2018

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Original Publication Citation

Onate, J. A., Starkel, C., Clifton, D. R., Best, T. M., Borchers, J., Chaudhari, A., . . . Van Lunen, B. L. (2018). Normative functional performance values in high school athletes: The functional pre-participation evaluation project. *Journal of Athletic Training*, *53*(1), 35-42. doi:10.4085/1062-6050-458.16

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Journal of Athletic Training 2018;53(1):35–42
doi: 10.4085/1062-6050-458.16

www.natajournals.org

Normative Functional Performance Values in High School Athletes: The Functional Pre-Participation Evaluation Project

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Context: The fourth edition of the *Preparticipation Physical Evaluation* recommends functional testing for the musculoskeletal portion of the examination; however, normative data across sex and grade level are limited. Establishing normative data can provide clinicians reference points with which to compare their patients, potentially aiding in the development of future injury-risk assessments and injury-mitigation programs.

Objective: To establish normative functional performance and limb-symmetry data for high school-aged male and female athletes in the United States.

Design: Cross-sectional study.

Setting: Athletic training facilities and gymnasiums across the United States.

Patients or Other Participants: A total of 3951 male and female athletes who participated on high school-sponsored basketball, football, lacrosse, or soccer teams enrolled in this nationwide study.

Main Outcome Measure(s): Functional performance testing consisted of 3 evaluations. Ankle-joint range of motion, balance, and lower extremity muscular power and landing control were assessed via the weight-bearing ankle-dorsiflexion–lunge, single-legged anterior-reach, and anterior single-legged hop-for-distance (SLHOP) tests, respectively. We used 2-way analyses of variance and χ^2 analyses to examine the effects of sex and grade level on ankle-dorsiflexion–lunge, single-legged anterior-reach, and SLHOP test performance and symmetry.

Results: The SLHOP performance differed between sexes (males = 187.8% ± 33.1% of limb length, females = 157.5% ± 27.8% of limb length; $t = 30.3$, $P < .001$). A Cohen d value of 0.97 indicated a large effect of sex on SLHOP performance. We observed differences for SLHOP and ankle-dorsiflexion–lunge performance among grade levels, but these differences were not clinically meaningful.

Conclusions: We demonstrated differences in normative data for lower extremity functional performance during preparticipation physical evaluations across sex and grade levels. The results of this study will allow clinicians to compare sex- and grade-specific functional performances and implement approaches for preventing musculoskeletal injuries in high school-aged athletes.

Key Words: adolescent athletes, preparticipation examination, limb symmetry

Key Points

- Normative data for lower extremity functional performance during preparticipation physical evaluations (PPEs) differed across sex and grade level in high school-aged athletes.
- These normative data will allow clinicians to compare sex- and grade-specific functional performances to improve patient health.
- Researchers should examine the ability of functional PPEs to assess injury risks and the merits of including these tests in the PPE process.

In the 1970s, the American Medical Association Committee on Medical Aspects of Sports recognized the importance of the preparticipation physical evaluation (PPE) and recommended that individuals complete a PPE before athletic participation.[1] The National Federation of State High School Associations considers the PPE to be a prerequisite to athletic participation and its primary goal to maximize safe participation in physical activity.

Whereas PPE requirements vary by state, typical examinations consist of several sections, including medical and family history and general health, cardiovascular, and musculoskeletal (MSK) screenings.[2] One goal of the PPE MSK examination is to predict which individuals are at potentially increased risk for MSK injury.[3] Traditionally, the MSK portion of the PPE has been a 2-minute orthopaedic screening focused on general range of motion, strength, and joint laxity.[4,5] However, minimal evidence supports this examination as an effective predictor of future injuries.[5,6] The *Preparticipation Physical Evaluation*, fourth edition,[3] guidelines promote a "functional" aspect of testing by incorporating performance-based tests designed to identify movement-control deficits that predispose individuals to injury. Current PPE recommendations for functional assessment include a duck walk or single-legged hop, with limited guidance as to which type of single-legged hop should be performed (ie, hop for distance, crossover hop, or vertical jump). Evidence for the effectiveness of these tests for injury prediction and prevention is also minimal.[5,6] This void presents an opportunity for practitioners, particularly certified athletic trainers (ATs), to improve the PPE for evaluating prospective injury risk and developing personalized prevention programs to mitigate the likelihood of future injury. Before the PPE can be used to predict injuries and subsequently aid in injury prevention, a better understanding of typical functional performance and limb symmetry is needed. Three assessments that may help improve the PPE, and for which establishing normative values would be beneficial, are the weight-bearing ankle-dorsiflexion–lunge (ankle-DF ROM),[7] single-legged anterior-reach (SLAR),[8,9] and anterior single-legged hop-for-distance (SLHOP)[10–13] tests.

Several methods are available to assess ankle-dorsiflexion range of motion, including but not limited to electric goniometers,[14] rulers,[15] the weight-bearing–lunge test,[7] and visual estimation.[16] The weight-bearing–lunge test is practical and reliable for assessing ankle-dorsiflexion mobility in the clinical setting[7,17] and was selected due to its low cost, high reliability, and speed of examination compared with other methods. This closed chain assessment of ankle-DF ROM is a quicker, more reliable, and externally generalizable measure of ankle mobility compared with goniometric or open chain methods.[18–20] We also chose it because of its potential to identify individuals at greater risk of lower extremity MSK injury. Poor ankle-dorsiflexion range of motion and asymmetry may increase the risk of injury.[21,22]

The SLAR test is a means of assessing postural stability that does not require expensive force or balance platforms. It was adapted from the Star Excursion Balance Test (SEBT), which has strong intrarater and interrater reliability and is sensitive for detecting functional deficits associated with chronic ankle instability.[9,23,24] The SEBT was originally created with 8 components; however, dynamic balance ability can be assessed using only the anteromedial, posteromedial, anterolateral, and posterolateral directions, which compose the Y-Balance Test.[25] We also chose the SLAR as an assessment because of its potential relationship to lower extremity MSK injury risk. Poor postural control and asymmetry, as measured by an anterior-reaching task, may increase the risk of injury.[8,26]

Table 1. Group Demographics

Characteristic	Group: Males (n = 2623)	Group: Females (n = 1328)	Total (n = 3951)
Age, y (mean ± SD)	15.5 ± 1.2	15.3 ± 1.2	15.4 ± 1.2
Height, cm (mean ± SD)	176.2 ± 8.9	164.9 ± 7.3	172.4 ± 10.0
Mass, kg (mean ± SD)	73.3 ± 16.6	60.0 ± 10.0	68.9 ± 16.0
Grade level, No.			
9	949	532	1481
10	641	342	983
11	527	275	802
12	506	179	685
Sport, No.			
Basketball	596	620	1216
Football	1273	0	1273
Lacrosse	164	126	290
Soccer	590	582	1172

Single-legged hop tests are clinically convenient unilateral tests that have high measurement reliability in healthy individuals and individuals after lower extremity injury.[10] The SLHOP test can be used to assess the functional ability of the lower extremity, particularly the knee.[27,28] It may also have implications for injury-risk assessment. Brumitt et al[11] identified poor or asymmetric hop performance as being associated with an increased risk of lower extremity MSK injury in collegiate athletes.

Therefore, the purpose of our study was to determine normative performance and limb-symmetry values for 3 lower extremity functional performance tests (ie, ankle-DF ROM, SLAR, and SLHOP tests) in high school male and female athletes. Establishing normative data will provide clinicians, and ATs in particular, a reference point with which to compare their patients and may aid in developing future injury-risk assessments and injury-mitigation programs.

METHODS

Participants

We used a cross-sectional design. A total of 3951 male and female high school student-athletes from 33 high schools across 14 states in the United States participated (Table 1). Volunteers were included if they were 13 to 19 years of age; members of a high school-sponsored basketball, football, lacrosse, or soccer team; and cleared for full sport participation without restriction by a health care professional. All participants and their parents or guardians provided written informed assent or consent, and the study was approved by the Institutional Review Board of The Ohio State University.

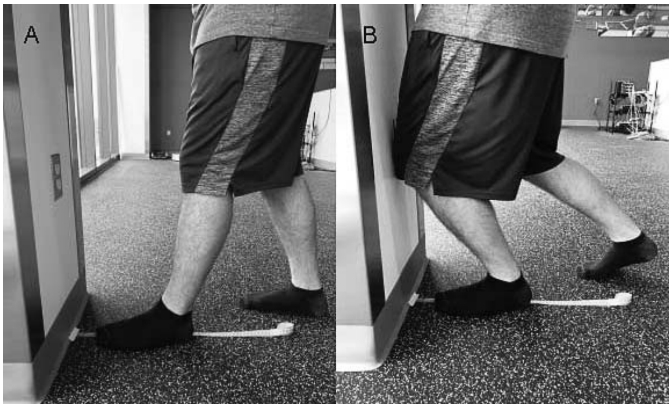

Figure 1. Ankle-dorsiflexion range-of-motion assessment.

Data Collection

All testing was conducted before the start of each sport's competitive season during the 2013–2014 to 2015–2016 academic years. Each participant completed a questionnaire, including age, grade level, dominant limb, and self-reported injury history, on state-mandated PPE forms. We defined *dominant leg* as the self-reported best lower extremity to kick a ball as far as possible. We recorded participants' height to the nearest 0.5 inch with a tape measure and mass to the nearest 0.1 pound with a standard scale. After the questionnaire, participants completed a functional performance assessment that consisted of ankle-DF ROM, SLAR, and SLHOP tests. The data were collected by experienced ATs, and testing was performed in high school athletic training facilities and gymnasiums across the United States. Before testing, ATs at each high school reviewed a standardized training manual, completed onsite training conducted by a member of the Functional Pre-Participation Physical Evaluation team, and passed a testing evaluation. The training manual was developed by members of the research team and included specifications for administering the tests, as well as a standardized script to ensure that participants received consistent instructions.

Ankle-dorsiflexion range of motion was assessed using a previously described weight-bearing–lunge test[7] (Figure 1). Participants performed 2 trials per limb to obtain the farthest distance possible while keeping their heels in complete contact with the floor. The score was recorded as the farthest distance from the wall to the great toe of the stance limb in centimeters.

The SLAR was conducted using a modification to the Y-Balance Test (Functional Movement Systems, Danville, VA) and only in the anterior direction according to previously published protocols[9] (Figure 2). For the test score to be recorded, the participants had to remain in a single-legged stance throughout each trial and had to avoid kicking the reach indicator or using it as support by stepping on it. Participants performed a minimum of 1 practice reach on each limb and then 3 maximal-effort trials per limb. The maximal-reach distance was measured to the nearest 0.5 cm by reading the tape measure at the edge of the reach indicator nearest the participant. Reach distances for each limb were averaged and normalized to limb length (% LL), which was measured from the anterior-superior iliac spine to the medial malleolus. If individuals touched the ground with their hand or foot, could not control the reach indicator properly, moved their stance foot from side to side to regain balance, or fell to the ground, the trial was discarded and repeated until 3 successful trials were completed.

The SLHOP was conducted in the anterior direction and completed according to previously described methods[12,29] (Figure 3). Participants began in a single-legged stance, with the toes of the stance limb in line with the start of the tape measure. They hopped forward on the stance limb as far as possible along the measurement line and landed on the same stance limb. Participants were required to maintain postural control upon landing for at least 2 seconds. Distances were measured at the first toe to the nearest 0.1 cm. We instructed participants to perform a minimum of 1 practice jump per limb to become familiar with the task. Three trials were conducted for each limb, and the average of the 3 trials was normalized to limb length (% LL) and used for subsequent statistical analyses. If participants touched the ground with their hand, could not control landing for 2 seconds, moved their stance foot from side to side to regain balance, or fell to the ground, the trial was discarded and repeated until 3 successful trials were completed.

Limb-symmetry index (LSI) values were calculated for ankle-DF ROM, SLAR, and SLHOP values as the ratio of the lower to higher average distance. Based on the literature and mean values for each test, *symmetric athletes* were defined as having LSI values greater than 85% for the ankle-DF ROM and SLHOP[13] assessments and less than a 4-cm difference between limbs for the SLAR[8] assessment.

Statistical Analysis

Descriptive statistics were calculated for each measure. Paired-samples *t* tests were used to compare functional performance between the dominant and nondominant limbs. Cohen d_z effect sizes were calculated for differences in ankle-DF ROM, SLAR, and SLHOP test performance

Figure 2. Single-legged anterior-reach test.

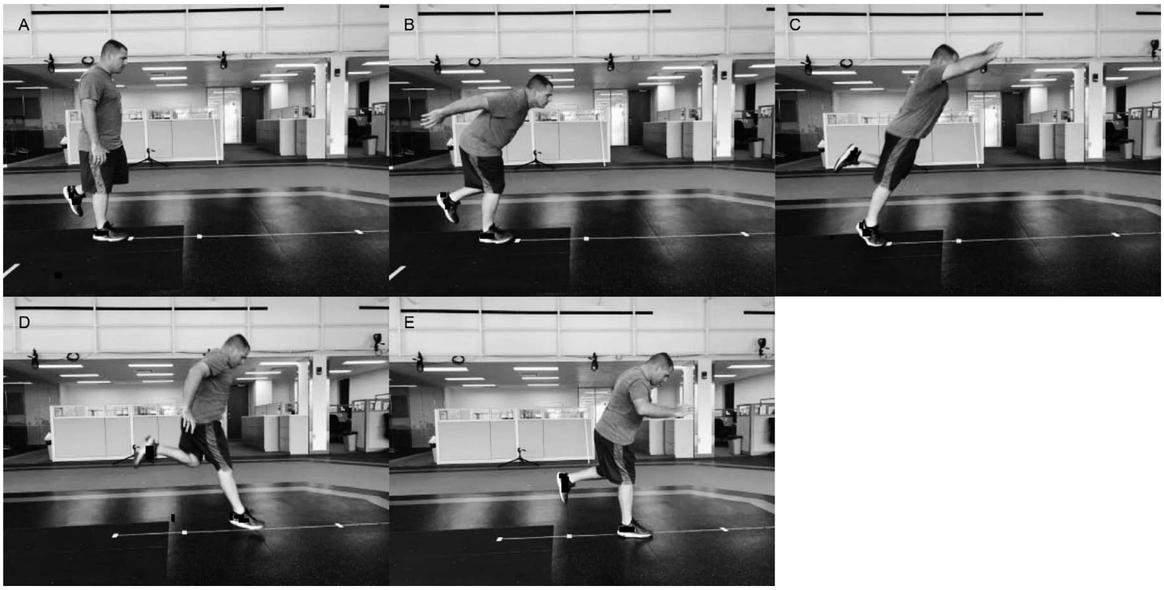

Figure 3. Anterior single-legged hop-for-distance test.

between limbs as the difference between limbs divided by the standard deviation of that difference. A 2-way analysis of variance was conducted to examine the effects of sex and grade level on ankle-DF ROM, SLAR, and SLHOP test performance. Tukey post hoc comparisons were performed to determine grade-level differences. Independent-samples *t* tests were used to compare ankle-DF ROM, SLAR, and SLHOP test performance and LSI between sexes. Cohen d effect sizes were calculated for differences between sexes in ankle-DF ROM, SLAR, and SLHOP test performance, as well as the LSI, as the difference between groups divided by the pooled standard deviation. Effect sizes were interpreted as *very small* (<0.2), *small* (0.2–0.5), *medium* (0.5–0.8), or *large* (>0.8). Lastly, a χ^2 analysis between sex and symmetry category (symmetric/asymmetric) and layered by grade level was completed to examine the effects of sex and grade level on the presence of ankle-DF ROM greater than 4 cm, SLAR asymmetry greater than 15%, and SLHOP asymmetry greater than 15%. We set the α level a priori at .05. All statistical analyses were performed with SPSS (version 21 for Windows; IBM Corp, Armonk, NY).

RESULTS

Of the 3951 athletes, 3108 (78.7%) did not report a previous lower extremity MSK injury, 588 (14.9%) reported a previous lower extremity injury, and 95 (2.4%) reported a previous injury but did not provide details on the injury. Injury history information was not supplied by 160 (4.0%) individuals. Tables 2, 3, and 4 provide normative values for ankle-DF ROM, SLAR, and SLHOP test performance by limb dominance, sex, and grade, respectively. Table 5 provides normative values for ankle-DF ROM, SLAR, and SLHOP limb symmetry for the total sample and by sex.

Limb Dominance

We observed a difference between limbs for SLHOP test performance (dominant limb = 177.5% ± 34.5% LL, nondominant = 175.2% ± 35.2% LL; t = 10.7, $P < .001$) but no difference between limbs for ankle-DF ROM or SLAR test performance (Table 2). The effect of limb on SLHOP performance was very small (Cohen d_z = 0.17, 95% confidence interval [CI] = 0.13, 0.22).

Sex

The ankle-DF ROM (males = 10.1 ± 3.5 cm, females = 10.3 ± 3.2 cm; t = –2.1, P = .03) and SLHOP (males = 187.8% ± 33.1% LL, females = 157.5% ± 27.8% LL; t = 30.3, $P < .001$) test performances were different between sexes, but no difference was found for SLAR test performance (Table 3). The effect of sex on SLHOP test performance was large (Cohen d = 0.97, 95% CI = 0.90, 1.03), whereas the effect on ankle-DF ROM test performance was very small (Cohen d = 0.07, 95% CI = 0.004, 0.14).

Table 2. Functional Performance by Limb (Mean [95% Confidence Interval])

	Limb				
Test	Dominant	Nondominant	Mean Difference	Effect Size	*P* Value
Weight-bearing ankle-dorsiflexion lunge, cm	10.2 (10.1, 10.3)	10.1 (10.0, 10.2)	0.03 (−0.03, 0.08)	0.02 (−0.03, 0.06)	.31
Single-legged anterior reach, % limb length	71.6 (71.3, 71.9)	71.8 (71.5, 72.1)	−0.13 (−0.27, −0.005)	−0.03 (−0.07, 0.01)	.06
Single-legged hop for distance, % limb length	177.5 (176.5, 178.6)	175.2 (174.1, 176.3)	2.31 (1.88, 2.73)	0.17 (0.13, 0.22)	<.001[a]

[a] Difference ($P < .05$).

Table 3. Functional Performance by Sex (Mean [95% Confidence Interval])

Test	Sex		Mean Difference	Effect Size	P Value
	Male	Female			
Weight-bearing ankle-dorsiflexion lunge, cm	10.1 (10.0, 10.2)	10.3 (10.1, 10.5)	−0.24 (−0.46, −0.01)	0.07 (0.004, 0.14)	.03[a]
Single-legged anterior reach, % limb length	71.6 (71.2, 72.0)	71.6 (71.1, 72.2)	−0.06 (−0.68, 0.57)	0.006 (−0.06, 0.07)	.86
Single-legged hop for distance, % limb length	187.8 (186.5, 189.0)	157.5 (156.0, 159.0)	30.3 (28.22, 32.37)	0.97 (0.90, 1.03)	<.001[a]

[a] Difference ($P < .05$).

Grade Level

Normative performance values for each functional test by grade, sex, and limb are presented in Table 4. Trends for the effects of grade and sex on ankle-DF ROM, SLAR, and SLHOP test performance were similar between the dominant and nondominant limbs; therefore, results of only the dominant-limb analysis are presented and are referenced without the dominant-limb or nondominant-limb notation. We observed sex-by-grade interactions for SLAR ($F = 3.1$, $P = .03$) and SLHOP ($F = 3.6$, $P = .01$) test performance but not ankle-DF ROM test performance ($F = 0.7$, $P = .54$). Main effects of grade were found for ankle-DF ROM ($F = 3.1$, $P = .03$) and SLHOP ($F = 20.8$, $P < .001$). We noted main effects of sex only for SLHOP test performance ($F = 771.3$, $P < .001$). Differences existed for ankle-DF ROM, SLAR, and SLHOP test performance between grade levels. Post hoc tests showed that ankle-DF ROM test performance was greater for athletes in grade 10 (10.3 ± 3.4 cm) than in grade 9 (10.0 ± 3.3 cm; $P = .03$) and SLAR test performance was greater for male athletes in grade 12 (73.1% ± 9.2% LL) than in grades 9 (71.2% ± 9.2% LL; $P = .001$), 10 (71.4% ± 9.5% LL; $P = .01$), and 11 (71.0% ± 9.0% LL; $P = .001$). These tests also revealed SLHOP test performance was greater for male athletes in grades 10 (187.4% ± 33.0% LL; $P < .001$), 11 (191.0% ± 33.9% LL; $P < .001$), and 12 (197.5% ± 31.8% LL; $P < .001$) than in grade 9 (181.0% ± 31.7% LL). We demonstrated greater SLHOP test performance for female athletes in grades 11 (159.8% ± 27.7% LL; $P = .001$) and 12 (161.1% ± 27.6% LL; $P = .001$) than in grade 9 (154.6% ± 27.6% LL).

Limb Symmetry

We observed differences in LSI between sexes for ankle-DF ROM ($t = –2.6$, $P = .01$) and SLAR ($t = –3.5$, $P < .001$) test performance but not for SLHOP test performance ($t = –0.69$, $P = .49$; Table 5). The effects of sex on the ankle-DF ROM LSI (Cohen d = 0.09, 95% CI = 0.02, 0.15) and SLAR LSI (Cohen d = 0.12, 95% CI = 0.05, 0.18) were very small. In addition, differences were present among grade levels for the SLHOP LSI ($F = 4.9$, $P = .002$) but not for the other functional tests. The SLHOP LSI was higher for athletes in grade 12 (95.1% ± 4.5%) than in grades 9 (94.3% ± 5.3%; $P = .003$) and 10 (94.4% ± 5.2%; $P = .03$), but these differences were not clinically meaningful. We noted effects for sex at each grade level except grade 12 and for the total population for SLAR asymmetry greater than 4 cm (Table 6). Grade level and sex had no effect on ankle-DF ROM asymmetry greater than 15% or SLHOP asymmetry greater than 15%.

DISCUSSION

Despite recent recommendations for a functional evaluation during the PPE, minimal published normative data are available to guide clinicians. Our cross-sectional study is the first and largest source of normative data for functional PPE lower extremity measures in high school-aged athletes by grade. We selected the 3 tests because they are considered cost effective, time efficient, and easy to administer and require limited space and equipment.[30] They were also selected because of their proposed relationships to lower extremity MSK injury risk.[8,11,22,26,31] Poor ankle-dorsiflexion range-of-motion,[22] postural-control,[26] and power-generation[11] performance, as well as asymmetry,[8,11,21,22,26] may increase the risk of lower extremity MSK injury. This information should help clinicians reference normative values for different sexes and grade levels to determine performance levels, return-to-participation criteria, and potentially injury risk.

A clinically important finding was that functional performance differences in the SLHOP test occurred between sexes and across grade levels, with increased performance by higher grade-level males. The most meaningful finding was the difference in SLHOP test

Table 4. Mean (95% Confidence Interval) Normative Performance Values by Grade, Sex, and Limb

Test	Grade	Males		Females	
		Dominant Limb	Nondominant Limb	Dominant Limb	Nondominant Limb
Weight-bearing ankle-dorsiflexion lunge, cm	9	9.9 (9.7, 10.1)	9.8 (9.6, 10.0)	10.1 (9.8, 10.4)	10.1 (9.8, 10.4)
	10	10.2 (9.9, 10.5)	10.1 (9.9, 10.4)	10.7 (10.3, 11.0)	10.8 (10.5, 11.2)
	11	10.3 (10.0, 10.6)	10.0 (9.7, 10.3)	10.3 (9.9, 10.6)	10.2 (9.8, 10.6)
	12	10.1 (9.8, 10.5)	10.2 (9.9, 10.5)	10.4 (9.9, 10.8)	10.7 (10.2, 11.1)
Single-legged anterior reach, % limb length	9	71.2 (70.7, 71.8)	71.3 (70.7, 71.9)	71.6 (70.8, 72.4)	71.7 (71.0, 72.5)
	10	71.4 (70.7, 72.2)	71.6 (70.8, 72.3)	71.5 (70.4, 72.5)	71.6 (70.6, 72.7)
	11	71.0 (70.3, 71.8)	71.2 (70.5, 72.0)	72.3 (71.0, 73.6)	72.1 (70.8, 73.3)
	12	73.1 (72.3, 73.9)	73.2 (72.4, 74.0)	71.2 (69.9, 72.5)	72.3 (71.0, 73.6)
Single-legged hop for distance, % limb length	9	181.0 (178.9, 183.0)	178.9 (176.8, 180.9)	154.6 (152.3, 157.0)	151.4 (149.1, 153.7)
	10	187.4 (184.8, 190.0)	183.9 (181.3, 186.6)	158.1 (155.1, 161.1)	154.3 (151.3, 157.3)
	11	191.0 (188.1, 193.9)	189.8 (186.8, 192.8)	159.8 (156.5, 163.1)	157.5 (154.2, 160.8)
	12	197.5 (194.7, 200.2)	196.5 (193.6, 199.4)	161.1 (157.0, 165.1)	160.0 (156.1, 163.9)

Table 5. Mean (95% Confidence Interval) Limb-Symmetry Index Values for Males, Females, and the Total Population

Test	Total, %	Male, %	Female, %	Mean Difference	Effect Size	*P* Value
Weight-bearing ankle-dorsiflexion lunge	88.0 (87.6, 88.4)	87.6 (87.1, 88.1)	88.7 (88.1, 89.4)	−0.01 (−0.02, −0.003)	0.09 (0.02, 0.15)	.01[a]
Single-legged anterior reach	95.6 (95.4, 95.7)	95.4 (95.3, 95.6)	96.0 (95.7, 96.1)	−0.004 (−0.007, −0.002)	0.12 (0.05, 0.18)	<.001[a]
Single-legged hop for distance	94.5 (94.4, 94.7)	94.5 (94.3, 94.7)	94.6 (94.4, 95.0)	−0.001 (−0.005, 0.002)	0.02 (−0.04, 0.09)	.49

[a] Difference ($P < .05$).

performance between sexes, with sex having a large effect on hop distance. It is not surprising that males tended to demonstrate greater single-legged–hop capabilities as they increased in grade level. Sumnik et al[32] showed similar age and sex differences in single- and double-legged jumps by individuals aged 6 to 19 years. This increase in capability for high school-aged males may provide some insight into the increased injury risk for female high school athletes and inform clinicians if muscular power and control could be improved in high school athletes before sport participation. Females are considered at greater risk than males for various lower extremity MSK injuries, and various anatomical, hormonal, and biomechanical reasons for this increased risk have been explored.[33] Power generation and control are hypothesized to be related to lower extremity MSK injury risk[11]; therefore, the increased risk of injury in females may be partially explained by worse, on average, power generation and control ability.

Ankle-DF ROM

Ankle-DF ROM test performance did not vary by limb dominance or across all grade levels. It was different between grades 9 (10.0 ± 3.3 cm) and 10 (10.3 ± 3.4 cm) and between sexes (males = 10.1 ± 3.5 cm, females = 10.3 ± 3.2 cm), but these differences were not clinically meaningful. These findings are similar to those from researchers examining joint range of motion by sex and age.[34] Soucie et al[34] identified average ankle-dorsiflexion range of motion in 9- to 19-year-old females and males as 17.3° and 16.3°, respectively. Differences in ankle-DF ROM symmetry between sexes were also not clinically meaningful. Therefore, clinicians can compare the values of student-athletes with the same normative values, regardless of sex, grade level, or limb.

Establishing what constitutes normal ankle-dorsiflexion range of motion may be useful to clinicians, given its hypothesized relationship to lower extremity MSK injury. Söderman et al[22] identified increased ankle-dorsiflexion asymmetry as being associated with an increased risk of overuse leg injury. In addition, individuals with restricted ankle-dorsiflexion range of motion landed from a jump in a more erect posture, which may increase the risk of anterior cruciate ligament injury.[31] However, the true relationship between ankle-dorsiflexion range of motion and injury risk is unclear. Wiesler et al[35] did not observe an association between ankle-dorsiflexion range of motion and lower extremity injury. Twellaar et al[36] also did not find a relationship between ankle-dorsiflexion range of motion and injury. Ankle-DF ROM deficits may also reflect current unresolved injuries requiring rehabilitation before participation.

Table 6. Mean (95% Confidence Interval) Single-Legged Anterior-Reach Asymmetry by Sex and Grade Level

	Sex			
Grade Level	Male, %	Female, %	χ^2	*P* Value
9	28.3 (25.4, 31.1)	20.0 (16.6, 23.4)	12.4	<.001[a]
10	29.7 (26.1, 33.2)	21.9 (17.5, 26.3)	6.8	.009[a]
11	30.4 (26.4, 34.3)	23.1 (18.1, 28.1)	4.7	.03[a]
12	28.9 (24.9, 32.8)	21.8 (15.7, 27.9)	3.3	.07
Total	29.1 (27.4, 30.9)	21.4 (19.2, 23.6)	27.4	<.001[a]

[a] Difference between sexes ($P < .05$).

Single-Legged Anterior Reach

The SLAR test performance did not vary by limb dominance or sex. It was greatest among males in grade 12 (grade 9 = 71.2% ± 9.2% LL, 10 = 71.4% ± 9.5% LL, 11 = 71.0% ± 9.0% LL, 12 = 73.1% ± 9.2% LL), but this difference was not clinically meaningful. Similar to the ankle-DF ROM findings, differences in SLAR symmetry between sexes were not clinically meaningful. Our findings differ from those of researchers examining the effect of sex and age on reach performance, but several methodologic differences existed among the studies, such as population studied and the age of participants.[37,38] Chimera et al[37] assessed anterior-reach asymmetry among collegiate athletes, and Teyhen et al[38] assessed Lower Quarter Y-Balance Test composite score in service members. Therefore, clinicians can compare the SLAR test performances of student-athletes with the same normative values regardless of sex, grade level, or limb.

Given research findings related to lower extremity MSK injury risk, establishing what constitutes normal SLAR test performance may be clinically advantageous. In a study of deficits in Y-Balance Test performance across 235 high school basketball players, Plisky et al[8] found that a reach of less than 94% LL was associated with a 6.5-times higher injury risk and athletes with an asymmetry of more than 4 cm between anterior left and right distances were 2.5 times more likely to sustain injury. Therefore, using only a single portion of the SEBT, the anterior reach, may be most efficient during PPEs due to large populations and time constraints.

Single-Legged Hop for Distance

We observed a large effect of sex on SLHOP test performance, with males (187.8% ± 33.1% LL) performing better than females (157.5% ± 27.8% LL). The SLHOP test performance also differed by grade level. It was worse for athletes in grade 9 (171.5% ± 32.8% LL) than in grades 10 (177.2% ± 34.3% LL), 11 (180.3% ± 35.2% LL), and 12 (188.0% ± 34.7% LL). Our findings of sex differences in hop distance were similar to previous research in which investigators identified that, among high school soccer and basketball players, males hopped farther than females.[39] The SLHOP test performance was not different between limbs, a finding similar to previous research,[39] and SLHOP LSI was not different between sexes. The SLHOP LSI was higher in athletes in grade 12 (95.1% ± 4.5%) than in grade 9 (94.3% ± 5.3%), but this difference was not clinically meaningful. These results suggest that clinicians can compare SLHOP test performance with similar normative values regardless of limb, as well as SLHOP LSI regardless of sex or grade. Differences in normative SLHOP distance by sex and grade level suggest, however, that clinicians may benefit from hop-distance standards that are specific to sex and grade level.

Establishing what constitutes normal SLHOP test performance may be clinically valuable for lower extremity MSK injury-risk assessment and functional performance evaluation after injury. Brumitt et al[11] identified that poor or asymmetric SLHOP test performances may be related to increased lower extremity MSK injury risk. In recent work, Myer et al[28] used a series of functional performance-based assessments to identify lower extremity performance deficits in athletes who had undergone unilateral anterior cruciate ligament reconstruction and returned to sport participation. Functional performance was evaluated using double- and single-legged hop tests. Only the single-legged hop tests were able to differentiate between anterior cruciate ligament reconstruction and control groups, as well as between the limbs of the anterior cruciate ligament reconstruction group. These findings indicate that single-legged performance should be isolated during functional assessments to identify functional deficits and can affect future clinical screening and MSK injury-risk mitigation programs.

Limitations

The normative values for functional PPEs in our study were based on a sample of 4 sports, making it difficult to generalize results across the entire high school student-athlete population. However, these data represent a large sample across multiple high schools throughout the nation in sports that have a high percentage of participation in the United States. Another limitation is that participant numbers decreased as grade level increased, which may result in less accurate normative data for athletes in grade 12, especially females. It is unclear why numbers declined and whether it was due to participants withdrawing from sport participation or electing not to return for testing. Future research is warranted to establish normative values for other tests that may improve the functional component of the PPE. Despite these limitations, this first and largest study of normative data for high school-aged athletes provides clinicians with reference normative values for different sexes and grade levels to aid in determining performance levels, return-to-participation criteria, and potentially injury risk.

CONCLUSIONS

Normative data for lower extremity range of motion and dynamic postural control, as well as power generation and acceptance, can provide clinicians with reference points with which to compare their patients during PPEs to identify individuals who require further medical evaluation. However, the absence of normative values for functional assessments has created challenges for clinicians who attempt to determine if their patients' functional characteristics are abnormal. The results of our study will allow clinicians to make sex- and grade-specific functional performance comparisons to improve patient health, such as helping to determine performance levels and return-to-participation criteria. Researchers should aim to assess the injury-risk capabilities of these functional PPE tests specifically and their merits in the PPE process.

ACKNOWLEDGMENTS

This study was supported by grant 5R01AR062578-02 from the National Institute of Arthritis and Musculoskeletal and Skin Diseases and the National Institutes of Health (principal investigator: Dr Onate; co-investigators: Drs Best, Borchers, Chaudhari, Comstock, Cortes, Hertel, Hewett, Pan, and Van Lunen). We thank the Functional Pre-Participation Evaluation team for their contributions.

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