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HOW THE KENYAN RUNNER'S BODY STRUCTURE AFFECTS SPORTS RESULTS

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ABSTRACT
Purpose. The aim of this study was to determine the dependency between somatic parameters of selected Kenyan marathon runners and results achieved in long-distance runs (marathon, half-marathon, 10,000 meters). **Methods.** The research study was conducted on a sample of 9 top-level long-distance Kenyan runners whose results in Poland correspond to International Masterclass. All runners' (mean ± *SD*) age: 23.67 ± 4.41 years, weight: 55.98 ± 4.84 kg, height: 169.18 cm ± 4.15cm. All participants had their anthropometric measurements taken: length, width, size and sum of three skin-folds. Having taken those anthropometric measurements, Body Mass Index (BMI), Arm Muscle Circumference (AMC), Waist to Hip Ratio (WHR), body mass and body fat (FM) (%), fat free mass (FFM) were calculated using the Durnin-Womersley method. **Results and conclusions.** Significant relations (significant correlation, important dependency) were observed in dependency between 10,000 meters results and the foot breadth (r = 0.765) and torso length (r = 0.755). Similar relationships occurred between marathon results and the arm length (r = 0.73), forearm length (r = 0.75) and hip width (r = 0.77).

Key words: somatic characteristics, body composition indices, Kenyan runners

Introduction

Many sport disciplines show correlation between selection of candidates for a particular sport discipline and somatic features. For instance, the taller the basketball player is, the more rebounds he makes during the game. It comes as no surprise that a basketball player's height influences the efficiency in basketball. Predisposition for physical competition was a subject of many reports [1–3]. It became clear that not only physical traits (height, width and circumference measurements) play an important role in sport but also body composition: adipose tissue and its location throughout the body, fat free mass or water content in the body etc. [4–5]. Thanks to constant selections of candidates for sport disciplines, it is possible to identify athletes of such a body structure that enables them to score top results and at the same time eliminate athletes with poor results. The athletes' strong will to beat their personal bests make sport activists and coaches alter their selection criteria and choose the ones that promise masterful results. Particularly interesting with regard to what has been said is the phenomenon of extreme endurance abilities of Kenyan runners who have been ranked among top athletes in middle- and long-distance runs for the last 25 years. Their dominance is reflected in a series of world records set in the majority of endurance events. The laboratory tests revealed that black runners consume more oxygen (at maximum ontogenetic absorption ability) than white runners at the same running speed [6–8]. It may lead to an increased utilization of fats while saving glycogen during physical activity as fats need oxygen to be oxidized. The consequence of extremely intensive training and selection of athletes, as not all Kenyans are predestinate for endurance events, is a specific body type that tends to be extremely thin, low in body mass, low in adipose tissue and with not very developed muscle tissue. Is it correct to state that this subpopulation is close to a somatic ideal in selected sport disciplines? Giving an answer to the above question may enrich the knowledge on building an endurance ability with the use of particular body parts.

The aim of this study was to determine the dependency between some somatic parameters of selected Kenyan runners and their results in long-distance runs (marathon, half-marathon, 10,000 meters).

Material and methods

The research sample consisted of nine professional, long-distance Kenyan runners (all black) who for several years took part in a series of running competitions in Poland (street runs, marathons, half-marathons). They ran once a week, every weekend for 5–6 weeks and then they went back to their country. All tested competitors hold leading times for top running events, which in Poland are equivalent to Masterclass. All runners come from the same geographic region, that is the Great Rift Valley in Kenya and train in St Patrick International Sport Club in Iten town. Profile of the runners – (values are given in mean ± *SD*) age: 23.67 ± years, height: 169.18 ± 4.15 cm, weight: 55.98 ± 4.84 kg. Measure-

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ments and calculations were done in July 2013 during the athletes' presence in Poland, in the civilian-military sports club "Zawisza" in Bydgoszcz. The following anthropometric measurements were taken: length measurements (cm): body height (V–B), arm length (a–r), forearm length (r–sty), upper limb length (a–da III), lower limb length (tro–B), foot length (ap–pte); width measurements: shoulder breadth (a–a), hip width (ic–ic), pelvic width (is–is), hand width (mm–mu), palm width (mr–mu), foot breadth (mtt–mtf); and the circumferences of: fully expanded/deflated chest, waistline, hipline, fully flexed and extended arm muscle, thigh and calf. Measurements of the thickness of three skinfolds were taken in the following body parts: triceps skinfold (TSF), vertical fold, subscapular skinfold (SCSF), horizontal fold, suprailiac skinfold (SISF), diagonal fold. On the basis of those measurements Body Mass Index (BMI) kg/m^2, Arm Muscle Circumference (AMC), Waist to Hip Ratio (WHR), Fat Mass (FM) (kg), Fat Mass (FM)(%), Fat Free Mass (FFM) (kg), Fat Free Mass (FFM) (%) were calculated using the Durnin and Womersley formula [9].

Body Mass was measured on a commercial scale (TANITA BF 662M Japan). The length and width measurements were taken using an anthropometric apparatus. The circumference measurements were taken with the use of an anthropometric tape, the thickness of skinfolds was measured with skinfold calipers. All the measuring instruments were part of an anthropometric apparatus set made by Siber Hegner & Co., Ltd (Switzerland). All measurements were taken by the same investigator, applying standard anthropometric methods according to the procedure of the International Biological Programme [10]. The study was performed according to the Declaration of Helsinki. Written informed consents were obtained from all participants.

In order to find some association between the results of long-distance events and results of anthropological measurements Spearman's correlation coefficient was calculated. Correlation dependency between two characteristics X and Y is distinguished by the fact that merit of one feature is equivalent to median merit of the other feature. The interpretation proposed by the correlation coefficient Guilford is an assessment of the strength (power) of the correlation, to verify the statistical significance of the Student t-test can be used for correlation coefficient. As a result of this test for the sample $n = 9$ correlation coefficients with a value greater than 0.58 are statistically significant at $\alpha = 0.05$ significance level (below 0.20 – weak correlation, slight dependency; 0.20–0.40 – low correlation, evident dependency but slightly important; 0.40–0.70 – moderate correlation, important dependency; 0.70–0.90 – high correlation, significant dependency; 0.90–1.00 – very high correlation, strong dependency).

Subjects of the study were examined taking into consideration two variables: characteristic X (somatic parameters) and characteristic Y (run results). Statistical information crucial for estimating correlation between features X and Y was prepared on the basis of correlation table.

Results

Table 1 reports the results of anthropological measurements and the results of long-distance events. In Table 2 the results of measurements of tested circumferences and some anthropological features of Kenyan runners are presented. Table 3 shows correlation coefficients between results of the following events: 10,000 meters, half marathon, marathon and selected anthropometric measurements. Important relationships were observed between the following results: important correlation (statistically significant dependency at the level of materiality 0.05) – between results obtained in 10,000 meters run and foot breadth ($\rho = 0.76$), and torso length ($\rho = 0.75$). Similarly, an important correlation (significant dependency) was observed between marathon results and the following parameters: arm length ($r = 0.73$), forearm length ($r = 0.75$), hip width ($\rho = 0.77$). A moderate correlation (statistically significant dependency at the level of materiality 0.05) was found between 10,000 meters results and the following parameters: body mass ($r = 0.49$), BMI ($r = 0.43$), arm length (r = 0.54), shoulder breadth ($r = 0.53$), thigh circumference (negative correlation, $r = -0.46$). The same moderate correlation (important statistically significant dependency at the level of materiality 0.05) was shown in relationship between half marathon results and the following parameters: arm length ($r = 0.50$), upper limb length ($r = 0.45$), foot length ($r = 0.51$), hips breadth ($r = 0.43$), foot breadth ($r = 0.54$), torso length ($r = 0.40$), calf circumference (negative correlation, $r = -0.43$). Moderate correlation (statistically significant dependency at the level of materiality 0.05) was found between marathon results and the following parameters: BMI ($r = 0.40$), upper limb length ($r = 0.58$), torso length ($r = 0.46$), WHR index ($r = 0.41$). No relationship was observed between results of the examined runs and other somatic parameters.

Discussion

Black Kenyan and Ethiopian runners have dominated endurance events in recent years. Those athletes mostly come from a high-altitude region of the Great Rift Valley (2300 m above sea level). That region is a homeland of champions who are ranked as the best middle- and long-distance runners in the world. Kenyan runners' superiority in long-distance runs is often linked to the advantage of living in thinner air (hypoxia), which is the likeliest reason of their increased endurance ability.

Presently, Kenyan runners from this region hold most of the world records in the following events: men's 800 meters, 3,000 meters steeplechase, 5,000 meters, 10,000 meters and marathon; women's 5,000 meters.

Table 1. Number profile of selected anthropological measurements of Kenyan marathon runners and their results achieved in selected events

Tested feature	$\bar{x}$	*SD*	Min	Max
10,000 meters (s)	1730.43	33.24	1791.0	1698.47
Half-marathon (s)	3753.61	67.84	3840.16	3600.15
Marathon (s)	8080.30	158.59	7800.57	8280.25
Body height (cm) (B–V)	169.18	4.15	161.0	177.0
Body mass (kg)	55.98	4.84	48.0	63.1
Fat mass FM (%)	5.41	1.75	4.56	9.28
Fat free mass FFM (%)	94.59	1.75	90.72	96.83
Sum of skinfolds (mm):	13.97	1.96	11.7	18.5
– subscap	5.46	1.70	3.5	9.6
– triceps	4.09	0.81	3.0	5.0
– suprial	4.42	1.10	3.0	5.0
Length measurements (cm):				
– arm (a–r)	33.04	1.93	30.50	35.80
– forearm (r–sty)	26.38	2.99	23.40	27.20
– upper limb (a–da III)	80.51	3.80	76.40	87.10
– lower limb (tro–B)	90.02	2.77	85.60	97.70
– foot (ap–pte)	25.72	0.88	24.00	26.60
– torso (tro–a)	50.96	3.20	46.00	54.30
Width measurements (cm):				
– shoulder (a–a)	38.66	2.72	33.40	41.50
– hip (ic–ic)	28.73	1.47	26.20	31.00
– pelvis (is–is)	23.02	1.21	20.80	24.60
– hand (mm–mu)	10.04	0.56	9.50	10.50
– palm (mr–mu)	8.00	0.56	7.00	9.00
– foot (mtt–mtf)	9.77	0.68	9.00	11.20

Numerous scientists, e.g. Temfemo et al. [11], seeking for a reason of such an exceptional endurance ability indicate the difference in quadriceps of white runners and black Kenyan ones. Kenyans have a lot more capillary around microfibers and much more mitochondria. Smaller fibers of African athletes enable mitochondria to approach capillary vessels that encompass fibers, which allow easier oxygen diffusion from capillaries to mitochondria and efficient oxidation.

Weston et al. [12] reported that black athletes tend to have increased muscle enzyme levels that burn fat and store glycogen when compared to their white counterparts. This enables them to improve their endurance especially when finishing middle- and long-distance runs. It is worth mentioning that a great density of capillaries and increased number of mitochondria in the muscular system were observed in the inhabitants of other high-altitude regions such as Peru, Mexico and Tibet.

Some researchers pay closer attention to Kenyans' diet [13–14]. The diet is very simple: small portions of fried meat, boiled and raw vegetables, fruit, eggs, milk and their favorite *ugali* groats. Additionally, they use vegetable sauces, bean, corn, fruit or parts of plant sprouts and sometimes meat. Such a diet contains a lot of carbohydrates, mineral components, vitamins and fibre but lacks fats, especially animal ones. It is worth mentioning that traditionally Kenyans eat 2 meals a day.

Most researchers accentuate existence of dependency between consumption of drinks rich in simple sugars and building running endurance and physical capacity in comparison with sportsmen who consume pure water.

Burke [15] notices that Kenyans and Ethiopians quite often undertake commonly known eating habits that aim at mobilization of muscle glycogen. It is mostly about periodic reduction of carbohydrates, especially simple ones (glucose, fructose) in the marathon runner's diet followed by a radical increase in simple sugar supply. It may enhance adaptation to endurance effort and thus improve sports results. According to Beis et al. [16], the improvement in physical capacity and endurance is also related to higher oxidation of simple carbohydrates (aqueous solution of glucose + fructose 60g/h) that leads to better effects than doses of 30g/h or 15g/h. Big portions of simple sugars (> 90g/h) may cause higher production of energy, up to 20–50%. Jeukendrup [17] notices that high physical effort that leads to intensive carbohydrates oxidization, even its high contents, works against harmful consequences of glycemic index (GI).

Comparing morphological structures of black and white athletes, we noticed the following somatic charac-

Table 2. Number profile of selected measurements (circumferences) and indicators (anthropologic) of examined Kenyan marathon runners

Tested feature	$\bar{x}$	*SD*	Min	Max
Circumference measurements (cm):				
– chest measurement – aspiration (cm)	87.28	3.88	83.00	94.50
– chest measurement – expiration (cm)	82.53	4.63	78.00	90.00
– waist measurement (cm)	70.33	4.52	64.50	76.00
– hip measurement (cm)	85.33	3.25	81.00	91.00
– arm measurement – tensed (cm)	26.06	2.81	22.00	32.50
– arm measurement – relaxed (cm)	23.56	2.16	21.50	29.00
– thigh measurement (cm)	47.66	6.29	46.00	47.00
– calf measurement (cm)	37.84	6.43	33.00	54.10
Indexes				
BMI	19.55	1.51	17.50	22.90
AMC Index	22.27	2.10	20.24	27.56
WHR Index	0.82	0.05	0.78	0.92

Examined runners were thin and had low body mass with low anthropological indicators.

Table 3. The correlation of selected parameters and results of long-distance runs

	10,000 meters	Half-marathon	Marathon
Height	0.26	–0.13	–0.03
Body mass	0.49*	0.17	0.34
BMI	0.43*	0.25	0.40*
Sum of fat-skin folds	–0.36	–0.06	0.16
Adipose tissue %	–0.36	–0.06	0.16
Fat free mass %	0.36	0.06	–0.16
Arm length	0.54*	0.50*	0.73**
Forearm length	–0.04	0.08	0.75**
Upper limb length	0.14	0.45*	0.58*
Lower limb length	–0.34	–0.37	–0.13
Foot length	0.36	0.51*	0.57
Shoulder breadth	0.53*	–0.15	0.25
Hip width	0.30	0.43*	0.77**
Foot breadth	0.76**	0.54*	0.29
Torso length	0.75**	0.40*	0.46*
WHR	–0.38	–0.15	0.41*
AMC	0.13	–0.05	–0.08
Thigh circumference	–0.46*	–0.26	0.01
Calf circumference	–0.19	–0.43*	–0.23

* moderate correlation (statistically significant dependency at the level of materiality 0.05)
** significant correlation, important dependency (statistically significant dependency at the level of materiality 0.05)

teristics of black runners: lower body mass, significantly lower adipose tissue that results in much lower BMI, longer lower limbs, smaller calf circumference and shorter torso [18]. They certainly increase endurance abilities, especially in endurance events. In our study all the Kenyan runners were distinguished by low BMI (19.55 ± 1.51), low body fat (5.41 ± 1.75%) and slim calves (37.84 ± 6.43 cm). Similar results were published by Knechtle et al. [19] and Kong et al. [20]. In the chosen elite Kenyan runners they noticed low BMI (20.1 ± 1.8), low body fat (5.1 ± 1.6%) and slim legs (34.5 ± 2.3 cm), however in our study a negative correlation between the calf circumference and run time was found. The aforementioned authors tested duration of ground contact time during an endurance run and observed the difference between both limbs. They noted that the ground contact time of dominant leg was 170–212 ms, while that of the other leg was longer, about 177–220 ms. The short ground contact time, according to the authors, may be related to the running economy as there is less time needed to stop the front of the body. The differences in ground contact time between both limbs are most likely related to their slightly different functions.

According to a biomechanical model for running, speed depends on a) the step length b) the frequency of gait ($v = l \times f$, where: v – speed, l – length, f – frequency of gait). On the other hand, the step length depends on the length of the lower limbs, flexion angle (to the front side) as well as the extension (to the back side). The step length is also related to the body morphology, however the aforementioned angles depend on movement technique Erdman [21]. If a runner of a certain height of the body has a too long torso, his limbs are relatively shorter. Thus, his step length is going to be shorter as well. Hence, the positive correlation between the run time and the torso length is observed. Whereas, a runner of the same body height but longer lower limbs will make longer steps. This in turn results in negative correlation between the run time and the length of a lower limbs. The step frequency is related to the muscle preparation as well as muscle-nerve stimulation at a certain frequency, especially as far as endurance is concerned. The discussed frequency depends also on overcoming resistances such as: a) limbs inertia and, to less extent, b) the soft tissue extensibility. The limb with a broad expanded foot has a higher moment of inertia. The moment of inertia, among others, is the sum of the foot mass and its squared distance from the rotation axis of the hip-joint. The higher moment of inertia is, the bigger effort must be done by the muscles to move the limbs. Therefore, it is not recommended to have too expanded feet (hence, the positive correlation between the foot size and run time), but it is also not good to have too long lower limbs, because of the too long distance between the foot and the hip-joint, which results in more difficult lower limbs movements.

According to the above, too long upper limbs also do not favor a fast and long-term rotary motion around the axis of the shoulder-joint. Hence, the positive correlation between its length and run time.

The negative correlation between the thigh circumferences and shinbone is the results of the need for lower limb strength during the run, especially for the 10 km distance. There is no need to have too much basic strength; principally, the muscular endurance is important.

Another issue to discuss is the racing tactic, which, among others, consists of speed distribution during the whole distance. Erdmann and Lipińska [22] found that when the best runners were braking the world records for the long-distance runs, their speed distribution was horizontal (the speed was closed to constant) or slightly rising. Whereas, many other runners start the race at excessive speed and then slow down, which results in a worse run time. For runners who have better physiological and morphological predispositions, it is easier to keep the pace steady, close to constant running speed, and have better running times.

It is remarkable that three fourth of the best Kenyan runners belong to the Kalenjin tribe [23]. Kalenjin people make up only 12% of Kenya's population while the Kalenjin tribe makes up around 1/2000 of the world's population. In recent years Kenyan athletes have dominated the majority of the most important athletic events such as the IAAF World Indoor Championships, World Cross Country Championships, Olympic Games and most famous marathon races. It was estimated that they had won three eighth of all the trophies in middle- and long-distance races. Their achievements were described by specialists as "The highest geographic density of sport achievements ever recorded". Seeking for reasons of the remarkable endurance abilities of the Kalenjin tribe members, researchers point out that the fundamental factor is living in a high-altitude region (over 2000 m a. s. l.). It seems that people living in thin air for generations have developed acclimatization to hypoxia. Weston et al. [24] points out that living in high-altitude areas always is linked with lowered oxygen concentration. To compensate lack of oxygen, the body has to increase the number of erythrocytes that transport oxygen, which at lower altitudes creates advantageous conditions to increase compound aerobic capacity. Although some reports do not confirm the above findings. The study by Saltin et al. [25] showed no disparity in maximum oxygen consumption (VO_2max) of elite Kenyan and Scandinavian runners or unqualified Kenyan runners and a group of young people from Denmark. Further research is needed.

According to Larsen [26], members of the Kalenjin tribe are described as people with a higher concentration of those enzymes in skeletal muscles that stimulate better utilization of oxygen and decreased production of lactic acid. As a result of that, the Kalenjins are able to transform oxygen into energy in much more efficient manner. As some authors claim [27], abilities of increased aerobic capacity among the Kalenjins are the results of genetic transfer and odd environmental conditions. If they undergo special training and follow a healthy lifestyle, they become athletes of enormous endurance abilities and absolutely exceptional abilities to regenerate. Thus it is extremely difficult to beat an athlete who, like his ancestors, originates from the highlands of the Great Rift Valley. Generally all researchers agree that the exceptional endurance abilities result from an interaction of genetic heritage, environmental conditions (hypoxia) as well as cultural, social and economic determinants. In view of extremely difficult living conditions, underdeveloped economy and lack of job opportunities, young Kenyans and Ethiopians choose to become athletes. Thanks to their strong will and hard work they become successful in sport all around the world, which improves their and their families' living standard.

Conclusions

As a results of conducted study following conclusions were made:

1. The BMI of the examined Kenyan runners was fairly low compared to the health norms, in some cases even below the norm.

2. The following correlations have been found:

– positive (important) – the 10 km run time was correlated with the foot width and torso length,

– positive (important) – the marathon run time was correlated with the arm, forearm length, and the hip width,

– positive (moderate) – the 10 km run time was correlated with body mass, BMI, arm length, width shoulders,

– negative (moderate) – the 10 km run time was correlated with the thigh circumference,

– positive (moderate) – between the half-marathon run time was correlated with the arm length, lower limb length, foot length, hip width, foot width, and torso length,

– negative (moderate) – the half-marathon run time was correlated with the calf circumference,

– positive (moderate) – the marathon run time was correlated with BMI, upper limb length, torso length, and WHR index.

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