positive association of body weight to finishing time was observed in both male and female athletes (p<0.05; Table 3). However, the partial effect of body weight on finishing time by controlling its covariants was found insignificant (p>0.05) in both men and women (Table 4).

Male runners' body height correlated positively to running time (p<0.05). In contrast, female runners did not show a significant correlation between body height and finishing time (p>0.05) (Table 3). However, the body height of male runners, despite its bivariant effect on finishing time, did not show a significant association with finishing time when the effect of its covariants such as body weight, thigh length, and leg length was controlled (p>0.05; Table 4). This shows that being heavier, taller and larger had a negative effect on better performance for men as well as women. This finding agrees with that of Cureton et al,[24] that stated, "Being larger and heavier is like being caught by a heavy backpack which engages the individual to work harder. Therefore, this may favor runners of relatively lighter, shorter/average and smaller to perform better (to finish earlier). However, despite the significant

effect of body weight and body height along with their covariants, none of them shows a significant effect on performance when each of them is checked by controlling the corresponding covariant (s). This is true for both men and women runners.

This implies that the effect of body weight, body height and body mass index on performance is significant only in the presence of their corresponding covariants' effect.

The findings of the present study also indicate that the length of arm, forearm, leg in both sexes and length of the thigh in women had no significant association with running time (p>0.05; Table 3). The longer the length of the thigh, the lower the performance becomes. Men's thigh length showed a significant positive association with running time (p<0.05; Table 3). However, thigh length did not show an apparent effect on performance when its covariants were controlled. This implies that the significant correlation between thigh length and performance is a combined effect of thigh length and its covariants. This is in agreement with a study by Lucia et al,[25] who investigated the relationship between anthropometric characteristics and performance in Eritrean and Spanish runners. They noted a better performance of the Eritreans who were characterized by shorter thigh length than the Spaniards on condition that the Eritreans are lighter, shorter and smaller than the Spaniards. On the contrary, a study by Knechtle et al,[26] on the association between performance and anthropometric variables of male Caucasian endurance runners, found out a positive correlation between longer lengths of the leg (total lower limb, in their context) and time performance.

In the present study, a relatively smaller arm and calf circumferences have a positive effect on the better performance of both men and women (p<0.05; Table 3). On the other hand, smaller thigh circumference showed a positive

**Table 4** Multiple Linear Regression Analysis Results of Predictor Variables in Men and in Women

| Male | | | Female | | |
|---|---|---|---|---|---|
| **Predictor Variable** | **Standardized Beta (β)** | **p-value** | **Predictor Variable** | **Standardized Beta (β)** | **p-value** |
| Experience | −0.284 | 0.062 | Experience | 0.295 | 0.242 |
| Body weight | 0.094 | 0.659 | Body weight | 0.176 | 0.383 |
| Body height | 0.653 | 0.000* | Arm circumference | 0.388 | 0.030* |
| Thigh length | −0.093 | 0.682 | Calf circumference | 0.089 | 0.674 |
| Arm circumference | 0.147 | 0.40 | | | |
| Thigh circumference | 0.200 | 0.226 | | | |
| Calf circumference | 0.201 | 0.180 | | | |

**Notes:** For men (Adjusted R-square = 0.742; F2, 13 =22.55), and for women (Adjusted R square = 0.643; F2, 13 =14.492, p<0.05). p<0.05 was considered significant (*); β = regression coefficient. Dependent variable - running time.

association only to better performance of men (p<0.05). This finding agrees with the findings of Tanaka and Matsura[27] who reported that smaller thigh circumference is related to better performance runners over 5000 meters. Similarly, Rahmani et al,[28] in their report of comparative study between Senegalese and Italian runners, and Lucia et al,[25] in their comparative study between Eritreans and Spaniards, found out that African runners have lighter thigh and legs. On the other hand, Knechtle et al,[26] found out a negative association of arm circumference with the performance of endurance runners. However, the latter study did not find a significant correlation between performance and circumferences of the thigh and calf.

## Conclusion

In the present study, the age of the runners did not correlate with their performance. In both sexes, experienced athletes performed better in 10,000 meters distance. Anthropometric variables displayed significantly higher values in men than in women. For both male and female athletes, those who had lighter body weight, shorter/average body height, and smaller body size, shorter thigh, smaller circumferences (arm, thigh, and calf) performed better. No single anthropometric variable showed a partial correlation with running time in the absence of its corresponding covariant(s) with that of running time. The results of this study showed that morphological characteristics of runners have a significant impact on race performance and achievement of better results. Anthropometric parameters may be useful for selection, prediction and improving running performance as well as for preventing injuries and health risk assessment.

## Data Sharing Statement

The data sets analyzed during this study are available from the corresponding author on reasonable request.

## Disclosure

The authors declare no conflicts of interest.

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