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CRITICALLY APPRAISED TOPIC

The Association Between the Single Leg Hop Test and Lower-Extremity Injuries in Female Athletes: A Critically Appraised Topic

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Clinical Scenario: Female college student-athletes (SA) often experience time loss from musculoskeletal injuries to the lower extremities. This can lead to lengthy rehabilitation, expensive medical bills, and declines in health-related quality of life. Identifying at-risk athletes prior to the start of an athletic season may allow coaches or athletic trainers to prescribe an injury prevention program. ***Clinical Question:*** In female college SA, are preseason single leg hop (SLH) scores associated with identifying those at risk for lower-extremity musculoskeletal injuries? ***Summary of Key Findings:*** Five prospective cohort studies in female SA scored athletes on the SLH prior to the start of the athletic sport season. One of 5 studies found an association of SLH with injury risk. An additional 2 studies found that the SLH as part of a battery of functional performance tests was associated with injury risk in some anatomic locations (eg, thigh/knee), but not overall injury risk. ***Clinical Bottom Line:*** Methodological limitations of the reviewed studies limits a final conclusion, and there is insufficient evidence to determine if the SLH should be used as a sole functional performance test to identify at-risk female SA; it may be useful as part of a battery of functional performance tests for female college SA. ***Strength of Recommendation:*** All studies were prospective cohort studies (level 3).

Keywords: hopping, preseason screening, prevention

Clinical Scenario

Musculoskeletal injuries to the lower extremities are common among female college student-athletes (SA) in sports that require hopping, pivoting, and running.[1,2] From 2009 to 2014, 80,674 injuries occurred in National Collegiate Athletic Association female SA, resulting in an injury rate of 5.2 injuries per 1000 athlete-exposures (95% confidence interval, 5.1–5.4).[2] Common injuries in female college SA included ankle sprains (eg, injury rate = 1.15 per 1000 athlete-exposures [95% confidence interval, 1.10–1.20] in women's basketball), and serious time-loss injuries included anterior cruciate ligament (ACL) injuries (eg, injury rate = 0.28 per 1000 athlete-exposures [95% confidence interval: 0.26–0.31] in women's soccer).[1] Injuries can lead to short-term consequences, including direct medical costs and indirect consequences that may affect scholarships and playing time.[3–5] In addition, injuries can result in long-term limitations in physical activity participation.[6] Injuries have also been reported to result in diminished quality of life both while a college SA,[7] as well as after retirement from the sport.[8]

As a result of the high occurrence and impact of lower-extremity injuries in female college SA, some health care providers have included functional screening tests during preparticipation examination to identify college SA at increased injury risk. Many functional screening tests have been evaluated for use to identify at-risk SA, but many focus on low-impact activities (eg, Functional Movement Screen,[9] proximal hip strength[10]), which may not reflect the sport-specific movements that place female college SA at risk. Using a functional performance test that mimics some sport-specific movements may help determine which SA would benefit from injury mitigation interventions.

Hopping for distance tests (single, triple, and crossover) or timed hopping tests is the most commonly utilized functional performance test in making return-to-sport decisions after ACL injury.[11] Differences between injured and uninjured limbs (ie, asymmetry) are also important in tracking progress in rehabilitation after injury.[12] Because more than 50% of all reported injuries in college SA were in the lower extremity (ankle and knee),[1] the hopping tests for distance may be a good functional performance test to help identify limitations that put SA at higher risk of injury.

The single leg hop (SLH) for distance test requires an athlete to hop as far as possible starting and ending on 1 leg. The protocol for performing the SLH test is short and provided verbally.[11] The instructions consist of asking an athlete to stand on 1 leg with his/her great toe on the starting tape line. A successful hop is defined by sticking the landing for 2 seconds. A hop is considered unsuccessful if the athlete takes additional hops or places the contralateral limb down. An athlete is given 3 trials, 1 practice and 2 recorded trials. All trials are normalized to the height of the athlete as expressed as a percentage of height.[11] Alternatively, a limb symmetry index of the ratio or difference between limbs can be calculated.

Focused Clinical Question

In female college SA, is the SLH for distance associated with identifying those at risk for lower-extremity musculoskeletal injuries?

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Summary of Search, "Best Evidence" Appraised, and Key Findings

- We searched for studies that investigated the association between SLH for distance and lower-extremity musculoskeletal injury risk in female college SA.
- Five studies,[13–17] all prospective cohort designs, tested athletes prior to the beginning of his/her sport season.
- The current data from the available prospective cohort studies presents conflicting results.
- One study provided support for the use of the difference in distance hopped between limbs (ie, limb symmetry index)[13] to identify female college SA at higher odds for risk of time-loss foot/ankle injuries, but not all injuries or thigh/knee injuries.
- Two of the studies included SLH as part of a battery of functional performance tests to identify female SA at a higher odds of risk for injury.[14,15]

Clinical Bottom Line

There is insufficient evidence to determine if SLH should be used as a sole functional performance test to identify at-risk female SA,[13,16,17] but may be useful as part of a battery of functional performance tests for female college SA.[14,15]

Strength of Recommendation

All 5 studies included in this critically appraised topic (CAT) are prospective cohort studies, which are level 3 per the Oxford Center for Evidence-Based Medicine.[18]

Search Strategy

The search terms below were used in an online search in November 2019 (Figure 1[19]). The search terms were combined:

- **P**opulation: athletes
- **I**ntervention: single hop*OR single leg hop*
- **C**omparison: n/a
- **O**utcome: lower-extremity injury

Sources of Evidence Searched

- PubMed
- Cumulative Index to Nursing and Allied Health Literature
- Google Scholar
- Hand searches of published studies

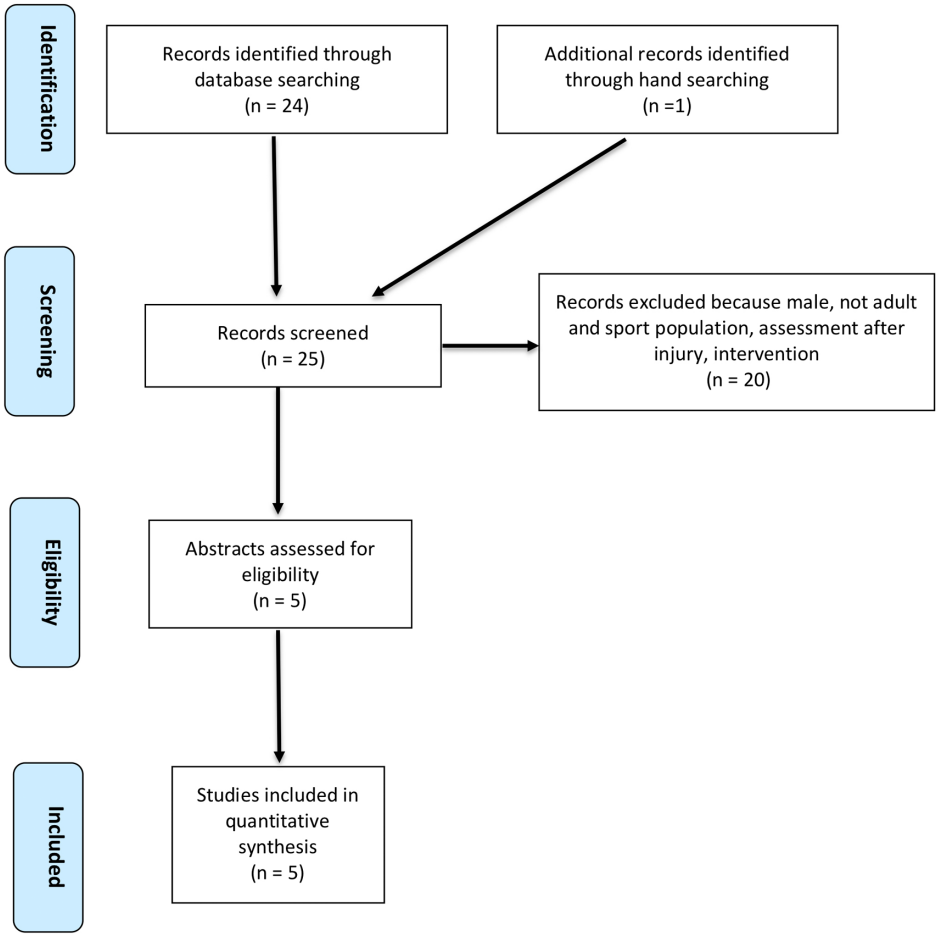

Figure 1 — PRISMA flow diagram[19] presenting search results.

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Inclusion and Exclusion Criteria

Inclusion Criteria

- Studies of National Collegiate Athletic Association female college SA over the age of 18 years
- Studies using the SLH test for distance as one of the independent variables
- English language

Exclusion Criteria

- Studies that focused on prediction of reinjury after a previous lower-extremity injury
- Studies using hopping test for return to play after ACL reconstruction
- Studies using vertical hopping test
- Studies that included only male college SA

Results of Search

The initial database searches resulted in a total of 24 studies; 1 additional study was included from hand searching references (Figure 1). After reviewing the title, 25 abstracts were read, in detail, for assessment of meeting the inclusion and exclusion criteria. Five studies met the inclusion and exclusion criteria for this CAT (Table 1). The validity of the selected studies was assessed using the Newcastle–Ottawa scale for cohort studies.[20] The included studies also received a level of evidence from the Oxford Center for Evidence-Based Medicine.[18]

Best Evidence

The 5 studies[13–17] in Table 1 were the best evidence for this CAT. The reasons for selecting these studies were:

- Met all inclusion and exclusion criteria
- Assessed association with injury using SLH, either alone or in combination with other functional performance tests

Summary of the Best Evidence

Table 2 describes characteristics of the 5 included studies on the association of the SLH with injury in college SA.

Table 1 Summary of Study Design of Articles Retrieved

Level of evidence	Study design/ methodology of articles retrieved	Number located	Author
3	Prospective Cohort	5	Brumitt et al[13] Brumitt et al[14] Brumitt et al[15] Walbright et al[16] Warren et al[17]

Implications for Practice, Education, and Future Research

Despite the frequency of injury in female college SA,[1,2] and the proposed injury etiology model that includes measures of physical fitness (eg, muscle strength and power) and skill level (eg, sport-specific technique),[22] preparticipation examinations for college SA do not routinely include functional performance tests. Although there are many candidate functional performance tests to use, the SLH had several advantages. The SLH test is easy to learn and administer. The SLH test is an inexpensive test to administer with minimal equipment, requiring only a tape measure, athletic tape, and a flat surface. Many clinicians may be familiar with the SLH as it is a standard test used in rehabilitation for return to play after an ACL injury or reconstruction.[11,23] Finally, the SLH test reflects many of the action's athletes perform in sport; soccer, basketball, and volleyball have movements that involve actions on a single leg. These actions often change the motions and stresses placed on the lower-extremity and the SLH test mimics some of these motions.

Despite the advantages of the SLH, this CAT found the current studies have limited evidence for the use during preseason (ie, preparticipation examination) to identify female college SA who are at increased risk for injury. Considering SLH as a sole test to identify female college SA at increased injury risk, only one of the 5 studies included found an association. In 2013, Brumitt et al[13] reported a limb symmetry index of more than 10% may identify female Division III college SA with a higher odds of time-loss foot and ankle injuries, but not all lower-extremity or thigh and knee injuries.

Two other studies in Division III female college SA used a battery of functional performance tests, including SLH, standing long jump, and lower-extremity functional test during preseason. In 2018,[14] the SLH (≤64% of height) combined with the standing long jump and lower-extremity functional test was significantly associated with an increased odds of noncontact time-loss thigh and knee injuries, but not all lower-extremity injuries. In 2019,[15] the SLH (≤64% of height), along with the standing long jump, identified those at a high risk of all lower-extremity and foot and ankle noncontact time-loss injuries, but not for thigh and knee injuries.

For all 5 studies in female college SA, the functional performance tests were completed at preseason and the follow-up time was 1 sport season, but that is where the similarities in the studies end. The results of this CAT highlight the need for standardization in sports injury epidemiology studies in order to better understand the use of functional performance test to identify at-risk college SA. Although all of the studies were moderate–high quality methodologically for observational studies, differences in the methodology limit comparability. First, a consistent injury definition could help clarify the association of SLH with injury. About 4 of the 5 studies included only time-loss injuries,[13–16] which is known to underestimate the number of injuries.[24] In addition, there were differences in injury mechanism, including noncontact injuries only,[14,15,17] or both contact and noncontact injuries.[13,16] Second, the protocol for the SLH differed widely. Some studies included a 5- to 10-minute warm-up before any functional performance test,[13–15] and some did not.[16,17] Studies included the SLH alone[16] or combined with other tests.[13–15,17] The Brumitt et al[13–15] studies had the SA clasp their arms behind their back for the entirety of the test, whereas Walbright et al[16] and Warren et al[17] had no restrictions on arm movement. For a test to be counted, a SA had to hold the position for between 1 and 5 seconds, practice trials ranged from 0 to 6, and measured trials ranged from 2 to 3. In one study, the longest

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Table 2 Characteristics of Included Studies

Characteristics	Brumitt et al[13]	Brumitt et al[14]	Brumitt et al[15]	Walbright et al[16]	Warren et al[17]
Study deign	Prospective cohort	Prospective cohort	Prospective cohort	Prospective cohort	Prospective cohort
Participants	110 18+ Division III SA; no restriction in sport participation	106 18+ Division III soccer, volleyball, cross-country, lacrosse, tennis, softball, and track SA; no restriction in sport participation	82 18+ Division III volleyball SA; no restriction in sport participation	35 18+ basketball and volleyball SA; currently participating in sport without injury	68 18+ Division I basketball, soccer, and volleyball SA; cleared for sport participation, no current injury, no history of concussion in the last 6 months
Intervention investigated	SLJ, SLH, LEFT as a test battery in this order during preseason	SLJ, SLH, LEFT as a test battery in this order during preseason	SLJ and SLH as a test battery in this order during preseason	SLH, YBT, and FMS during preseason (no testing order specified)	SLH, TLH, COH, isometric hip abduction and external rotation strength in a randomized order during preseason
Outcome measures	Injury defined as: "Any muscle, joint, or bone problem/injury of the low back or lower extremity that occurred either during practice or during competition that required the athlete to be removed from that day's event or to miss a subsequent practice or competition" for 1 sport season	Same as Brumitt et al 2016[21]	Same as Brumitt et al 2016[21]	Injury defined as: "Injury to the low back, hip, knee, ankle, or foot regions, during participation in athletic team activities that resulted in a minimum of 1 lost day of practice or the inability to participate in at least 1 full competition" for 33 wk	Injury defined as: "First lower body (ie, spine or lower-extremity) musculoskeletal problem with a noncontact mechanism that causes the athlete to report to the athletic training room and required intervention" for 1 sport season
Main findings for SLH Effect (95% CI)	All injuries: ≤64% – R: OR = 1.3 (0.5–3.0) and L: OR = 0.8 (0.3–2.0); < 70% height – R: OR = 1.3 (0.5–3.3) and L: OR = 1.0 (0.4–2.8) LSI: OR = 2.3 (0.9–6.0) Thigh/knee injuries: ≤64% height– R: (OR = 1.6 (0.5–5.7) and L: OR = 3.2 (0.9–12.8); < 70% height – R: OR = 1.4 (0.3–0.6) and L: OR = 1.7 (0.3–8.3); > 10% LSI: (OR = 1.4 (0.3–5.7) Foot/ankle injuries: ≤64% height – R: OR = 0.9 (0.5–3.1) and L: OR = 0.5 (0.2–1.8); < 70% height – R: OR = 1.0 (0.3–3.6) and L: OR = 1.1 (0.3–4.3); LSI OR = 4.4 (1.2–15.4)	All injuries: ≤64% height – R: OR = 0.7 (0.3–1.9), Sn = 0.5 (0.29–0.71), Sp = 0.57 (0.46–0.68) and L: OR = 1.2 (95% CI not reported), Sn = 0.46 (0.26–0.67), Sp = 0.50 (0.39–0.61); LSI: OR = 2.3 (0.9–6.1), Sn = 0.38 (0.19–0.59), Sp = 0.79 (0.69–0.87) When SLH combined with other tests: ≥1 SLH with LEFT below cutoff scores: OR = 2.0 (0.8–5.3), Sn = 0.38 (0.21–0.56), Sp = 0.77 (0.72–0.82) 1 SLH with SLJ, and LEFT below cutoff scores: OR = 2.2 (0.8–6.3), Sn = 0.29 (0.14–0.46), Sp = 0.84 (0.80–0.89) B SLH with SLJ and LEFT below cutoff scores: OR = 3.1(0.95–10.0), Sn = 0.25 (0.12–0.40), Sp = 0.90 (0.86–0.95) B SLH and LSI with SLJ and LEFT below cutoff scores: OR = 7.4 (0.6–85.0), Sn = 0.08 (0.01–0.27), Sp = 0.99(0.93–0.99) Thigh/knee injuries: ≤64% of height – R: (OR = 2.0 (0.5–7.6), Sn = 0.60 (0.26–0.88), Sp = 0.57 (0.47–0.68) and L: OR = 4.7 (0.9–2.34); Sn = 0.80 (0.44–0.97), Sp = 0.54 (0.44–0.64) > 10% LSI: (OR = 1.4 (0.3–5.7), Sn = 0.30 (0.07–0.65), Sp = 0.76 (0.66–0.84) When SLH combined with other tests: ≥1 SLH with LEFT below cutoff scores: OR = 8.3 (2.0–35.0), Sn = 0.70 (0.35–0.93), Sp = 0.78 (0.69–0.86) 1 SLH with SLJ and LEFT below cutoff scores: OR = 5.4 (1.4–21.0), Sn = 0.50 (0.19–0.81), Sp = 0.84 (0.76–0.91) B SLH with SLJ and LEFT below cutoff scores: OR = 9.7 (2.3–39.9), Sn = 0.50 (0.19–0.81), Sp = 0.91 (0.83–0.96) B SLH and LSI with SLJ and LEFT below cutoff scores: OR = 5.2 (0.4–63.4), Sn = 0.10 (0.0–0.45), Sp = 0.98 (0.93–0.99)	All injuries: ≤69% of height – R: RR = 1.7 (95%CI: 0.6–4.8) and L: RR = 1.0 (95% CI, 0.4–2.7); > 10% LSI: (RR = 2.1 (95% CI, 0.8–5.1) When SLH combined with SLJ: B SLH with SLJ below cutoff scores: RR = 1.9 (0.8–4.7) B SLH, LSI, with SLJ below cutoff scores: RR = 4.6 (2.1–10.1) Thigh/knee injuries: ≤69% of height – R: (RR = 1.2 (95% CI, 0.2–6.3) and L: RR = 0.5 (95% CI, 0.1–2.4); > 10% LSI: (RR = 1.6 (95% CI, 0.3–7.8) When SLH combined with SLJ: B SLH with SLJ below cutoff scores: RR = 0.8 (0.2–4.2) B SLH, LSI, with SLJ below cutoff scores: RR = 2.2 (0.3–16.1) Ankle/foot injuries: ≤69% of height – R: (RR = 2.1 (95%CI: 0.5–10.0) and L: RR = .8 (95% CI, 0.4–8.2; > 10% LSI: (RR = 2.5 (95%CI: 0.7–8.4) When SLH combined with SLJ: B SLH with SLJ below cutoff scores: RR = 3.3 (0.9–12.2) B SLH, LSI, with SLJ below cutoff scores: RR = 6.3 (2.1–19.2)	SLH distance in injured vs noninjured (R: 50.8 [7.1] inches vs 49.8 [9.3] inches; $P = .74$ or L: 50.8 [6.3] inches vs 50.8 [10.4] inches; $P = .98$)	>4 cm LSI: AOR = 1.91 (95% CI, 0.5–7.0), Sn = 0.77, Sp = 0.43, AUC = 0.53

(continued)

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Table 2 *(continued)*

Characteristics	Brumitt et al[13]	Brumitt et al[14]	Brumitt et al[15]	Walbright et al[16]	Warren et al[17]
Level of evidence	3	3	3	3	3
Quality score (NOS)	8/9	8/9	8/9	6/9	8/9
Conclusion	LSI at preseason may help identify female SA with higher odds for time-loss foot/ankle injuries, but not all injuries or thigh/knee injuries.	The SLH alone was not associated with an increased odds of noncontact, time-loss injury in female SA, but combined with SLJ and LEFT, the cutoff scores did identify those at higher odds of noncontact, time-loss thigh/knee injuries.	The SLH alone was not associated with an increased risk of noncontact, time-loss injury in female SA, but combined with SLJ; the cutoff scores did identify those at higher risk of all lower-extremity and foot/ankle non-contact, time-loss injuries.	No difference in inches in SLH between those female SA with a time-loss injury and those uninjured.	The SLH was not associated with an increased odds of noncontact, non-time-loss lower body injuries in female SA.

Abbreviations: 95% CI, 95% confidence interval; AOR, adjusted odds ratio; AUC, area under the curve; B, Bilateral; COH, crossover hop for distance; FMS, Functional Movement Screen; FPT, functional performance test; L, left limb; LEFT, lower-extremity functional test; LSI, limb symmetry index; NOS, Newcastle–Ottawa scale; OR, odds ratio; R, right limb; RR, Relative risk; SLH, single leg hop for distance; SLJ, standing long jump; Sn, sensitivity, Sp, specificity; TLH, triple leg hop for distance; YBT, Y-Balance Test.

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distance hopped in inches was reported,[16] another did the absolute difference between the average of the right and left leg as a limb symmetry measure,[17] and still others the average distance relative to height and ratio of the shortest to the longest limb.[13–15] Of the studies who developed cut points, only one was able to identify cut points using receiver characteristic curves (ROC)[17]; 2 studies could not find a cut point in ROC analysis, and used previously published cut points.[14,15] Most of the included prospective cohort studies scored as moderate–high quality, but most were limited in adjustment for confounders, a critical bias issue in observational studies.[25] Finally, the size of the samples in the included studies should also be taken into consideration. The studies included in this CAT have sample sizes ranging from 35 to 193 SA. Although all studies included *a priori* sample size determination or *post hoc* power calculations, limitations exist in attempting to interpret the sample size and power.

Future research on the use of the SLH as a functional performance test to identify female college SA at risk for injury should consider consistent methods; calls have already been made for a consistent injury definition,[26] and this should be combined with the use of consistent, published protocols for the SLH.[11] Appropriately powered studies with well-justified assumptions/inputs for sample size calculations are also required to make meaningful conclusion about the use of the SLH to identify at-risk SA.

The SLH is an easy, field expedient, inexpensive test for health care provides to administer to college SA, and is commonly used for return to play decisions after injuries.[11,23]Although a popular test clinically and in research,[12,27] there is inconsistent evidence from moderate–high quality observational studies for its use to screen female college SA for injury risk; the SLH combined with other functional performance tests may show promise. This CAT should be reviewed in 2 years to determine whether additional best-research evidence has been published that could aid in answering the focused clinical question.

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