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Original Research

Performance on the Single-Legged Step Down and Running Mechanics

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Context: Previous authors have shown associations between kinematics on the single-legged step down (SLSD) and running mechanics. Therefore, the SLSD may be a useful tool for identifying runners with poor running mechanics when 2- or 3-dimensional gait analysis is not available. However, the associations between SLSD performance and running kinetics, as well as the influences of sex and muscle strength on these relationships, remain unclear.

Objective: To evaluate whether kinematics on the SLSD predict kinematics and kinetics while running and whether the relationships differ between men and women and are mediated by muscle strength.

Design: Cross-sectional study.

Setting: Biomechanics research laboratory.

Patients or Other Participants: Fifty highly trained runners (25 men, 25 women; age = 27.8 ± 9.2 years, height = 1.69 ± 0.26 m, mass = 66.3 ± 15.0 kg, running distance = 45.2 ± 19.1 mile/wk [72.32 ± 30.56 km/wk]).

Main Outcome Measure(s): Relationships between kinematics on the SLSD and kinematics and kinetics during running were evaluated. We also assessed whether muscle strength moderated these relationships.

Results: For men, linear regression revealed that peak hip adduction ($R^2 = 0.306$, $P = .012$), internal rotation ($R^2 = 0.439$, $P = .002$), knee valgus ($R^2 = 0.544$, $P = .001$), and rearfoot eversion ($R^2 = 0.274$, $P = .008$) on the SLSD were strongly predictive of kinematics during running. In women, only peak hip internal rotation ($R^2 = 0.573$, $P = .001$), knee valgus ($R^2 = 0.442$, $P = .001$), and rearfoot eversion ($R^2 = 0.384$, $P = .012$) predicted running kinematics. In women, total medial collapse on the SLSD predicted peak hip-adductor moment ($R^2 = 0.364$, $P = .001$) during running. None of the relationships were moderated by muscle strength in either men or women.

Conclusions: Kinematics during the SLSD predicted kinematics while running in both men and women but only predicted kinetics while running in women. Given that none of the relationships between SLSD performance and running mechanics were moderated by muscle strength, clinicians should assess movement quality and strength independently.

Key Words: movement screening, kinematics, kinetics, sex differences, clinical assessment

Key Points

- Kinematics during the single-legged step down (SLSD) predicted kinematics while running in men and women but only predicted kinetics while running in women.
- The strength of the hip abductors and external rotators did not moderate any of the relationships between performance on the SLSD and running.
- It may be advantageous for clinicians to consider both movement quality and muscular strength when using functional screening, such as the SLSD, to assess runners for injury risk or rehabilitation progress.

Injuries are an unfortunate but large problem among runners, with up to 79% of runners reporting an injury in any 1-year period.[1] Many common running injuries have been linked to increased hip adduction, internal rotation, or increased rearfoot eversion while running.[2–4] Given the role of faulty running mechanics in running-related injuries, clinicians must be able to quickly and easily evaluate an individual's running mechanics. Although 3-dimensional (3D) kinematic and kinetic analysis is considered the criterion standard, equipment for such analysis is not readily available to many runners and may not be feasible for use in clinical settings. As an alternative, clinicians can use functional screening tests to evaluate a runner's neuromuscular control of the lower extremity, from which they can infer how the individual would move while running if associations between functional screens and running mechanics was known.

The single-legged step down (SLSD) is one such functional screen. To perform the SLSD, individuals stand on top of a box, lower themselves in a controlled manner until the nonstance heel touches the ground, and then return to an upright standing position.[5] The SLSD can be easily implemented in clinical settings in which constraints on space or time allotted for patient assessment limit the ability to conduct running-gait analysis. The SLSD has excellent interrater and intrarater reliability and, compared with 2-dimensional (2D) or 3D motion analysis, has concurrent validity when evaluated using qualitative observational scoring.[6–8] Because of these traits, the SLSD has been used to evaluate neuromuscular control of the lower extremity in many patient populations.[4,5,9] When compared with healthy control individuals, patient populations typically displayed worse performance on the SLSD, as indicated by increased contralateral pelvic drop, hip

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adduction and internal rotation, knee valgus, and rearfoot eversion.[4,10,11] This combination of movements is termed *medial collapse*. Similar medial collapse while running has been observed during prospective studies of subsequently injured runners with patellofemoral pain syndrome,[12] iliotibial band syndrome,[3] and medial tibial stress syndrome.[2] These findings, combined with ease of implementation even in constrained clinical settings, suggest that the SLSD could be a useful screening tool for identifying runners with poor running mechanics that may place them at risk for developing overuse injuries.

Several factors must be considered when evaluating the utility of the SLSD for identifying runners with poor running mechanics. First, researchers showed that kinematics differed between men and women during running[13] and the SLSD.[14] However, to date, the authors[15] of the only study to evaluate relationships between kinematics on the step down and kinematics during running did not differentiate between male and female participants. Therefore, whether associations between SLSD performance and running kinematics were similar for men and women is unknown. Second, overuse running injuries occur because of repetitive stress below the absolute failure limit of a specific tissue but with inadequate recovery time between stress applications. Thus, assessing injury risk requires an assessment of both kinetic and kinematic variables. Although no single variable has consistently predicted running injuries across studies, the results of individual prospective studies[16–18] indicated that hip- and knee-abductor moments and impulses and vertical loading rates predicted the development of running injuries. Yet whether runners with poor performance on the SLSD have higher values for these kinetic variables is unclear. Finally, strength of the hip abductors and external rotators influenced both running mechanics[19] and performance on the SLSD,[20–22] with stronger individuals typically displaying less medial collapse during both tasks. However, whether strength moderates any relationships between SLSD performance and running mechanics is undetermined. If strength does moderate these relationships, it would be important for clinicians to evaluate both the SLSD and strength; otherwise, possible deficits in running mechanics might be masked.

Given these gaps in the literature, the purpose of our study was 3-fold. First, we sought to determine whether kinematics on the SLSD predicted kinematics while running and, if so, whether the relationships differed between men and women. Second, we aimed to assess whether runners with greater medial collapse on the SLSD demonstrated higher values for kinetic variables previously linked to running injuries. Third, we planned to evaluate the extent to which the strength of the hip-abductor and external-rotator muscles moderated these relationships. We hypothesized that kinematics on the SLSD would predict kinematics while running to a similar extent for both men and women, that runners with greater medial collapse on the SLSD would display higher values for injury-related kinetic variables, and that these relationships would be moderated by hip-muscle strength, such that stronger runners would display stronger relationships between SLSD performance and running mechanics.

METHODS

Participants

Fifty highly trained runners (25 men, 25 women; age = 27.8 ± 9.2 years, height = 1.69 ± 0.26 m, mass = 66.3 ± 15.0 kg, running distance = 45.2 ± 19.1 mi/wk [72.32 ± 30.56 km/wk]) participated in this study. Volunteers were included if they were between the ages of 18 and 60 years, ran at least 20 mi/wk (32 km/wk), were injury free at the time of testing, and had no self-reported injuries in the 6 months before testing. All participants provided written informed consent, and the study was approved by the Institutional Review Board of Montana State University.

Muscle-Strength Measurements

Isometric strength of the hip abductors and external rotators was evaluated using a System 3 isokinetic dynamometer (Biodex Medical Systems, Shirley, NY). Hip-abductor strength was measured with the participant standing facing the dynamometer and the hip abducted to 10°. The axis of the dynamometer was aligned just inferior to the ipsilateral anterior-superior iliac spine. The arm of the dynamometer was strapped to the thigh approximately 8 cm above the lateral femoral epicondyle, and the dynamometer moved the participant into position before testing. Hip external-rotator strength was assessed with the participant seated in the dynamometer and the height of the chair adjusted so the knee was flexed to 90°. The dynamometer axis was aligned with the long axis of the femur, and the dynamometer arm was strapped to the shank approximately 8 cm above the lateral malleoli. For all strength tests, participants were instructed to push against the dynamometer with maximal effort for a 5-second contraction. Three trials per muscle group were recorded, and 5 seconds of rest was provided between trials.

Running and Step-Down Motion Capture

Whole-body kinematics during running and the SLSD trials were recorded using a 10-camera motion-capture system (model Raptor and Kestrel; Motion Analysis Corp, Rohnert Park, CA). Thirty-nine reflective markers were placed on bony landmarks according to a previously described marker set.[2] A standing calibration trial was performed, after which the markers on the medial femoral epicondyles and malleoli were removed. Overground running trials were conducted with participants running down a 20-m runway at a self-selected easy pace that approximated their easy training-run pace. Ground reaction forces were collected from 3 force plates (model Optima HPS464508; AMTI, Watertown, MA) located in series in the data-capture region. Ten successful trials were recorded for each limb, with a *successful trial* defined as one in which the foot landed in the middle of a force plate with no visible signs that the participant altered stride.

After the running protocol, bilateral SLSD trials were performed on a 15-cm box. Participants were instructed to slowly lower themselves until the heel of the nonstance limb touched the floor and then stand back upright, with a specific emphasis placed on moving up and down rather than stepping forward. They were also instructed the keep their hands on their hips and try to maintain an upright torso. Participants were allowed practice trials before

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assessment, for which feedback and corrections were given as needed. Ten continuous repetitions were performed on each limb. Participants wore their own shoes for both the running and SLSD trials.

Data Analysis

We calculated mean torque produced during the middle 3 seconds of each dynamometer trial and then averaged the values across the 3 trials for each muscle group. Marker trajectories and ground reaction forces were exported to Visual 3D (version 6; C-Motion, Inc, Germantown, MD), where they were filtered using fourth-order, zero-lag, Butterworth filters with cutoff frequencies of 8 Hz and 50 Hz, respectively. We computed joint angles for the hip, knee, and ankle during both the SLSD and running trials using a Cardan rotation sequence corresponding to flexion and extension, abduction and adduction, and internal and external rotation, which referenced the orientation of the distal segment relative to the proximal segment. Pelvic orientation was determined similarly but referenced relative to the fixed laboratory coordinate system. For the SLSD trials, the following dependent variables were then calculated: peak contralateral pelvic drop, hip adduction, hip internal rotation, knee valgus, tibial internal rotation, and rearfoot eversion. Total medial collapse was characterized by summing the frontal-plane variables. For each variable, the peak value for each trial was calculated, and the average of each participant's 10 trials was used for subsequent analysis.

The same 7 kinematic variables were calculated during the stance phase of each running trial, with *stance phase* defined using a 50-N threshold for the vertical ground reaction force. We determined joint moments using Newtonian-Euler inverse dynamics and expressed them as internal moments in the proximal segment coordinate system. Peak hip- and knee-abductor moments and impulses were then computed. Last, we identified the peak vertical instantaneous loading rate by differentiating the vertical ground reaction force across time. For trials with a clearly visible impact peak, the maximal loading rate between 20% and 80% of the time between foot contact and the impact peak was extracted. For participants for whom an impact peak was not clearly distinguishable, the loading rate at 13% of stance was used.[18] Joint moments and impulses were normalized by body mass, and loading rates were normalized by body weight.

Statistical Analysis

All variables were assessed for distribution normality using box-and-whisker plots and Shapiro-Wilk tests. We conducted multivariate multiple regression to evaluate whether kinematics on the SLSD predicted kinematics while running. In the event of an omnibus test with an $\alpha = .05$, univariate regressions for each kinematic variable were performed. The critical α for each univariate regression was adjusted using the method of Holm.[23] This method has been recommended for biomechanical research because of its ability to control for type I error across multiple comparisons while maintaining statistical power.[23]

A multivariate regression was used to determine whether total medial collapse on the SLSD predicted the 5 kinetic variables during running. In the event of an omnibus test with an $\alpha = .05$, univariate regressions were conducted with the critical α adjusted using the method of Holm.[23] The kinematic and kinetic regressions were calculated separately for men and women. For any regression that was statistically significant for both men and women, we compared regression coefficients by computing an interaction term for each predictor variable (sex $\times$ predictor variable: males coded as 0, and females coded as 1) and performing a regression using sex, the predictor variable, and the interaction term as inputs.[24]

The moderating effect of hip-abductor and external-rotator strength on the relationship between kinematics during the SLSD and kinematics and kinetics during running were assessed using hierarchical multiple regressions.[24] For each predictor variable, 2-step regression models were created. In the first step, 2 variables were included: muscle strength and the predictor from the SLSD. Next, an interaction term (muscle strength $\times$ predictor variable from the SLSD) was added. The change in variance (ΔR^2) accounted for between steps was interpreted to indicate whether strength moderated the relationship between the SLSD and running variable. All statistical analyses were performed using SPSS (version 26; IBM Corp, Armonk, NY).

RESULTS

Box-and-whisker plots showed that 97% of the data points fell within the upper and lower whiskers, with no values flagged as extreme outliers. This finding, combined with P values $> .05$ for all Shapiro-Wilk tests, reflected normal distributions of all variables. The mean values for kinematics during running and the SLSD and kinetic values during running appear in Table 1. For men, kinematics on the SLSD predicted kinematics during running ($\lambda = 0.02$, $P = .001$). Univariate regressions revealed that peak hip adduction ($P = .01$), hip internal rotation ($P = .002$), knee valgus ($P = .001$), and rearfoot eversion ($P = .008$) during the SLSD predicted their respective kinematics during running (Figure). For women, kinematics on the SLSD also predicted kinematics while running ($\lambda = 0.017$, $P = .001$), with peak hip internal rotation ($P = .001$), knee valgus ($P = .001$), and rearfoot eversion ($P = .01$) during the SLSD predicting their respective kinematics during running (Figure). The regression coefficients for men and women were not different for peak hip internal rotation ($P = .23$), knee valgus ($P = .47$), or rearfoot eversion ($P = .52$).

Total medial collapse during the SLSD did not predict kinetic variables during running for men ($\lambda = 0.928$, $P = .91$; Table 2). However, for women, total medial collapse during the SLSD did predict kinetics while running ($\lambda = 0.603$, $P = .046$). Post hoc comparisons demonstrated that total medial collapse on the SLSD predicted peak hip-abductor moments during running ($P = .001$; Table 2). For women, total medial collapse during the SLSD also predicted peak hip-abductor impulses ($P = .03$), peak knee-abductor moments ($P = .02$), and knee-abductor impulses ($P = .03$) during running; however, none of the values were less than the corrected critical α level (Table 2).

We observed no differences between men and women in the strength of the hip abductors (0.82 ± 0.18 Nm/kg and 0.80 ± 0.24 Nm/kg, respectively; $P = .74$) or external

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Table 1. Kinematic Values During Running and the Single-Legged Step Down and Kinetic Values During Running,[a] Mean ± SD

Variable	Running		Single-Legged Step Down	
	Women	Men	Women	Men
Contralateral pelvic drop, °	5.40 ± 1.81	5.64 ± 1.82	3.41 ± 2.18	4.59 ± 2.36
Hip adduction, °	14.94 ± 3.27	12.22 ± 3.23	17.21 ± 5.19	16.88 ± 6.40
Hip internal rotation, °	10.67 ± 7.88	12.14 ± 6.99	10.94 ± 6.40	16.97 ± 7.08
Knee valgus, °	4.75 ± 3.29	8.37 ± 5.14	7.21 ± 6.40	15.53 ± 8.81
Tibial internal rotation, °	3.47 ± 2.82	4.11 ± 2.99	4.87 ± 4.08	3.69 ± 2.58
Rearfoot eversion, °	10.56 ± 4.68	11.51 ± 4.52	10.83 ± 4.52	9.87 ± 5.01
Total medial collapse, °	35.65 ± 6.17	37.59 ± 7.35	38.66 ± 8.92	46.72 ± 10.81
Hip-abductor moment, Nm/kg	1.87 ± 0.39	2.05 ± 0.42	NA	NA
Hip-abductor impulse, Nm/kg·s	0.21 ± 0.05	0.22 ± 0.06	NA	NA
Knee-abductor moment, Nm/kg	0.91 ± 0.39	1.26 ± 0.35	NA	NA
Knee-abductor impulse, Nm/kg·s	0.07 ± 0.04	0.13 ± 0.05	NA	NA
Vertical instantaneous loading rate, body weight/s	81.11 ± 20.15	86.47 ± 20.06	NA	NA

Abbreviation: NA, not assessed.

[a] Values indicate the peak during stance phase.

rotators (0.54 ± 0.16 Nm/kg and 0.46 ± 0.15 Nm/kg, respectively; $P = .08$). For both sexes, strength of the hip abductors and external rotators did not moderate any of the relationships between performance on the SLSD and performance during running (Table 3).

DISCUSSION

The purposes of our study were to evaluate whether kinematics on the SLSD predicted kinematics and kinetics during running and, if so, whether the relationships differed between men and women. We also sought to determine whether any relationships between performance on the SLSD and running mechanics were moderated by muscle strength. In support of our first hypothesis, kinematics on the SLSD did predict kinematics during running, albeit with some differences between men and women. However, contrary to our second hypothesis, total medial collapse on the SLSD did not predict kinetic variables during running for men although it did for women. Finally, contrary to our third hypothesis, strength of the hip-abductor and external-rotator muscles did not moderate any of the relationships between SLSD performance and running mechanics.

Generally, the kinematics on the SLSD that we noted agree with the ranges presented by other researchers.[14,15,25–27] Yet direct comparisons are difficult because of differences in study populations and methods. Only Brocato[27] specifically analyzed runners. Authors[15,26,27] of 3 studies either did not report the sex of their participants or did not analyze men and women independently, whereas Araújo et al[25] only evaluated women. Earl et al[14] did analyze men and women separately; however, the height of the step used in their assessment was twice that of the step we used. Step height has been shown to influence lower extremity kinematics during the SLSD,[26] and as a result, researchers who evaluated performance on the SLSD have used either steps with fixed heights[5,14,26] or heights adjusted based on a percentage of participant height.[4,9,21] Last, investigators[14,15,25] in some SLSD studies have determined peak joint kinematics during the motion, whereas others[26,27] measured joint kinematics at specific degrees of knee flexion. From an applied perspective, given the slight differences in methods used by authors and the resulting differences in kinematics, we recommend that clinicians using the SLSD as a screening tool choose a source for reference values that matches their unique population and protocols as closely as possible.

Researchers[15,27] have suggested the SLSD could be an appropriate assessment for runners in particular, given the similarities of the movement and the associations between kinematics on the SLSD and kinematics during running. Our results partially support this hypothesis, as kinematics on the SLSD strongly predicted peak hip internal rotation, knee valgus, and rearfoot eversion during running for both men and women. However, our findings also raise the question of whether the SLSD was an equally good assessment for male and female runners. For men, performance on the SLSD did not predict any kinetic variables while running. We chose the specific kinetic variables for our work because they had predicted running injuries in prospective studies involving both male and female populations.[16–18] For women, although total medial collapse on the SLSD did predict joint kinetics while running, hip adduction during the SLSD did not predict hip adduction while running. Larger amounts of hip adduction, especially in female runners, have been noted with common running injuries.[11,28] Given these conflicting findings, perhaps at best, performance on the SLSD can inform a clinician or coach about how a male or female runner would move while running and about the joint kinetics that a woman would experience while running. Whether these relationships are related to or predictive of injury risk requires further examination.

Investigators have shown that, in both men and women, strength and running mechanics[19] and strength and performance on the SLSD were associated.[20,22] Stronger individuals typically displayed smaller joint excursions while running and less medial collapse during the SLSD than weaker individuals. Therefore, we hypothesized that we would observe stronger relationships between movement on the SLSD and running in stronger runners. However, this was not the case, as in neither men nor women did strength moderate relationships between performance on the SLSD and during running for any of the variables investigated. This finding may reflect our participant profile. All individuals were highly trained and ran relatively high mileage. Therefore, the range of muscle strength in the sample may have been insufficiently wide to detect a moderating influence. In 2 studies, Whatman et al[15,29] evaluated the relationships between kinematics on

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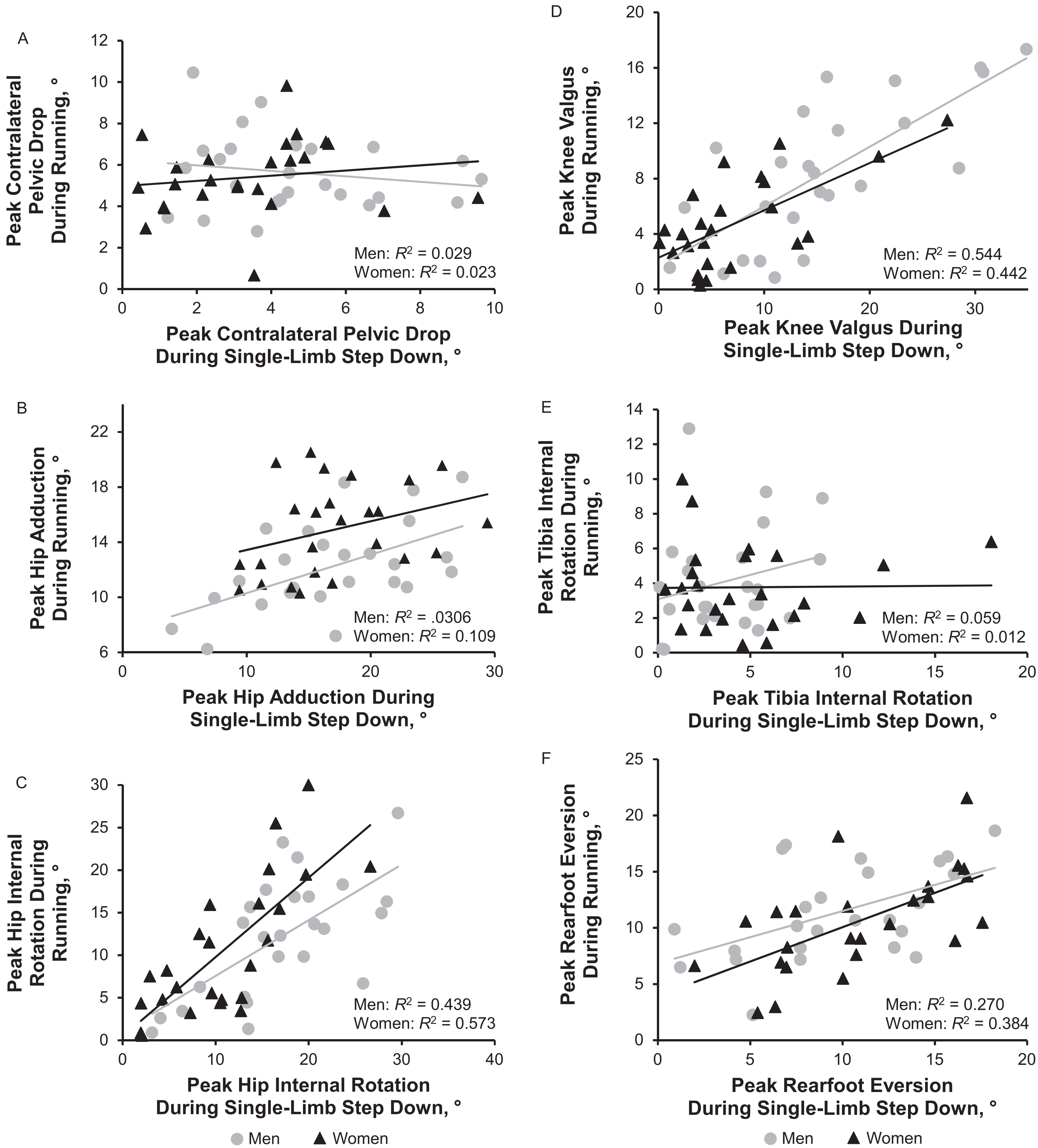

Figure. Regression plots showing the relationships among, A, peak contralateral pelvic drop, B, peak hip adduction, C, peak hip internal rotation, D, peak knee valgus, E, peak tibial internal rotation, and, F, peak rearfoot eversion for women and men. Men are represented by gray circles and women by black triangles.

the SLSD and during running, with 1 study[29] of adolescents (mean age = 11 years) and the other[15] of young adults (mean age = 22 years). On average, relationships between kinematics on the SLSD and kinematics during running showed weaker associations in the adolescent runners. Although the authors did not measure strength, it likely was lower in the adolescent runners. Thus, if our study was repeated with participants who possessed a wide range of muscle strength, any moderating effects of strength might be more evident.

For the variables with relationships that were different, performance on the SLSD explained between 30% and 57%

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Table 2. Regression Results of Total Medial Collapse During the Single-Legged Step Down Versus Kinetic Variables During Running

Variable	Women			Men		
	β Value	95% Confidence Interval	R^2 Value	β Value	95% Confidence Interval	R^2 Value
Peak hip-abductor moment	.27	0.12, 0.42	0.364[a]	.01	−0.01, 0.02	0.017
Hip-abductor impulse	.03	0.01, 0.05	0.195[b]	.01	−0.01, 0.02	0.001
Peak knee-abductor moment	.02	0.01, 0.04	0.209[b]	.01	−0.01, 0.02	0.008
Knee-abductor impulse	.02	0.01, 0.04	0.201[b]	.01	−0.02, 0.02	0.011
Vertical instantaneous loading rate	.74	−0.18, 1.66	0.108	−.27	−1.03, 0.53	0.021

[a] Relationship was different at the Holm-corrected α level.
[b] Relationship was different ($P < .05$).

of the variance in kinematics during running. If strength was moderating these relationships, its inclusions should have increased the variance explained. It is possible that factors other than strength, such as motor learning, muscle activation, joint mobility and flexibility, or dynamic balance, may influence the relationship between SLSD performance and running mechanics. These factors may also play important roles in how well functional screens, such as the SLSD, yield information about injury risk, although the importance of any one factor requires further investigation. Yet from an applied perspective, clinicians who incorporate the SLSD in their assessment protocols, either as preparticipation screening or as part of rehabilitation, can be confident that the SLSD predicts running kinematics and kinetics equally well for stronger and weaker individuals.

A few limitations should be considered when interpreting the results of our study. First and foremost is that all participants were healthy at the time of testing. Therefore, we could not determine whether the relationships between SLSD performance and running mechanics identified in the study were predictive of injury or would remain similar if injured participants were evaluated. Although clinical populations performing the SLSD have generally shown greater medial collapse than healthy individuals,[4,5,9] the individuals in these trials were all evaluated while already injured. Hence, the greater medial collapse could be a result of or an accommodation to the injury. Similarly, researchers[4] found that injured individuals displayed less muscle strength than healthy individuals. Both the presence of injury and the reduced strength could affect the moderating effects of muscle strength on relationships between SLSD performance and running mechanics. To our knowledge, no one has conducted a prospective study to evaluate the ability of the SLSD to identify injury risk in any athletic population. However, such a study may be warranted given the relationships between SLSD performance and running mechanics we observed.

In terms of clinical applications, we quantified movement on the SLSD using 3D motion capture. In clinical settings, either 2D video or qualitative observational assessment of movement quality would likely be used to evaluate movement quality on the SLSD. Compared with 3D motion capture, both approaches have displayed excellent interrater reliability and concurrent validity.[6–8,30] Still, whether the relationships identified in our study between running mechanics and SLSD performance would be evident when SLSD performance was scored via 2D or qualitative observational methods requires further investigation.

Methodologic limitations should also be considered. First, all participants performed both SLSD and running trials in their own shoes. Whether footwear influences performance on assessments such as the SLSD is unknown. Performing the trial barefoot may yield different movements than when performing it in shoes. Second, the order in which participants completed the running and SLSD trials was not randomized: all participants completed the SLSD after running. Consequently, we cannot rule out the possible effects of fatigue. However, given the training status of the participants, the volume of running performed in the trial would have been unlikely to present a fatiguing challenge. Related to this point, we also cannot determine whether the relationships we observed in our study would be present if the SLSD was performed in a fatigued state. Performing such screening assessments while fatigued may provide greater insight into how a runner moves. Third, we

Table 3. Regression Results of Variables on the Single-Legged Step Down (SLSD) Versus Running When the Interaction Term of Muscle Strength Was Added to the Model

Comparison	Women		Men	
	ΔR^2	P	ΔR^2	P
Hip-abductor muscle strength				
SLSD and running peak hip adduction	[a]	[a]	0.004	.65
SLSD and running peak hip internal rotation	0.001	>.99	0.003	.71
SLSD and running peak knee valgus	0.004	.70	0.021	.32
SLSD and running peak rearfoot eversion	0.039	.30	0.036	.30
SLSD total medial collapse and running peak hip-abductor moment	0.004	.73	[a]	[a]
Hip external-rotator muscle strength				
SLSD and running peak hip adduction	[a]	[a]	0.059	.07
SLSD and running peak hip internal rotation	0.018	.34	0.003	.76
SLSD and running peak knee valgus	0.001	.81	0.065	.07
SLSD and running peak rearfoot eversion	0.027	.31	0.061	.17
SLSD total medial collapse and running peak hip-abductor moment	0.001	.88	[a]	[a]

[a] Initial regression was not different.

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did not control the running speed during this trial. All participants ran at a pace they described as their training-run speed. Many of the kinematic and kinetic variables assessed during the running trials vary with speed, so some of the relationships may be influenced by speed. Nonetheless, the range of speeds chosen was small (1.2 m/s spread from slowest to fastest), limiting the possible effects.

Fourth, SLSD trials were conducted using a fixed box height rather than an adjustable, relative box height. Although fixed box heights are frequently used in SLSD studies,[5,14] Lewis et al[26] showed that differences in box height produced different kinematics. Whether the relationships observed in our study would still be evident with different box heights requires further investigation. Fifth, to evaluate relationships between performance on the SLSD and running kinetics, we used a variable that we called *total medial collapse*. This was a composite sum of the frontal-plane motions at the hip, knee, and ankle. The intent was to summarize multijoint movements in a single measurement similar to other commonly used clinical measurements, such as the frontal-plane projection angle. To our knowledge, total medial collapse, as characterized in this study, is a novel variable. The validity and reliability of this measure compared with 2D or 3D joint rotations require further attention. Additionally, the total medial collapse calculation did not include any transverse-plane motion, which is often clinically cited as a component of medial collapse.[14,20] Including transverse-plane motion in the total medial collapse variable might change the relationships observed in this study.

CONCLUSIONS

We evaluated relationships between performance on the SLSD and running kinematics and kinetics, whether these relationships were moderated by strength of the hip abductors and external rotators, and whether these relationships differed between men and women. Kinematics during the SLSD predicted kinematics while running in both men and women but only predicted kinetics while running in women. Strength of the hip abductors and external rotators did not moderate any of the relationships between performance on the SLSD and running. Therefore, it may be advantageous for clinicians to consider both movement quality and muscular strength when using functional screening, such as the SLSD, to assess runners for injury risk or rehabilitation progress.

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