Journal of Athletic Training 2020;55(12):1300–1306
doi: 10.4085/1062-6050-565-19

www.natajournals.org

Original Research

Factors Influencing Base of Gait During Running: Consideration of Sex, Speed, Kinematics, and Anthropometrics

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Context: A narrow base of gait (BOG), the mediolateral distance between the foot and the body's line of gravity at midstance, during running is a suggested cause of injuries such as iliotibial band syndrome and tibial stress injury. However, an understanding of modifiable and nonmodifiable factors that influence BOG is lacking, which limits the development of corrective strategies.

Objective: To determine if BOG varies by sex and running speed and the influence of running kinematics and anthropometrics on BOG.

Design: Cross-sectional study.

Setting: Record review of routinely collected performance data from a National Collegiate Athletic Association Division I intercollegiate athletic program.

Patients or Other Participants: A total of 166 Division I collegiate athletes (basketball, cross-country, football, soccer).

Main Outcome Measure(s): Running biomechanics (N = 166) and dual-energy x-ray absorptiometry-derived anthropometric data (n = 68) were extracted. Running variables were BOG, step rate, stride length, foot-inclination angle, center-of-mass vertical displacement, heel-to-center of mass anteroposterior distance, and peak stance-phase angles: hip flexion, hip adduction, pelvic drop, knee flexion, and ankle dorsiflexion. Extracted anthropometric variables were height; leg, femur, and tibia length; and anterior-superior iliac spine, hip-joint, and greater trochanter width. We calculated linear mixed-effects models to assess the influence of sex and running speed on BOG and identify the kinematic and anthropometric variables most associated with BOG.

Results: A significant interaction between sex and running speed on BOG was observed, with males demonstrating a smaller BOG than females at faster speeds and BOG decreasing overall with speed. The kinematic measures most associated with BOG at preferred running speed were foot-inclination angle at initial contact and peak stance-phase hip adduction and ankle dorsiflexion. Anterior-superior iliac spine width was the anthropometric variable most associated with BOG at preferred running speed.

Conclusions: Sex and running speed must be considered when determining the appropriateness of an individual's BOG. Additionally, BOG was associated with several potentially modifiable kinematic parameters.

Key Words: crossover, step width, biomechanics, dual-energy x-ray absorptiometry

Key Points

- A runner's sex and running speed must be considered when assessing the appropriateness of his or her base of gait (BOG), as the BOG tended to be smaller in males at faster running speeds and decreased with speed, regardless of sex.
- The BOG was related to both modifiable biomechanical and nonmodifiable anthropometric factors.
- Peak hip adduction during stance phase was most strongly related to the BOG and may be a target for future development of gait-retraining strategies for modifying the BOG.

The base of gait (BOG) during running is a frontal-plane variable that describes the mediolateral distance between the placement of the foot during midstance relative to the individual's line of gravity.[1] A narrow BOG has been suggested as a primary contributing factor to running-related injuries such as iliotibial band syndrome[2] and tibial stress injuries.[3] Despite its potential importance, a basic characterization of BOG between males and females and at varying running speeds has not been conducted, limiting our ability to evaluate the appropriateness of an individual's BOG.

During running, the foot can fall on either side of the line of gravity in the frontal plane, resulting in positive (same-side) and negative (opposite-side) values. A negative BOG value is commonly termed *crossover* and can lead to excessive tissue loads at the distal medial tibia, lateral thigh, and hip.[1] However, a more narrow BOG may naturally accompany faster running speeds, similar to what occurs during faster walking.[4,5] If so, a negative BOG (crossing over the line of gravity) at fast running speeds may be normal in a healthy population. Similarly, BOG likely differs between males and females, consistent with many other lower extremity running biomechanics.[6] Thus, a better understanding of how BOG is influenced by sex and running speed is needed before this metric can be effectively interpreted.

Modifying the BOG has been suggested as a strategy for altering lower extremity tissue loads and potentially reducing the risk of specific injuries such as tibial stress injuries.[7] A change in BOG will necessitate changes in lower extremity kinematics, reflecting an inherent interdependence. However, one's BOG may be partially determined by nonmodifiable factors such as skeletal anthropometry. Consequently, if the BOG is more associated with anthropometry, then attempts to modify it may be unsuccessful and potentially problematic. A better understanding of which kinematic and anthropometric measures are associated with BOG is warranted.

The purpose of our study was to provide a thorough understanding of the key contributors to BOG during running. The initial aim was to determine if the BOG varied by sex and running speed. We hypothesized that both sex and speed would influence the BOG, supporting the need to account for these factors in subsequent analyses. Secondary aims were to assess the associations between the BOG and kinematic and anthropometric variables to determine the association of the BOG with modifiable and nonmodifiable factors, respectively. We proposed that both kinematic and anthropometric variables would demonstrate significant associations with the BOG at preferred running speed.

METHODS

In this study, we analyzed data collected routinely in the University of Wisconsin–Madison Badger Athletic Performance database from 2015 to 2018. The database contains results from a standardized battery of preseason assessments, including running biomechanics and dual-energy x-ray absorptiometry (DXA) images, which National Collegiate Athletic Association Division I student-athletes undergo each year while at the University of Wisconsin–Madison. The database review was approved by the University's Health Sciences Institutional Review Board. Athlete demographics (age, height, weight) and running-gait data were extracted if the athlete (1) was cleared for full participation at the time of testing; (2) had running-biomechanics data available at 2.68, 2.95, 3.35, 3.80, and 4.47 $m\cdot s^{-1}$ and at preferred running speed; (3) had no history of lower extremity surgery; and (4) had no history of lower extremity bone stress injury within 3 months of the testing session. From among this pool of eligible participants, DXA scans acquired at the same time as the running biomechanics were also extracted where available. If an athlete had multiple eligible data-collection sessions from sequential years, 1 session was selected for inclusion at random to reduce the potential effects of maturation and training.

Data Acquisition and Processing

Running Kinematics. Data-collection procedures for running biomechanics have been previously described.[6] Briefly, whole-body kinematics were recorded at 200 Hz using an 8-camera passive marker system (Motion Analysis Corp, Santa Rosa, CA) with 42 reflective markers. Markers were placed by the same researcher (M.R.S.-J.) for all data collection. Ground reaction forces were synchronously recorded at 2000 Hz using an instrumented treadmill (Bertec Corp, Columbus, OH). The treadmill assessment was conducted according to a standardized testing protocol. Athletes walked for a minimum of 2 minutes to acclimate to the treadmill and motion-capture setup. They then began running at 2.68 $m\cdot s,^{-1}$ and the speed was incrementally increased to 2.95, 3.35, 3.80, and 4.47 $m\cdot s^{-1}$. After the athlete had acclimated to the speed for at least 30 seconds, 15 seconds of data were recorded. Fifteen seconds of data were also recorded at each athlete's preferred running speed, a speed that the individual indicated represented a moderate-intensity training run.

The whole body was modeled as a 14-segment, 31 degrees-of-freedom articulated linkage.[8] Body segments were scaled using the participant's height, mass, and segment lengths.[9] For each stride, model coordinates were calculated at each time step using a global optimization inverse kinematics routine.[10] Gait cycles were identified by subsequent initial foot contacts, with the *stance phase* of the gait cycle defined from initial contact to toe-off, when the vertical ground reaction force rose above and fell below 50 N, respectively. Biomechanical variables of interest extracted from the running gait data were BOG, step rate, stride length, foot-inclination angle at initial contact (FIA),[6] center-of-mass (COM) vertical excursion, anterior-posterior distance from heel to COM, and peak values of hip-flexion, hip-adduction, pelvic-drop, knee-flexion, and ankle-dorsiflexion angles during stance phase (Table 1). All signal processing and analyses of the running-biomechanics data were conducted using a custom script developed in MATLAB (version 2018a; The MathWorks, Inc, Natick, MA).

Anthropometric Data. Anthropometric measures were obtained from whole-body scans acquired using a GE Healthcare Lunar iDXA densitometer (Madison, WI). Scans were conducted by technologists who were trained by a single lead technologist and followed protocols developed for this National Collegiate Athletic Association Division I athletic performance-assessment facility. Custom anthropometric bone measures for all scans were determined by a single rater and consisted of bilateral leg, femur, and tibia lengths and anterior-superior iliac spine (ASIS), hip-joint, and greater trochanter widths (Table 1). All scans were acquired and analyzed using enCORE software (version 14.1; GE Healthcare, Madison, WI).

Statistical Analyses

We calculated linear mixed-effects models to assess the influences of sex and speed and a potential interaction effect on the BOG. Data averaged across 15 strides for each limb separately were included in the analyses at 5 speeds (2.68, 2.95, 3.35, 3.80, and 4.47 $m\cdot s^{-1}$), resulting in 10 BOG measurements per participant. The mixed-effects model accounted for the within-subject limb and speed correlation induced by the repeated measures via an unstructured covariance matrix for the left and right limb and an exchangeable covariance structure for the various speeds. Each athlete was modeled using a random effect.

Separate linear mixed-effects models were conducted to determine the independent associations between each kinematic and anthropometric variable of interest and the BOG while controlling for sex and speed. Variables that demonstrated an association with the BOG at the level of $P \leq .2$ were considered for inclusion in a multivariable linear mixed-effects model. We then created linear mixed-effects models separately for the kinematic and anthropometric

Table 1. Definitions and Calculations of Variables of Interest Used for Kinematic and Anthropometric Models

Variable	Definition
Kinematic variable	
Base of gait, cm	Mediolateral distance at midstance between the body's line of gravity and a heel marker placed at the midline of the heel and affixed to the shoe; positive values indicate a landing position ipsilateral to the line of gravity
Step rate, steps/min	Steps per min
Stride length, m	Distance traveled per stride
Foot-inclination angle, °	Sagittal angle of the foot segment with respect to the horizontal plane at initial contact; positive values indicate a rearfoot landing posture
Center-of-mass vertical excursion, cm	The difference between the highest and lowest position of the body's center of mass during the running stride cycle
Heel-to-center of mass anteroposterior distance, cm	Anteroposterior distance at initial contact between the body's line of gravity and the heel marker affixed to the shoe
Peak hip flexion, °	Maximal hip-flexion angle during stance phase
Peak hip adduction, °	Maximal hip-adduction angle during stance phase
Peak pelvic drop, °	Minimal frontal-plane pelvic angle during stance phase
Peak knee flexion, °	Maximal knee-flexion angle during stance phase
Peak ankle dorsiflexion, °	Maximal ankle-dorsiflexion angle during stance phase
Dual-energy x-ray absorptiometry-derived anthropometric value, cm	
Leg length	Distance from the anterior-superior iliac spine to the most distal aspect of the tibia
Femur length	Distance from the most proximal aspect of the femoral head to the most distal aspect of the medial condyle
Tibia length	Distance from the most proximal aspect of the tibia to the most distal aspect of the tibia
Hip-joint width	Distance between the most medial aspect of the femoral heads
Greater trochanter width	Distance between the most lateral aspect of the greater trochanters
Anterior-superior iliac spine width	Distance between the most prominent (indicated by signal intensity) aspects of the iliac crest

variables to distinguish the influences of the modifiable and nonmodifiable variables, respectively, on the BOG. All models used kinematic measures at preferred running speed only and accounted for repeated within-subject limb measures. The final kinematic and anthropometric multivariable models were determined using a combination of backward selection and Akaike information criterion (AIC) value comparisons.

Finally, to determine the joint contributions of both the kinematic and anthropometric models, we combined the final variables included in each respective model into a single linear mixed-effects model. Given that only a subset of athletes had undergone complete kinematic and DXA testing (n = 68), only the data from these athletes were included in this model. All analyses were performed in RStudio (version 1.2.1335; Boston, MA).

RESULTS

The records for 166 basketball, cross-country, football, or soccer athletes met the inclusion criteria (Table 2), 68 of whom also had DXA scans available from the same test session. Estimates for the model assessing the influences of sex and speed on the BOG are presented in Table 3. An interaction between sex and speed was observed, with males demonstrating smaller BOGs than females at 3.80 $m\cdot s^{-1}$ ($P = .008$) and 4.47 $m\cdot s^{-1}$ ($P < .001$). The BOG decreased with speed in both sexes (Table 3, Figure).

Based on the individual, univariable analyses of the kinematic measures (n = 166; Table 4, models 1–10) associated with the BOG at preferred running speed, we considered FIA, COM vertical excursion, peak values of hip flexion, hip adduction, pelvic drop, knee flexion, and ankle dorsiflexion during stance phase for inclusion in the final model. The optimal multivariable model consisted of sex, speed, FIA, peak hip-adduction angle, and peak ankle-dorsiflexion angle (Table 4, model 11), with FIA demonstrating a positive relationship and peak hip adduction and peak ankle dorsiflexion demonstrating negative relationships with BOG. For every 5° increase in FIA, the BOG increased by 0.39 cm (95% confidence interval [CI] = 0.25, 0.52), whereas for every 5° increase in peak hip-adduction

Table 2. Athlete Demographics, Mean ± SD

Variable	n	Age, y	Height, m	Weight, kg	Preferred Running Speed, $m\cdot s^{-1}$
Males	93	19.1 ± 1.1	1.83 ± 0.07	83.7 ± 14.4	3.78 ± 0.35
Cross-country	35	19.9 ± 1.2	1.80 ± 0.06	69.1 ± 5.2	4.07 ± 0.38
Football	58	18.6 ± 0.7	1.86 ± 0.06	92.5 ± 10.4	3.60 ± 0.28
Females	73	19.4 ± 1.4	1.68 ± 0.06	61.2 ± 7.5	3.61 ± 0.31
Basketball	7	19.4 ± 1.6	1.76 ± 0.08	72.7 ± 6.4	3.48 ± 0.22
Cross-country	44	19.8 ± 1.5	1.66 ± 0.05	57.8 ± 5.5	3.77 ± 0.20
Soccer	22	18.5 ± 0.5	1.68 ± 0.06	64.9 ± 5.6	3.36 ± 0.32

Table 3. Linear Mixed-Effects Model Assessing the Influences of Sex and Speed on the Base of Gait (N = 166)

Estimate[a]	Fixed Effect Estimate (95% Confidence Interval)	*P* Value
Intercept	1.358 (0.968, 1.747)	<.001
Sex[b] (2.95 m/s)	0.024 (−0.136, 0.185)	.767
Sex[b] (3.35 m/s)	−0.121 (−0.281, 0.040)	.142
Sex[b] (3.80 m/s)	−0.220 (−0.380, −0.059)	.008[b]
Sex[b] (4.47 m/s)	−0.409 (−0.570, −0.248)	<.001[b]
Sex	−0.150 (−0.670, 0.371)	.574
Speed (2.95 m/s)	−0.353 (−0.474, −0.233)	<.001
Speed (3.35 m/s)	−0.641 (−0.761, −0.521)	<.001
Speed (3.80 m/s)	−0.999 (−1.119, −0.878)	<.001
Speed (4.47 m/s)	−1.442 (−1.563, −1.322)	<.001

[a] Females and 2.68 m/s were the reference groups for sex and speed, respectively. Models accounted for repeated measures within limb and a random subject effect.

[b] Difference compared with the reference group at $P < .05$.

angle and peak ankle-dorsiflexion angle, the BOG decreased by 0.56 cm (95% CI = 0.31, 0.83) and 0.46 cm (95% CI = 0.27, 0.65), respectively.

Based on the univariable analysis of anthropometric measures among those who had DXA measures (n = 68) associated with BOG at preferred running speed, we considered height and ASIS width for inclusion in the final model (Table 5, models 1–7). Although ASIS, hip-joint, and greater trochanter width all demonstrated significant associations with BOG after adjusting for speed and sex, the 3 width values demonstrated strong intercorrelations ($r > 0.6$). Therefore, only ASIS width was considered for the final anthropometric mixed-effects model due to the feasibility of clinical measurement. The optimal final model contained sex, height, speed, and ASIS width (Table 5, model 8: $R^2 = 0.280$, AIC = 490.4). For every 10-cm increase in height, the BOG decreased by 0.06 cm (95% CI = −0.74, 0.61); for every 1-cm increase in ASIS width, the BOG decreased by 0.31 cm (95% CI = 0.06, 0.56). Although height was included in the final anthropometric model, the effect estimate had a wide CI and a nonsignificant *P* value ($P = .857$), suggesting that although height may have contributed to explaining the variability in BOG, it did not demonstrate a significant independent association with BOG.

When we combined the kinematic and anthropometric measures from each of the respective multivariable linear mixed-effects models for those with complete data (n = 68), a notable increase in the proportion of variance in BOG explained by the model was observed, with a minimal increase in AIC ($R^2 = 0.383$, AIC = 493.0) compared with the anthropometric variables-only model.

DISCUSSION

The purpose of our study was to assess the influences of sex and speed on the BOG during running with subsequent analyses to address the effects of running kinematics (modifiable) and anthropometric (nonmodifiable) factors. We found a significant interaction between sex and speed, with males demonstrating a narrower BOG (smaller, more negative values) compared with females at speeds of 3.80 m·s^{-1} (7:00-minute mile) and faster. Both males and females showed decreasing BOG with increasing speed.

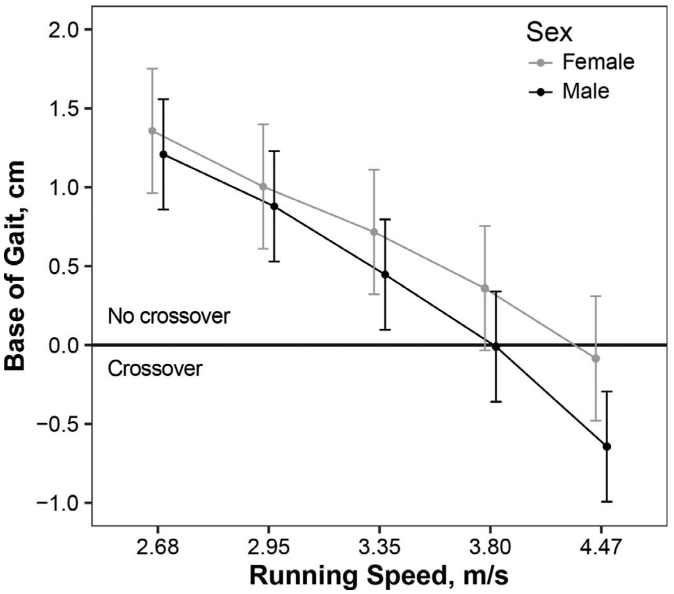

Figure. Base of gait by sex and speed. Error bars represent 95% confidence intervals of the least square means for each group, as estimated by the linear mixed-effects model with sex and speed as fixed effects and accounting for within-subject repeated limb measures.

On average, males demonstrated crossover at 4.47 m·s^{-1} (6:00-minute mile), whereas females did not demonstrate crossover at any speed.

Given the numerous differences that exist in frontal-plane running biomechanics between males and females, the difference in BOG between males and females was expected. Although minimal research exists on BOG during running, 1 research group[7] that analyzed step-width modifications observed no differences between males and females at preferred running speed. A small sample size (15 males, 15 females), running speed of 3.5 m·s^{-1}, and differences in calculating step width and BOG may explain the varied results compared with our current study.[7] We studied a more robust dataset of 93 males and 73 females across a wide range of running speeds and clearly demonstrated a more narrow BOG in males than in females at running speeds of 3.80 m·s^{-1} and faster. Although step width and BOG in the 2 investigations cannot be directly compared, the general directions and relationships may still hold. However, the use of a single variable (ie, step width) to quantify the mediolateral distance between the 2 feet may overlook asymmetries between limbs. Indeed, Cavanagh,[1] in an early study of BOG, indicated that limb asymmetries were typical and may provide insight into injury risk.

After adjusting for sex and speed, we determined that modifiable kinematic variables associated with the BOG were FIA, peak hip-adduction angle, and peak ankle-dorsiflexion angle during stance. The nonmodifiable variable associated with the BOG was ASIS width. Hip-adduction angle had the strongest relationship with BOG compared with the other variables in the kinematic model: greater hip-adduction angles were associated with narrower BOG. The relationship between hip-adduction angle and BOG is the most intuitive because as the femur moves closer to the midline (increased hip adduction), the foot may also move closer to, or past, the midline (decreased

Table 4. Univariable and Multivariable (Linear Mixed-Effects Model) Analyses Assessing the Associations of Kinematic Variables With Base of Gait, Controlling for Sex and Preferred Running Speed (N = 166)

Model	Variable	Fixed Effect Estimate (95% Confidence Interval)	*P* Value	
Univariable kinematic models[a]				
1	Step rate	0.006 (−0.021, 0.033)	.676	
2	Stride length	0.069 (−1.628, 1.761)	.937	
3	Foot-inclination angle	0.066 (0.042, 0.090)	<.001[c]	
4	Heel-to-center of mass anteroposterior distance	0.029 (−0.031, 0.088)	.348	
5	Center-of-mass vertical excursion	−0.162 (−0.340, 0.015)	.075[c]	
6	Peak knee flexion	0.050 (−0.002, 0.102)	.063[c]	
7	Peak hip adduction	−0.216 (−0.280, −0.161)	<.001[c]	
8	Peak pelvic drop	0.104 (0.028, 0.188)	.010[c]	
9	Peak hip flexion	0.070 (0.031, 0.108)	<.001[c]	
10	Peak ankle dorsiflexion	−0.059 (−0.101, −0.019)	.005[c]	
Multivariable kinematic model[b]			*P* Value	R^2
11	Intercept	6.274 (3.527, 9.038)	<.001	0.270
	Sex	−0.843 (−1.383, −0.318)	.002[d]	
	Speed	−0.549 (−1.304, 0.222)	.162	
	Foot-inclination angle	0.077 (0.050, 0.103)	<.001[d]	
	Peak hip adduction	−0.111 (−0.165, −0.062)	<.001[d]	
	Peak ankle dorsiflexion	−0.091 (−0.130, −0.053)	<.001[d]	

[a] Models were performed separately for each variable of interest, with variables demonstrating an association with base of gait at the $P < .2$ level considered for entry into the multivariable model. Models accounted for repeated measures within limb and a random subject effect and were adjusted for speed and sex.

[b] The optimal model was selected using a combination of backward selection and Akaike information criterion comparisons. Models accounted for repeated measures within limb and a random subject effect. Females were the reference group for sex.

[c] Significant contribution to the model at the level of $P < .2$.

[d] Significant contribution to the model at the level of $P < .05$.

BOG). Similarly, an increase in peak ankle-dorsiflexion angle during stance was also associated with a decreased BOG, whereas increases in FIA at initial contact were associated with a wider BOG. The biomechanical explanations for these associations are less clear; evidence-based clinical relationships have not been fully elucidated, and the final models were derived as a result of identified statistical relationships between variables. However, both FIA and ankle-dorsiflexion angle displayed relatively small effects compared with hip-adduction angle. This suggests that modifying the FIA or peak ankle-dorsiflexion angle may result in a small change in BOG for the same relative change in hip-adduction angle.

The anthropometric measure with the greatest proportionality to BOG was ASIS width. Although known anthropometric differences in pelvic geometry exist between males and females,[11] the influence of ASIS width on BOG held in our study after controlling for sex, which suggested that regardless of an athlete's sex, an individual with a wider pelvis may have a narrower BOG. Anthropometric measures are nonmodifiable, yet an athlete's ASIS width should be considered when the appropriateness of his or her BOG is being evaluated.

When the final kinematic and anthropometric multivariable linear mixed-effects models were combined, the subset of the sample with complete data ($n = 68$) revealed a notable increase in the proportion of variance in BOG explained by the model ($R^2 = 0.383$, AIC = 493.0) compared with the anthropometric-only model ($R^2 = 0.280$, AIC = 490.4). Thus, both modifiable and nonmodifiable factors contributed unique portions of the variance in an individual's preferred BOG and, when considered together, explained an increased amount of the variance. Qualitative analysis of running using 2-dimensional video can provide the clinician with a useful assessment of BOG and the influencing kinematic factors (ie, FIA, hip adduction, and ankle dorsiflexion).[12] Additionally, ASIS width can be easily assessed during a physical examination. As such, the identified modifiable and nonmodifiable factors related to BOG can be evaluated as part of a standard clinical examination and taken into account when one is determining if and when modification of a runner's BOG is warranted. However, further research to systematically determine the effects on BOG of modifying the associated variables identified in this model are needed to determine the clinical relevance of the relationships we characterized.

Limitations of this study include the different sample sizes in each model, a large portion of the variance in BOG that remained unexplained, and the generalizability of our findings to only the population analyzed: healthy collegiate athletes participating in basketball, cross-country, football, or soccer. Given the heterogeneity of this sample with regard to sport, it is unclear if these results may differ from those among a sample of endurance runners. The running-kinematics model was based on 166 athletes, whereas the DXA-derived anthropometrics model involved 68 athletes. However, both comprised the largest datasets published to date involving BOG. It is reasonable to expect similar findings in recreational athletes, although further investigation is needed for confirmation. Though the relationships among a variety of kinematic and anthropometric variables and BOG were assessed, up to 72% of the variance in BOG remained unexplained. Thus, future authors should aim to

Table 5. Univariable and Multivariable (Linear Mixed-Effects Model) Analyses Assessing the Associations of Anthropometric Variables With Base of Gait, Controlling for Sex and Preferred Running Speed ($N = 68$). Final model (9) Combined the Kinematic and Anthropometric Variables.

Model	Variable	Fixed Effect Estimate (95% Confidence Interval)	*P* Value	R^2 Value	Akaike information criterion
Univariable anthropometric models[a]					
1	Leg length	−0.032 (−0.102, 0.038)	.372		
2	Femur length	−0.073 (−0.219, 0.073)	.324		
3	Tibia length	0.021 (−0.112, 0.154)	.753		
4	Hip-joint width	−0.534 (−0.864, −0.205)	.002[c]		
5	Greater trochanter width	−0.435 (−0.640, −0.231)	<.001[c]		
6	ASIS width	−0.314 (−0.450, −0.128)	.001[c]		
7	Height	−3.607 (−8.809, 1.595)	.173[c]		
Multivariable anthropometric model[b]			*P* Value	R^2 Value	Akaike information criterion
8	Intercept	17.541 (6.080, 29.003)	.005	0.280	490.4
	Sex	−0.669 (−1.935, 0.596)	.314		
	Speed	−2.198 (−3.749, −0.646)	.008[d]		
	Height	−0.633 (−7.386, 6.118)	.857		
	ASIS width	−0.306 (−0.555, −0.056)	.02[e]		
Multivariable anthropometric and kinematic model					
9	Intercept	14.494 (3.190, 25.163)	.015	0.383	493.0
	Sex	−1.286 (−2.599, −0.067)	.057		
	Speed	−1.673 (−3.124, −0.061)	.040[d]		
	Foot-inclination angle	0.064 (0.026, 0.101)	.001[d]		
	Peak hip adduction	−0.076 (−0.184, 0.008)	.097		
	Peak ankle dorsiflexion	−0.103 (−0.162, −0.044)	<.001[d]		
	Height	1.991 (−4.349, 8.529)	.562		
	ASIS width	−0.380 (−0.510, −0.039)	.028[d]		

Abbreviation: ASIS, anterior-superior iliac spine.

[a] Univariable anthropometric models were performed separately for each variable of interest, with variables demonstrating an association with base of gait at the $P < .2$ level considered for entry into the multivariable model. Models accounted for repeated measures within limb and a random subject effect and were adjusted for sex and speed.

[b] The optimal model was selected using a combination of backward selection and Akaike information criterion comparisons. Models accounted for repeated measures within limb and a random subject effect. Females were the reference group for sex.

[c] Significant contribution to the model at the level of $P < .2$.

[d] Significant contribution to the model at the level of $P < .05$.

identify additional variables that could be related to BOG. Finally, the relationships we found are not causal. Researchers should systematically alter the kinematic variables associated with BOG in order to determine their effect on BOG.

In conclusion, BOG during running significantly differed by sex and running speed. Males had a narrower BOG than females at faster running speeds and the BOG decreased as speed increased. Additionally, BOG was associated with running kinematics (ie, FIA at initial contact, peak hip-adduction angle, peak ankle-dorsiflexion angle) and skeletal anthropometrics (ie, ASIS width). Therefore, both modifiable and nonmodifiable factors must be considered when evaluating an individual's BOG for potential modification.

ACKNOWLEDGMENTS

We acknowledge the Sports Medicine staff in the University of Wisconsin–Madison Division of Athletics for their commitment to the welfare of the student-athletes and contributions to the Badger Athletic Performance program.

The research presented was supported under National Institutes of Health award No. TL1TR002375. The content is solely the responsibility of the authors and does not necessarily represent the official views of the National Institutes of Health.

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