Science & Sports (2019) **34**, 412.e1—412.e9

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ORIGINAL ARTICLE

Do sex and body structure influence spatiotemporal step characteristics in endurance runners?

Le sexe et la structure du corps influencent-ils les paramètres spatio-temporels chez les coureurs d'endurance ?

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Received 31 August 2018; accepted 7 March 2019
Available online 26 June 2019

KEYWORDS
Body height;
Body mass;
Gender;
Running kinematics;
Somatic characteristics

Summary
Objectives. — To examine the influence of sex and anthropometric characteristics of recreationally-trained endurance athletes on spatiotemporal parameters during running at a constant velocity.
Equipments and methods. — In all, 97 runners (52 men and 45 women) performed a running protocol on a treadmill at 12 km.h^{-1}. Spatiotemporal parameters were measured using the OptoGait system and anthropometric characteristics were assessed by determining body mass, height, leg length and torso length.
Results. — Partial correlation analysis, adjusted by sex, revealed some significant correlations between anthropometric and spatiotemporal characteristics. Cluster k-means analysis grouped participants according to the body height, leg length and body mass. A 1-way Anova showed no between sex differences ($P \geq 0.05$) in any spatiotemporal parameters; whereas some differences were found between created sub-groups. Shorter contact time (CT) and step length (SL) and higher step frequency (SF) were obtained by the shorter group ($P < 0.01$, compared to the taller group) and by shorter leg length group ($P < 0.01$). As for the body mass, shorter CT were found in the lighter group compared to those heavier ($P < 0.05$). A linear regression analysis showed a significant association between CT and body height, leg length and body mass

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https://doi.org/10.1016/j.scispo.2019.03.009

($R^2 = 0.202$, $P < 0.001$). In conclusion, at a given running velocity, differences in body proportions seem to determine CT in amateur endurance runners, with higher values reported in taller and heavier runners. Nevertheless, although does exist a relationship between anthropometric characteristics and spatiotemporal parameters during running, the role of the somatic parameters measured in this study does not seem to be determinant in the spatiotemporal characteristics of amateur endurance runners.

MOTS CLÉS
Hauteur ;
Masse corporelle ;
Le genre ;
Cinématique ;
Caractéristiques somatiques

Résumé
Objectifs. — Examiner l'influence du sexe et des caractéristiques anthropométriques des athlètes d'endurance formés à la récréation sur les paramètres spatio-temporels pendant une course à vitesse constant.
Matériels et méthodes. — Au total, 97 coureurs (52 hommes et 45 femmes) ont exécuté un protocole de course sur un tapis roulant à 12 km.h^{-1}. Les paramètres spatiotemporels ont été mesurés à l'aide du système OptoGait et les caractéristiques anthropométriques ont été évaluées en déterminant la masse corporelle, la taille, la longueur des jambes et la longueur du torse.
Resultats. — L'analyse de corrélation partielle, ajustée par sexe, a révélé des corrélations significatives entre les caractéristiques anthropométriques et spatio-temporelles. L'analyse des k-means de groupe a regroupé les participants en fonction de la taille du corps, de la longueur des jambes et de la masse corporelle. Une Anova à 1 voie n'a montré aucune différence entre les sexes ($p \geq 0{,}05$) dans les paramètres spatio-temporels; alors que certaines différences ont été trouvées entre les sous-groupes créés. Un temps de contact plus court (TC) et une longueur de pas (LP) et une fréquence de pas plus élevée (FP) ont été obtenus par groupe plus court ($p < 0{,}01$) par rapport au groupe plus grand) et par groupe plus court ($p < 0{,}01$). En ce qui concerne la masse corporelle, des TC plus courts ont été trouvés dans le groupe le plus léger par rapport à ceux plus lourds ($p < 0{,}05$). Une analyse de régression linéaire a montré une association significative entre la TC et la taille du corps, la longueur des jambes et la masse corporelle ($R^2 = 0{,}202$, $p < 0{,}001$). En conclusion, à une vitesse de course donnée, les différences de proportions corporelles semblent déterminer la TC chez les coureurs d'endurance amateurs, les valeurs les plus élevées étant rapportées chez les coureurs plus grands et plus lourds. Néanmoins, bien qu'il existe une relation entre les caractéristiques anthropométriques et les paramètres spatio-temporels pendant la course, le rôle des paramètres somatiques mesurés dans cette étude ne semble pas être déterminant dans les caractéristiques spatio-temporelles des coureurs d'endurance amateurs.

1. Introduction

It is well-known that running biomechanics can favour or limit running performance by influencing the economy and efficiency of running [1—4]. Some years ago, obtaining biomechanical data about running was expensive, exclusive and equipment-dependent. Today, many devices provide real-time feedback on spatiotemporal parameters while running (e.g., OptoGait™, Stryd™ or Myotest™). Therefore, the limitation is not how to collect the data but how to interpret them.

Spatiotemporal step characteristics during running have been widely studied. Some previous works have examined the dynamic of spatiotemporal parameters during different running protocols [5—8], while other studies have determined the effects of running velocity [7,9,10] or the influence of uphill running on those spatiotemporal parameters [11—14]. Likewise, spatiotemporal step characteristics have been related either with athletic performance [2,15,16] or with risk of injury [17—19]. In terms of athletic performance, spatiotemporal variables have been related to running economy - longer ground contact time (CT) and shorter flight time (FT) are associated with poorer economy [20]. Whereas in terms of risk of injury, some variables such as step length (SL) or step frequency (SF) at a fixed speed can alter variables associated to running-related injuries (i.e., muscle loads [17], joint forces [18] and running mechanics [19]).

Despite the big amount of evidence around spatiotemporal step characteristics during running, limited evidence is available on the influence of potential confounding variables such as sex or anthropometric data. When compared to men, women are almost twice as likely to sustain a running injury, such as patellofemoral pain syndrome, iliotibial band syndrome or gluteus medius injury [21]. While the reasons for the sex discrepancies in these injury rates (women: 62—76%; men: 24—32%) are not fully understood [21], sex differences in lower extremity kinematics during running have been suggested as a contributing factor [22—24]. Regarding to the influence of the body structure on spatiotemporal parameters, even though some previous works have suggested that anthropometric characteristics might impact running performance [25—29], a limited number of studies have directly covered this topic. For example, Maciejczyk et al. [27] assessed the physiological response during running in athletes with similar body mass but different body composition concluding that increased body mass resulting from high body fat adversely affects the running economy. Additionally, in an attempt to justify the successful of African runners in endurance events, and some studies [30—32] reported differences in some somatic parameters, which suggests that body structure might play an important role in running kinematics. These points leave certain questions unanswered, including whether endurance runners show similar spatiotemporal step characteristics during running regardless sex, or variables related to body size and body composition (i.e., body height, body mass or leg length).

Therefore, this study aimed to examine the influence of sex and anthropometric characteristics of recreationally-trained endurance athletes on spatiotemporal parameters during running on a treadmill at a constant velocity (12 km.h^{-1}).

2. Materials and methods

2.1. Participants

A group of 97 (52 men and 45 women) recreationally trained endurance runners (age: 27 $\pm$ 8 years; range: 18—40 years; height: 172 $\pm$ 9 cm; body mass: 66 $\pm$ 10 kg) voluntarily participated in this study. All participants met the inclusion criteria:

- over 18 years old;
- recreationally active (3—4 running sessions per week, at least once on a treadmill);
- able to run 10-km in less than 50 minutes (46.13 $\pm$ 2.25 min);
- have not suffered from any injury within the last 6 months before data collection.

After receiving detailed information on the objectives and procedures of the study, each participant signed an informed consent form in order to participate, which complied with the ethical standards of the World Medical Association's Declaration of Helsinki [33]; it was made clear that the participants were free to leave the study if they saw fit. The study was approved by the local ethics committee.

2.2. Procedures

The study was conducted in February 2017. At the time of these observations, the participants had completed between 2 and 4 months of training. Participants were individually tested. Prior to all testing, participants refrained from severe physical activity for at least 48 h and all testing was at least 3 h after ingestion of a meal. Tests were performed with the participants' usual training shoes to attain their most typical performance.

The treadmill protocol (on a motorized treadmill, Salter M-835, Salter Int., Barcelona, Spain) was preceded by a standardized 10-min accommodation program (as a warm-up). Athletes were experienced in running on a treadmill, but previous studies [34,35] on human locomotion have shown that accommodation to a new condition occurs in ~6—8 min. The accommodation period was carried out at 10 km.h^{-1}. After warming-up, running velocity was increased 1 km.h^{-1} every minute until a speed of 12 km.h^{-1} was reached. The participants ran at that velocity for 1 minute with an acclimatization period (30 s) and a recording period (30 s). This is a normal pace for these athletes and is consistent with previous studies [36]. All participants verbally reported feeling comfortable running on the treadmill at the set speed. The short duration of the speed condition aimed to minimize the effect of fatigue on running kinematics.

2.3. Materials and testing

Anthropometry. Body height (cm) and body mass (kg) were determined using a precision stadiometer and weighing scale (SECA 222 and 634, respectively, SECA Corp., Hamburg, Germany). Leg length (cm) was measured as the distance between great trochanter and ground in a standing postion, whereas the torso length (cm) was calculated as the difference between body height and leg length. Both parameters were measured using an anthropometric measuring tape (SECA 201, Birminghan, UK). The leg length to standing height ratio (LL:H) and the body mass index (BMI, kg.m^{-2}) were also calculated. All measurements were taken with the participants wearing running shorts and underwear.

Spatiotemporal parameters were measured using the OptoGait system (Optogait; Microgate, Bolzano, Italy), which was previously validated for the assessment of spatiotemporal parameters of the gait of young adults, reporting a high correlation with all spatiotemporal parameters via intra-class correlation coefficients (0.785—0.952), coefficients of variation (1.66—4.06%), standard error of measurement (2.17—5.96%), and minimum detectable change (6.01—16.52%) [37]. The two parallel bars of the device system were placed on the side edges of the treadmill at the same level as the contact surface. This device was connected to a computer controlled by the researcher. Data were recorded and averaged for the subsequent analysis. In accordance with the findings from a previous study [38], limb dominance was not taken into account. Spatiotemporal parameters were measured for every step during the treadmill test:

- contact time (CT, in seconds [s]): time from when the foot contacts the ground to when the toes lift off the ground.
- flight time (FT, in seconds [s]): time from toe-off to initial ground contact of consecutive footfalls (i.e., right-left).
- step length (SL, in meters [m]): length the treadmill belt moves from toe-off to initial ground contact in successive steps.
- step frequency (SF, step per minute [step/min]): number of ground contact events per minute.
- step angle (SA, in degrees [$^{\circ}$]): Step angle is the angle of the parable tangent deriving from the SL and the height obtained with FT. These parameters allow us to tie in SL

with FT explaining it as a bound. The determination of SL is described above, and the maximal height of the foot during a stride was calculated by the Optogait system [39].

2.4. Statistical analysis

Descriptive statistics are represented as the mean, standard deviation and percentages. Tests of normal distribution and homogeneity (Shapiro Wilk and Levene's, respectively) were conducted on all data before analysis. A partial correlation analysis, adjusted by sex, was conducted between anthropometric parameters and spatiotemporal gait characteristics. The following criteria were adopted to interpret the magnitude of correlations between measurement variables: < 0.1 (trivial), 0.1—0.3 (small), 0.3—0.5 (moderate), 0.5—0.7 (large), 0.7—0.9 (very large) and 0.9—1.0 (almost perfect) [40]. The correlation analysis let us determine which anthropometric variables showed higher coefficients of correlation with spatiotemporal parameters. Based on that, three cluster k-means analysis were performed by grouping according to:

- the body height (taller group [TG, $n = 48$] vs. shorter group [SG, $n = 49$]);
- the leg length (longer leg length [LLL, $n = 42$] vs. Shorter leg length group [SLL, $n = 55$]);
- the body mass (heavier group [HG, $n = 47$] vs. lighter group [LG, $n = 50$]).

A one-way analysis of variance (Anova) was performed in order to compare each dependent variable between subgroups (anthropometric characteristics and spatiotemporal parameters). Finally, a stepwise multiple linear regression analysis was conducted by considering spatiotemporal parameters as dependent variables and anthropometric characteristics (body height, leg length and body mass) as independent variables. The level of significance was $P < 0.05$, and the analysis was performed using SPSS (version 21, SPSS Inc., Chicago, IL, USA).

3. Results

Partial correlation analysis, adjusted by sex (Table 1), revealed some significant correlations between anthropometric characteristics and spatiotemporal parameters. Of note, the body height significantly correlated with all spatiotemporal parameters ($-0.204 < r > 0.435$, $P < 0.05$), and the leg length obtained significant correlations with CT ($r = 0.367$, $P < 0.001$), SL ($r = 0.201$, $P < 0.05$) and SF ($r = -0.228$, $P < 0.05$). Likewise, the body mass correlated with CT ($r = 0.350$, $P < 0.001$), SL ($r = 0.251$, $P < 0.05$) and SF ($r = -0.275$, $P < 0.05$).

Age and anthropometric characteristics according to sex, body height, leg length and body mass groups are shown in Table 2. Some differences ($P < 0.05$) were found between sexes, with women showing smaller body proportions than men. Likewise, groups with greater presence of women (shorter group, shorter leg length group and lighter group), reported similar results.

Spatiotemporal parameters are shown in the Table 3. No between sexes differences ($P \geq 0.05$) were obtained in any spatiotemporal parameters; whereas some differences were found between created sub-groups. Shorter CT and SL and higher SF were obtained by SG ($P < 0.01$, compared to TG) and by SLL group ($P < 0.01$, compared to LLL group). As for the body mass, shorter CT were found in the LG compared to those heavier ($P < 0.05$).

Stepwise linear regression analysis showed significant associations between spatiotemporal parameters and anthropometric characteristics. Specifically, CT showed a significant association with body height, leg length and body mass ($R^2 = 0.202$, $P < 0.001$), while the rest of spatiotemporal parameters did not show significant associations with anthropometric characteristics (FT, $P = 0.170$; SL, $P = 0.085$; SF, $P = 0.052$; and SA, $P = 0.127$).

4. Discussion

The aim of this study was to examine the influence of sex and anthropometric characteristics of recreationally-trained endurance athletes on spatiotemporal parameters during running on a treadmill at a constant velocity ($12\,km.h^{-1}$). The main finding indicates that, even though

Table 1 Partial correlation analysis (adjusted by sex) between anthropometric characteristics of participants and spatiotemporal parameters during running at 12 km/h.

	Contact time	Flight time	Step length	Step frequency	Step angle
Age (years)	−0.264*	0.149	−0.129	0.130	0.180
Body height (cm)	0.435***	−0.204*	0.234*	−0.264*	−0.233*
Torso length (cm)	0.314**	−0.149	0.165	−0.184	−0.175
Leg length (cm)	0.367***	−0.170	0.201*	−0.228*	−0.191
LL:H ratio	0.055	−0.025	0.033	−0.041	−0.021
Body mass (kg)	0.350***	−0.107	0.251*	−0.275*	−0.138
BMI ($kg.m^{-2}$)	0.038	0.064	0.108	−0.113	0.052

LL:H ratio: leg length to body height ratio; BMI: body mass index.
* $P < 0.05$.
** $P < 0.01$.
*** $P < 0.005$.

Table 2 Anthropometric characteristic of participants according to sex (men vs. women), body height (TG vs. SG), leg length (LLL vs. SLL) and body mass (HG vs. LG).

Variables	All ($n = 97$)	Sex		Body height		Leg length		Body mass	
		Men ($n = 52$)	Women ($n = 45$)	TG ($n = 48$)	SG ($n = 49$)	LLL ($n = 42$)	SLL ($n = 55$)	HG ($n = 47$)	LG ($n = 50$)
Age (years)	26.7 (7.5)	27.7 (7.6)	25.4 (7.4)	27.3 (7.7)	26.0 (7.4)	27.2 (7.7)	26.2 (7.4)	26.9 (7.3)	26.3 (7.8)
Body height (cm)	172.0 (8.9)	177.7 (7.3)	165.4 (5.6)***	178.3 (7.0)	165.8 (5.8)***	179.8 (6.1)	166.1 (5.7)***	178.7 (6.7)	165.8 (5.7)***
Torso length (cm)	81.8 (5.3)	85.1 (4.5)	78.1 (3.1)***	85.4 (4.3)	78.3 (3.3)***	86.2 (3.9)	78.4 (3.2)***	85.6 (4.1)	87.6 (4.3)***
Leg length (cm)	90.2 (5.2)	92.7 (4.6)	87.4 (4.3)***	93.0 (4.6)	87.6 (4.2)***	93.6 (4.5)	87.7 (4.1)***	93.1 (4.5)	87.6 (4.3)***
LL:H ratio	0.5 (0.0)	0.5 (0.0)	0.5 (0.0)*	0.5 (0.0)	0.5 (0.0)*	0.5 (0.0)	0.5 (0.0)*	0.5 (0.0)	0.5 (0.0)*
Body mass (kg)	66.0 (10.3)	72.9 (7.9)	58.0 (5.9)***	74.0 (6.9)	58.1 (6.0)***	74.8 (6.9)	59.3 (6.7)***	75.0 (5.8)	57.6 (5.1)***
BMI ($kg.m^{-2}$)	22.2 (2.1)	23.1 (1.8)	21.2 (1.8)***	23.3 (1.8)	21.1 (1.7)***	23.1 (1.7)	21.5 (2.0)***	23.5 (1.6)	21.0 (1.6)***
Sex (M, F)	50, 47	50, 0	0, 47	41, 7	11, 38	38, 4	14, 41	42, 10	5, 40

TG: taller group; SG: shorter group; LLL: longer leg length; SLL: shorter leg length; HG: heavier group; LG: lighter group; LL:H ratio: leg length to body height ratio; BMI: body mass index. ** $P < 0.01$.

* $P < 0.05$.

*** $P < 0.001$.

Table 3 Spatiotemporal parameters of endurance runners at 12 km.h^{-1}, according to sex (men vs. women), body height (TG vs. SG), leg length (LLL vs. SLL) and body mass (HG vs. LG).

Variables	All (n = 97)	Sex		Body height		Leg length		Body mass	
		Men (n = 52)	Women (n = 45)	TG (n = 48)	SG (n = 49)	LLL (n = 42)	SLL (n = 55)	HG (n = 47)	LG (n = 50)
Contact time (s)	0.292 (0.020)	0.296 (0.023)	0.288 (0.018)	0.299 (0.018)	0.286 (0.020)**	0.302 (0.016)	0.285 (0.020)***	0.297 (0.022)	0.288 (0.018)*
Flight time (s)	0.071 (0.020)	0.069 (0.020)	0.073 (0.019)	0.073 (0.020)	0.069 (0.019)	0.071 (0.020)	0.071 (0.020)	0.069 (0.018)	0.073 (0.021)
Step length (cm)	120.89 (6.18)	121.49 (6.12)	120.20 (6.25)	123.75 (5.48)	118.09 (5.55)***	124.19 (5.46)	118.36 (5.51)***	121.67 (5.71)	120.15 (6.56)
Step frequency (step/min)	165.87 (8.36)	165.08 (8.35)	166.79 (8.37)	161.88 (7.05)	169.79 (7.72)***	161.35 (7.05)	169.32 (7.66)***	164.70 (7.65)	166.97 (8.92)
Step angle (SA)	1.26 (0.66)	1.20 (0.66)	1.34 (0.67)	1.31 (0.65)	1.22 (0.68)	1.24 (0.64)	1.28 (0.68)	1.19 (0.59)	1.43 (0.73)

TG: taller group; SG: shorter group; LLL: longer leg length; SLL: shorter leg length; HG: heavier group; LG: lighter group; LL:H ratio: leg length to body height ratio; BMI: body mass index.

* $P < 0.05$.

** $P < 0.01$.

*** $P < 0.001$.

there is a small-to-moderate relationship between anthropometric characteristics and spatiotemporal parameters during running, the role of those parameters (body height, torso and leg length, and body mass) does not seem to be determinant in the spatiotemporal characteristics of amateur endurance runners at a given velocity.

As indicated earlier, despite abundant information is available about spatiotemporal gait characteristics during running, just a limited number of studies have investigated the influence of the body structure on spatiotemporal parameters [27,30—32]. Whereas Maciejczyk et al. [27] directly evaluated the influence of body composition on running economy, other studies [30—32] compared the somatic characteristics of African vs. Caucasian endurance runners and suggested that body structure might play an important role in running kinematics. Eksterowicz et al. [30] aimed to determine the relationship between some somatic parameters of Kenyan marathon runners and their athletic performance, concluding that body height and leg length were not significantly correlated with athletic performance in endurance running (i.e.,10-km, half-marathon and marathon); whereas torso length showed significant correlations with athletic performance in long-distance runs. Kong and de Heer [32], in a biomechanical approach to understand the success of Kenyan distance runners, analysed anthropometric, gait and lower extremity strength characteristics of six elite Kenyan distance runners, concluded that elite Kenyan athletes are characterized by a low BMI, low percentage body fat and slim limbs, by suggesting that their slim limbs might positively contribute to performance by having a low moment of inertia and thus requiring less muscular effort in leg swing. Likewise, referred to the slim lower-limb of Kenyan endurance runners, Temfemo et al. [31] concluded that Kenyan athletes showed smaller muscle fibers, and this might enable mitochondria to approach capillary vessels that encompass fibers, which would allow easier oxygen diffusion from capillaries to mitochondria and efficient oxidation.

Although most of evidence available about the potential influence of anthropometric characteristics on running performance and running biomechanics have been suggested, all those previous studies [25—32] are consistent and it suggests that body structure might play an important role in running kinematics. The current study specifically focuses on the influence of body structure on spatiotemporal gait characteristics in a big sample of amateur endurance runners, and the results provide support to the relationship between anthropometric characteristics and running kinematics, by highlighting that the CT is the spatiotemporal parameter that showed the strongest association with anthropometric characteristics but, despite some significant associations were found, the role of those parameters (body height, torso and leg length, and body mass) does not seem to be determinant in the spatiotemporal characteristics of amateur endurance runners at a given velocity.

Finally, regarding the sex influence, the main finding was the lack of differences (men vs. women) in spatiotemporal parameters during running. As expected, women showed shorter body proportions and lower body mass — female runners are generally smaller in body size than males —, and this must be taken into consideration in order to correctly interpret the lack of differences in spatiotemporal gait characteristics. In fact, non-significant differences can be observed between sexes, with men showing longer CT and SL and shorter FT and smaller SF and SA; results that exactly coincide with those obtain for the TG, LLL group and HG (groups vastly composed by men; see Table 3). The lack of research covering this topic makes comparison difficult. Perhaps as a consequence of sex discrepancies in running-related injury rates [21], most studies have focused on sex differences in lower extremity kinematics and its relationship with injuries [22—24]. Nevertheless, to the best of the authors' knowledge, no previous studies have described spatiotemporal differences between sexes in endurance runners. In a similar topic, three previous studies found no significant differences between sexes in foot strike pattern in adult endurance runners [41], in children 6—16 years old [42] and preschool children (3—6 years old) [43], but any previous study has addressed spatiotemporal differences between sexes directly.

Some limitations need to be addressed. First, the establishment of a standard running pace (12 km.h^{-1}). This may lead to differences in terms of relative intensity, so that a relative pace should have been chosen for each subject. Second, more information about fitness level and training background of the participants should have been collected and reported. Runners under 50 min in a 10-km trial might include a heterogeneous athletic level and thereby, it might influence on the response to that standard running pace. Third, a deeper biomechanical analysis may reveal further differences between groups. Of note, foot strike pattern was not controlled in this study. Rearfoot-, midfoot- and forefoot-strike runners have differing biomechanics and therefore may have a different response to running velocity. Notwithstanding these limitations, the current paper highlights the influence of potential confounding variables such as sex or anthropometric data on spatiotemporal parameters during running at a common velocity in a sample of 97 endurance runners.

5. Conclusion

At a given running velocity (12 km.h^{-1}), differences in body proportions seem to determine CT in amateur endurance runners, with higher values reported in taller and heavier runners. Nevertheless, although does exist a relationship between anthropometric characteristics and spatiotemporal parameters during running, the role of the somatic parameters measured in this study (body height, torso and leg length, and body mass) does not seem to be determinant in the spatiotemporal characteristics of amateur endurance runners at 12 km.h^{-1}.

From a practical standpoint, since the easy access to information about spatiotemporal parameters during running — many devices provide that information, even real-time feedback —, these findings must be interpreted as a warning for coaches, sport scientists and athletes, about the potential limitations of comparing data from athletes with different somatic characteristics.

Disclosure of interest

The authors declare that they have no competing interest.

References

[1] Barnes KR, Kilding AE. Running economy: measurement, norms, and determining factors. Sport Med - Open 2015;1(1):8.

[2] Tartaruga MP, Brisswalter J, Peyré-Tartaruga LA, Ávila AOV, Alberton CL, Coertjens M, et al. The relationship between running economy and biomechanical variables in distance runners. Res Q Exerc Sport 2012;83(3):367—75.

[3] Mooses M, Mooses K, Haile DW, Durussel J, Kaasik P, Pitsiladis YP. Dissociation between running economy and running performance in elite Kenyan distance runners. J Sports Sci 2015;33(2):136—44.

[4] Anderson T. Biomechanics and running economy. Sport Med 1996;22(2):76—89.

[5] García-Pinillos F, Molina-Molina A, Párraga-Montilla JA, Latorre-Román PA. Kinematic alterations after two high-intensity intermittent training protocols in endurance runners. J Sport Heal Sci 2016.

[6] Roche-Seruendo LE, García Pinillos F, Auria-Martin I, Bataller-Cervero AV, Latorre Román PA, Soto -Hermoso VM. Effects of different percentages of body weight support on spatiotemporal step characteristics during running. J Sports Sci 2017:1—6 [Internet], [cited 2017 Oct 25], https://www.tandfonline.com/doi/full/10.1080/02640414.2017.1394584.

[7] Roche-Seruendo LE, García-Pinillos F, Haicaguerre J, Bataller-Cervero AV, Soto-Hermoso VM, Latorre-Román PÁ. Lack of influence of muscular performance parameters on spatiotemporal adaptations with increased running velocity. J Strength Cond Res 2018;32(2):409—15.

[8] García-Pinillos F, Soto-Hermoso VM, Latorre-Román PÁ. Do running kinematic characteristics change over a typical HIIT for endurance runners? J Strength Cond Res 2016;30(10):2907—17.

[9] Brughelli M, Cronin J, Chaouachi A. Effects of running velocity on running kinetics and kinematics. J Strength Cond Res 2010;24(0):1—7.

[10] Padulo J, Annino G, Migliaccio GM, D'Ottavio S, Tihanyi J. Kinematics of running at different slopes and speeds. J Strength Cond Res 2012;26:1331—9.

[11] Padulo J, Annino G, Smith L, Migliaccio G, Camino R, Tihanyi J, et al. Uphill running at iso-efficiency speed. Int J Sports Med 2012;33(10):819—23.

[12] Vernillo G, Giandolini M, Edwards WB, Morin JB, Samozino P, Horvais N, et al. Biomechanics and physiology of uphill and downhill running. Sport Med 2017;47(4):615—29.

[13] Lussiana T, Hébert-Losier K, Mourot L. Effect of minimal shoes and slope on vertical and leg stiffness during running. J Sport Heal Sci 2014;4(2):195—202.

[14] García-Pinillos F, Latorre-Román PÁ, Ramírez-Campillo R, Párraga-Montilla JA, Roche-Seruendo LE. How does the slope gradient affect spatiotemporal parameters during running? Influence of athletic level and vertical and leg stiffness. Gait Posture 2018;68:72—7.

[15] Schubert AG, Kempf J, Heiderscheit BC. Influence of stride frequency and length on running mechanics: a systematic review. Sports Health 2014;6(3):210—7.

[16] Barnes K, Mcguigan M, Kilding A. Lower-body determinants of running economy in male and female distance runners. J Strength Cond Res 2014;28(5):1289—97.

[17] Lenhart RL, Thelen D, Heiderscheit B. Hip muscle loads during running at various step rates. J Orthop Sports Phys Ther 2014;44(10):766—74 [1—4].

[18] Lenhart RL, Thelen DG, Wille CM, Chumanov ES, Heiderscheit BC. Increasing running step rate reduces patellofemoral joint forces. Med Sci Sports Exerc 2014;46(3):557—64.

[19] Heiderscheit BC, Chumanov ES, Michalski MP, Wille CM, Ryan MB. Effects of step rate manipulation on joint mechanics during running. Med Sci Sports Exerc 2011;43(2):296—302.

[20] Williams KR, Cavanagh PR. Relationship between distance running mechanics, running economy, and performance. J Appl Physiol 1987;63(3):1236—45.

[21] Taunton JE, Ryan MB, Clement DB, McKenzie DC, Lloyd-Smith DR, Zumbo BD. A retrospective case-control analysis of 2002 running injuries. Br J Sports Med 2002;36(2):95—101.

[22] Takabayashi T, Edama M, Nakamura M, Nakamura E, Inai T, Kubo M. Gender differences associated with rearfoot, midfoot, and forefoot kinematics during running. Eur J Sport Sci 2017;17(10):1289—96.

[23] Sakaguchi M, Ogawa H, Shimizu N, Kanehisa H, Yanai T, Kawakami Y. Gender differences in hip and ankle joint kinematics on knee abduction during running. Eur J Sport Sci 2014;14(Suppl 1):302—9.

[24] Chumanov ES, Wall-Scheffler C, Heiderscheit BC. Gender differences in walking and running on level and inclined surfaces. Clin Biomech (Bristol, Avon) 2008;23(10):1260—8 [Internet], [cited 2014 Jul 27], Available from: http://www.ncbi.nlm.nih.gov/pubmed/18774631.

[25] Lacour JR, Padilla-Magunacelaya S, Barthélémy JC, Dormois D. The energetics of middle-distance running. Eur J Appl Physiol Occup Physiol 1990;60(1):38—43.

[26] Lacour JR, Candau R. Maximal oxygen uptake and performance in endurance runners. Sci Sports 1990;5(4):183—9.

[27] Maciejczyk M, Wiecek M, Szymura J, Szygula Z, Cempla J. Physiological response during running in athletes with similar body mass but different body composition. Sci Sports 2015;30(4):204—12.

[28] Peikriszwili Tartaruga M, Bolli Mota C, Peyré-Tartaruga LA, Martins Kruel LF, Vallier J-M, Brisswalter J. Running efficiency and long-distance performance prediction: Influence of allometric scaling. Sci Sports 2013;28(4):165—71.

[29] Hausswirth C, Brisswalter J. Factors modifying running economy in long distance running. Sci Sports 1999;14(2):59—70.

[30] Eksterowicz J, Napierała M, Zukow W. How the Kenyan runner's body structure affects sports results. Hum Mov 2016;17(1):8—14.

[31] Temfemo A, Laparadis C, Bishop D, Merzouk A, Ahmaidi S. Are there differences in performance, metabolism, and quadriceps muscle activity in black african and caucasian athletes during brief intermittent and intense exercise? J Physiol Sci 2007;57(4):203—10.

[32] Kong PW, de Heer H. Anthropometric, gait and strength characteristics of kenyan distance runners. J Sports Sci Med 2008;7(4):499—504.

[33] World Medical Association. World Medical Association Declaration of Helsinki. JAMA 2013;310(20):2191.

[34] Schieb DA. Kinematic accommodation of novice treadmill runners. Res Q Exerc Sport 1986;57(1):1—7.

[35] Lavcanska V, Taylor NF, Schache AG. Familiarization to treadmill running in young unimpaired adults. Hum Mov Sci 2005;24(4):544—57.

[36] Morin JB, Samozino P, Zameziati K, Belli A. Effects of altered stride frequency and contact time on leg-spring behavior in human running. J Biomech 2007;40(15):3341—8.

[37] Lee MM, Song CH, Lee KJ, Jung SW, Shin DC, Shin SH. Concurrent Validity and Test-retest Reliability of the OPTOGait Photoelectric Cell System for the Assessment of Spatio-temporal Parameters of the Gait of Young Adults. J Phys Ther Sci 2014;26(1):81—5 [Internet], [cited 2019 Jan 23], Available from: http://jlc.jst.go.jp/DN/JST.JSTAGE/jpts/26.81?lang=en&from=CrossRef&type=abstract.

[38] Brown AM, Zifchock RA, Hillstrom HJ. The effects of limb dominance and fatigue on running biomechanics. Gait Posture 2014;39(3):915—9.
[39] Santos-Concejero J, Tam N, Granados C, Irazusta J, Bidaurrazaga-Letona I, Zabala-Lili J, et al. Stride angle as a novel indicator of running economy in well-trained runners. J Strength Cond Res 2014;28(7):1889—95.
[40] Hopkins WG, Marshall SW, Batterham AM, Hanin J. Progressive statistics for studies in sports medicine and exercise science. Med Sci Sports Exerc 2009;41(1):3—13.
[41] Latorre-Román PÁ, Muñoz-Jiménez M, Soto-Hermoso VM, Sánchez JS, Molina AM, Robles-Fuentes A, et al. Acute effect of a long-distance road competition on foot strike patterns, inversion and kinematics parameters in endurance runners. Int J Perform Anal Sport 2015;15:588—97.
[42] Latorre Román PÁ, Balboa FR, García-Pinillos F. Foot strike pattern in children during shod-unshod running. Gait Posture 2017;58:220—2.
[43] Latorre-Román PÁ, Párraga-Montilla JA, Guardia-Monteagudo I, García-Pinillos F. Foot strike pattern in preschool children during running: sex and shod—unshod differences. Eur J Sport Sci 2018;17(3):407—14.