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The Running Readiness Scale and Injury in Collegiate Track and Field and Cross Country Athletes

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Context: Track and field and cross country athletes experience high rates of lower extremity injuries. The Running Readiness Scale (RRS) may help determine which athletes have a higher likelihood of lower extremity injury.

Objective: To determine if RRS performance at the start of the season was related to the likelihood of experiencing a lower extremity injury during the subsequent track and field or cross country season.

Design: Prospective cohort study.

Setting: University.

Patients or Other Participants: One hundred thirteen National Collegiate Athletic Association Division III track and field athletes in running, jumping, and vaulting events and cross country runners (50 women and 63 men, age = 19.9 ± 1.3 years [mean ± SD]).

Main Outcome Measure(s): Athletes were assessed on RRS tasks (double-leg hopping, plank, step-ups, single-leg squats, and wall sit) at the start of their season and were then observed by team athletic trainers during the season for occurrence of lower extremity injuries that resulted in missing 1 or more practices or meets. Adjusted odds ratios and 95% confidence intervals were used to assess the likelihood of lower extremity injury.

Results: Thirty-seven athletes (32.7%) experienced a lower extremity injury. Athletes scoring ≤3 on the RRS were almost 5 times more likely to experience a lower extremity injury (adjusted odds ratios = 4.8; 95% confidence interval: 2.1, 11.3) than athletes scoring ≥4. Athletes who failed the double-leg hop or wall sit task were more likely to experience a lower extremity injury ($P < .05$).

Conclusions: Track and field and cross country athletes with RRS scores of ≤3 had a higher likelihood of lower extremity injury than those with scores of ≥4.

Key Words: running injuries, risk factors, injury screening, intercollegiate

Key Points

- Track and field and cross country athletes with higher scores on the Running Readiness Scale were less likely to experience a lower extremity injury during their season.
- Athletes failing the double-leg hop and wall sit tests of the Running Readiness Scale had a higher likelihood of lower extremity injury.
- The Running Readiness Scale may serve as a clinical assessment tool to help identify running athletes at risk of developing a lower extremity injury.

Track and field and cross country are among the collegiate sports with the most participants. According to the National Collegiate Athletic Association (NCAA), 62 753 men and women participated in outdoor track and field and 29 408 in cross country in 2023.[1] Of concern is that track and field and cross country have high rates of overuse injury, most often sustained at the lower extremities.[2–4] Among 16 collegiate sports, the highest rates of overuse injury per 10 000 athlete exposures were found in men's and women's cross country (men = 13.67, women = 19.59) and outdoor track and field (men = 13.53, women = 15.76).[2] With high participation and injury rates in these sports, it appears prudent to identify athletes who may be at greater risk of developing an injury.

Several movement screening tools for athletes, including the Functional Movement Screen and Y Balance Test, have shown mixed findings when used to examine injury risk in running populations.[5,6] Although Hotta and colleagues did not observe a significant relationship between composite Functional Movement Screen scores and injuries in collegiate male middle- to long-distance runners, they did find that 2 individual components of the Functional Movement Screen, poorer scores on the deep squat and active straight leg raise components, were associated with increased injury.[5] In a prospective study of the Y Balance Test in male and female high school runners, normalized composite reach distance and composite reach differences were not associated with running-related injury (RRI); however, male runners with side-to-side posteromedial lower quadrant Y Balance Test reach differences of ≥4.0 cm were more likely to experience an RRI.[6]

As general movement screen results have had a limited relationship with running injury risk, the use of a running-specific screening assessment, like the Running Readiness

Table 1. Running Readiness Scale Evaluation Criteria (from Harrison et al[9])[a]

Task	Instructions	Good Form (Must Be Maintained For 1 Min Without Breaks To Pass)
Hopping (on 2 feet)	Hop on both feet in the same spot in time with the beat of the metronome. You may hop in front of a wall to provide a visual reference to avoid moving. You do not need to hop very high, just enough so your toes leave the ground.	Maintain pace of 160 hops/min Hop off toes Knees aligned (ie, no apparent knee collapse toward midline)
Plank	Hold a plank, on your forearms and toes, so that you make a straight line from your ankles to your head, and hold as still as possible.	Body in straight line Equal weight-bearing between left and right feet and forearms Neutral head alignment (ie, held in line with trunk)
Step-ups	Step-up onto the box in front of you, 1 foot after the other, and then step down from the box, 1 foot after the other, in an up-up-down-down pattern. Each step should fall on a metronome beat. Halfway through the minute, we will tell you to switch your lead leg.	Maintain pace of 160 steps/min Knees aligned (ie, no apparent knee collapse toward midline) Upright trunk (ie, no excessive forward or lateral lean)
Single-leg squat	Stand on 1 foot, with the opposite foot held off the ground in front of you. With each beat of the metronome, you will perform a minisquat. Halfway through the minute, we will tell you to switch legs.	Maintain pace of 80 beats/min (down on first beat, up on second) Maintain balance Level hips Knee aligned (ie, no apparent knee collapse toward midline) Upright trunk (ie, no excessive forward or lateral lean)
Wall sit	Place the stability ball behind you against the wall so it is held in place between the wall and your backside. Squat down so your thighs are parallel to the ground and the ball is against your lower back. Hold as still as possible for 1 minute.	Thighs parallel to floor Upright trunk (ie, no excessive forward or lateral lean) Equal weight-bearing on left and right feet

[a] Table 1 is reproduced with permission from the *Journal of Athletic Training*.

Scale (RRS), was recommended in a recent consensus statement on postpartum return to running.[7] The use of the RRS was also suggested in a clinical commentary in running rehabilitation.[8] In contrast to general movement screens, the RRS was established as a running-specific clinical assessment tool to help determine whether runners who were previously injured were ready to return to running.[9] The RRS is a series of five 1-minute tasks that assess lower extremity and trunk function believed important to running.[9] The RRS includes 3 dynamic tests (vertical double-leg hopping, step-ups, and single-leg squats) and 2 static tests (prone plank and wall sit).[9,10] The individual tasks are graded as pass or fail based on an athlete's ability to complete each task for a 1-minute duration and specified form elements (Table 1). Good interrater reliability has been reported for total RRS score ($r = 0.75$), and a range of $r =$ 0.58 to 1.00 has been reported for the RRS individual tasks.[9] Prior work suggests that clinician agreement on lower extremity movement task assessments like the single-leg squat is greater with dichotomous ratings.[11]

Harrison et al observed that frontal plane pelvis, hip, and knee kinematics during the dynamic tasks of the RRS were significantly correlated with kinematics of the same angles during running in novice female runners.[9] Peak knee internal rotation during running and step-ups was also significantly correlated. In the same study, runners with scores of 0 to 2 on the RRS displayed increased knee abduction during the stance phase of running compared with those scoring 4 or 5.[9] In asymptomatic runners, strong correlations have been observed between frontal plane projection angles during single-leg squats and running.[12] Whatman and colleagues reported that the visual rating of frontal plane dynamic pelvis and knee alignment in athletes was valid with moderate to very large correlations observed between the pelvis, hip, knee, and ankle kinematics of a single-leg knee bend task and running.[13] These observations are relevant as prior studies have linked increased hip adduction and knee internal rotation with the development of common running injuries of patellofemoral pain syndrome and iliotibial band syndrome.[14,15] Thus, these kinematic findings suggest that the RRS may have the potential to assess motions relevant to the development of RRI.

To our knowledge, only 1 study to date has investigated the RRS with respect to RRI. In a prospective study of 18 Division III collegiate cross country runners, the RRI rates were not significantly different among those who passed or failed individual RRS tasks. However, the study did not evaluate RRI rates based on RRS scores.[16] With the limited success of other functional movement screens to predict the likelihood of RRI, and a need for running-specific screening, the primary purpose of this study was to prospectively determine if RRS scores in track and field and cross country athletes were associated with sustaining a lower extremity injury during subsequent track and field and cross country seasons. We hypothesized that athletes with lower (ie, worse) RRS scores would have a higher likelihood of lower extremity injury. An additional objective of the study was assessing injury rates by individual RRS task results.

METHODS

Participants

Participants included 113 (50 women, 63 men) Division III cross country and track and field athletes in running, jumping, and vaulting events. All participants were cleared for full athletic participation and were free of any symptoms and from injuries limiting their participation in athletic activities at the time of assessment. The study was approved by the University of Wisconsin Oshkosh Institutional Review Board. All participants completed the Student-Athlete Authorization/Consent for Disclosure of Protected Health Information for NCAA-Related Research Purposes form before the season. Informed consent was obtained from each athlete before data collection.

An a priori power analysis was performed. Based on prior studies of injuries among track and field and cross country athletes, we expected that approximately 40% would experience a time-loss lower extremity injury during the season. Using conservative estimated distributions, we hypothesized that those with RRS scores of 0 to 3 would have twice the incidence of overuse injury than those with RRS scores of 4 to 5 (referent group). Using an α value of .05, power of 0.80, and a conservative expected odds ratio (OR) of 2.0, a sample of 87 athletes was estimated to show a statistically significant relationship between the RRS score and injury.[17]

Data Collection

At the start of their respective competitive seasons, athletes completed a questionnaire on demographics and preseason training. Athletes were also asked about any prior sport-related injury that limited their ability to practice or compete for 7 or more days and whether they experienced an injury in the past year. These factors were assessed as potential confounders on the relationships between RRS scores or RRS individual tasks and lower extremity injury.

Athletes were assessed while performing the 5 tasks of the RRS: hopping, plank, 6-inch step-ups, single-leg squat, and wall sit. The assessments were performed by 2 testers, a physical therapist and a senior undergraduate exercise science student, both trained in the RRS assessments. Consistent with procedures used by Harrison et al, training on the assessments included the testers reviewing criteria for good form and viewing video examples of athletes demonstrating and not demonstrating those criteria.[9] For assessment, the athletes were given standardized cues for each task as reported by Harrison et al (Table 1).[9] Each task was performed for 1 minute with 30 seconds of rest in between; the step-ups and single-leg squats were performed for 30 seconds on each leg. Hopping and step-ups were performed with a metronome at 160 beats/min, whereas single-leg squats were performed with the metronome at 80 beats/min (down on 1 beat and up on the next). Based on the athlete's ability to maintain specified form elements detailed by Harrison et al (Table 1) for 1 minute, each task was rated pass or fail within the cumulative RRS score range of 0 to 5 (0 = *no tasks passed successfully*, 5 = *all tasks passed successfully*).[9]

Ten athletes were each assessed in real time by the 2 testers to determine intertester reliability values.[9] Intertester reliability values were substantial ($r = 0.70$) for total RRS scores. For individual tasks, intertester reliability ranged from moderate (step-up $r = 0.41$, single-leg squat $r = 0.62$) to perfect (double-leg hop, plank, and wall sit $r = 1.0$).

From the beginning to the end of their sport season, the athletes were followed by athletic training staff for occurrence of lower extremity injury. A lower extremity injury was defined as any muscle, joint, or bone problem/injury of the lower extremity resulting from a practice or meet that required the athlete to be removed from a practice or meet or to miss a subsequent practice or meet.[18,19] Lower extremity injuries that occurred at a time other than during participation, or unrelated to running or a track event, were excluded.[20] A day lost to injury was any day in which the athlete was not able to participate in an unrestricted manner. Injury date, body site of injury, mechanism and type of injury, and days of missed or limited practice and/or competition were recorded by the university's athletic training staff using Athletic Trainer System software. The athletic training staff was blinded to questionnaire responses and RRS results. Injury data for participants were provided to the primary investigator by the head athletic trainer after the season ended.

Statistical Analysis

All statistical analyses were performed with IBM SPSS (V. 29.0) with an α significance level set at $P < .05$. Independent t tests were used to compare mean values of demographic characteristics, training experience, RRS, and preseason cardiovascular, speed, and resistance training by sex and by injury status during the season. A chi-square test was used to determine differences in the percentage of prior injury between sexes and between those who incurred or did not incur a lower extremity injury. Binomial logistic regression was used to calculate ORs and 95% confidence intervals (CIs) to determine the likelihood of lower extremity injury for athletes by RRS level, with RRS scores of ≤ 3 to those with scores of ≥ 4. Those with an RRS score of 3 or less were considered to have a greater likelihood of lower extremity injury than those with an RRS score of 4 or 5 (at lesser likelihood of lower extremity injury; referent group).[9] Sixty-three athletes reported a prior injury in the past year that limited their training and/or competition for ≥ 7 days. Prior injury has been established as a risk factor for future RRI.[21] Thus, multivariable logistic regression was used to adjust for prior injury for total RRS and individual RRS tasks with the exception of the wall sit task, where the percent for those injured and failing the wall sit task was 100 percent, negating the need for the adjustment.[18]

RESULTS

Although men were taller and heavier than women, no other significant mean differences were found between men and women for other demographic characteristics, training experiences, or preseason cardiovascular, speed, or resistance training (Table 2). A similar percentage of men and women reported prior injury (Table 2), and there was not a significant difference in the distribution of RRS scores between men and women ($P = .47$; Table 3). During the season, 37 (32.7%) athletes experienced a lower extremity injury. Injured athletes had a lower mean RRS score than noninjured athletes (3.4 ± 0.9 versus 3.9 ± 0.8, $P = .003$; Table 4). When assessing for confounders, no significant

Table 2. Baseline Characteristics of Division III Track and Field and Cross Country Student-Athletes

Variables	Total $n = 113$ Mean (SD)	Men $n = 63$ Mean (SD)	Women $n = 50$ Mean (SD)	P Value[a]	Effect Size
Age, y	19.9 (1.3)	20.1 (1.3)	19.6 (1.1)	.05	0.38
Body mass, kg	65.7 (9.5)	71.6 (7.2)	58.3 (6.5)	<.001	1.93
Height, cm	173.5 (9.5)	180.4 (5.3)	164.8 (5.7)	<.001	2.84
Body mass index, kg m^{-2}	21.8 (1.9)	22.0 (1.9)	21.4 (2.0)	.13	0.29
Track experience, y	6.7 (2.3)	6.8 (2.4)	6.5 (2.3)	.54	0.12
Running Readiness Scale score[b]	3.7 (0.9)	3.8 (0.9)	3.6 (0.9)	.25	0.06
Preseason cardiovascular sessions per week	3.1 (2.3)	3.0 (2.3)	3.2 (2.4)	.74	0.08
Preseason speed sessions per week	1.4 (1.2)	1.5 (1.1)	1.4 (1.3)	.69	0.08
Preseason resistance training sessions per week	2.1 (1.3)	2.1 (1.3)	2.2 (1.3)	.66	0.22
Prior injury limiting sport participation ≥7 days in the past year (%)	55.8	58.7	52.0	.41[c]	NA

Abbreviation: NA, not available.
[a] Two-sample t test of differences of means between men and women.
[b] Scale: 0 to 5 points.
[c] Chi-square test.

differences were found between injured and noninjured athletes for baseline characteristics, training experience, or preseason cardiovascular, speed, and resistance training (Table 4).

Athletes scoring 3 or less on the RRS were almost 5 times more likely to experience a lower extremity injury during the season (adjusted OR = 4.8; 95% CI: 2.1, 11.3) than athletes with an RRS score of 4 or 5 (Table 5). For individual tasks of the RRS, the double-leg hop and wall sit tasks were significantly related to lower extremity injury. Athletes who failed the double-leg hop task were over 4 times more likely to experience a lower extremity injury (adjusted OR = 4.5; 95% CI: 1.4, 14.7), whereas athletes who failed the wall sit task were almost 26 times more likely (OR = 25.9; 95% CI: 1.4, 482.0; Table 5).

DISCUSSION

The purpose of this study was to determine if lower RRS scores were associated with the occurrence of lower extremity injury in Division III track and field athletes and cross country runners during their respective sport seasons. The key findings support the hypothesis that athletes with an RRS score of 3 or less are at an increased likelihood of a lower extremity injury compared with those who score a 4 or 5. On average, total RRS scores were lower among injured athletes than among noninjured athletes, and, when considered individually, the double-leg hop and wall sit tasks were related to injury risk when athletes exhibited poor movement quality.

Table 3. Running Readiness Scale (RRS) Score Distribution by Sex Among Division III Track and Field and Cross Country Student-Athletes

RRS Score[a]	Total ($n = 113$) N	%	Men ($n = 63$) N	%	Women ($n = 50$) N	%
0	0	0	0	0	0	0
1	1	0.9	1	1.6	0	0
2	9	8.0	3	4.8	6	12.0
3	28	24.8	15	23.8	13	26.0
4	57	50.4	32	50.8	25	50.0
5	18	15.9	12	19.0	6	12.0

Abbreviation: RRS, Running Readiness Scale.
[a] RRS score: number of the 5 tests rated PASS (0–5).

Interrater reliability for the total RRS score in this study indicated moderate ($r = 0.70$) reliability and was similar to that reported by Harrison et al ($r = 0.75$).[9] Like their findings, the reliability varied by individual task. Our interrater reliability for the step-up was lower ($r = 0.41$ versus $r = 0.87$), whereas values for single-leg squats were similar ($r = 0.62$ versus $r = 0.72$). Although we observed perfect agreement ($r = 1.0$) for the double-leg hop and plank tasks, their values were somewhat lower ($K = 0.58$ and $K = 0.87$, respectively). Both studies reported perfect agreement ($r = 1.0$) for the wall sit task. The differences in reliability between the 2 studies for dynamic RRS tasks indicate the need for ensuring consistent training of what constitutes a failed or passed task.

In the only other prospective study that has reported examining the relationship between the RRS and risk of injury, Payne and colleagues reported that, in a sample of 18 Division III cross country runners, runners who failed individual RRS tasks did not have a higher risk of injury.[16] Their study did not report injury risk by total RRS score, so we were not able to make a direct comparison to our primary findings. The difference in our findings, that 2 of the individual RRS tasks (the double-leg hop and wall sit) were related to injury risk, may be due to several factors. First, the sample size of 18 runners may not have provided them with adequate power to appropriately detect differences between individual RRS task performance and injury. Second, the studies used different injury definitions. Payne and colleagues used the consensus definition for RRI in recreational runners by Yamato et al, defining an injury as 3 consecutive days or 7 days of restricted training due to pain or if an athlete consulted a health professional.[16,22] In their study, 37.5% of runners were injured. As the definition by Yamato was established for recreational runners, the first part of the definition may underestimate time-loss injuries of less than 3 days in collegiate athletes, whereas convenient access to health professionals, like team athletic trainers, may overestimate injuries if consultations occurred for symptoms that did not impact their sport participation.[22] We used the time-loss definition by Rauh and colleagues for competitive collegiate and high school athletes, as this definition recognizes injuries impacting participation much

Table 4. Baseline Characteristics of Division III Track and Field and Cross Country Student-Athletes by Injury Status

Variables	Total $n = 113$ Mean (SD)	Injured $n = 37$ Mean (SD)	Noninjured $n = 76$ Mean (SD)	P Value[a]	Effect Size
Age, y	19.9 (1.3)	19.7 (1.0)	19.9 (1.4)	.34	0.18
Body mass, kg	65.7 (9.5)	64.2 (9.5)	66.5 (9.6)	.24	0.24
Height, cm	173.5 (9.5)	171.9 (9.8)	174.3 (9.3)	.21	0.25
Body mass index, kg m^{-2}	21.8 (1.9)	21.6 (1.7)	21.8 (2.1)	.63	0.10
Track experience, y	6.7 (2.3)	6.9 (2.5)	6.6 (2.2)	.58	0.11
Running Readiness Scale score[b]	3.7 (0.9)	3.4 (0.9)	3.9 (0.8)	.003	0.00
Preseason cardiovascular sessions per week	3.1 (2.3)	3.1 (2.0)	3.1 (2.4)	.99	0.05
Preseason speed sessions per week	1.4 (1.2)	1.4 (1.2)	1.3 (1.1)	.81	0.10
Preseason resistance training sessions per week	2.1 (1.3)	2.0 (1.2)	2.2 (1.3)	.63	0.68
Prior injury limiting sport participation $\geq$7 days in the past year (%)	55.8	59.5	54.7	.63[c]	NA

Abbreviation: NA, not available.
[a] Two-sample t test of differences of means for athletes who experienced a time-loss lower extremity injury and noninjured athletes during the season.
[b] Scale: 0 to 5 points.
[c] Chi-square test.

earlier in relatively short sports seasons and allows for injury severity categorization based on the amount of time-loss.[18,19] Further, this may allow earlier injury rehabilitation to minimize the severity of the injury in efforts to return the athlete back to their event faster. Finally, performance on the RRS appeared to vary between participant groups with more of their study sample failing tasks. In their study, 55.6% failed the double-leg hop assessment, 55.6% failed the plank assessment, 38.9% failed the step-up assessment, 72.2% failed the single-leg squat assessment, and 27.8% failed the wall sit assessment.[16] For comparison, in our sample, 13.3% failed the double-leg hop, 15.9% failed the plank, 16.8% failed the step-up, 77.0% failed the single-leg squat, and 4.4% failed the wall sit. It is possible that the strength and fitness levels that may play a role in being successful in these tasks were higher in our sample than in theirs.

We identified that poor movement quality during the double-leg hop task was significantly linked to lower extremity injury. Although single-leg hops have been assessed as a clinical test in injured athletes, to our knowledge, there are no current studies that have reported examining the relationship between the double-leg hop task and lower extremity injuries in cross country and track and field athletes.[23,24] The primary form element assessed during the double-leg hop was the ability to keep knees aligned without apparent knee collapse toward midline.

The wall sit assessment has previously been associated with core and lower extremity sprain and strain injury risk in collegiate football players, with lower-duration hold times associated with higher risk.[25,26] As part of a battery, the test was used to assess muscle fatigue of hip and knee extensors, which seems prudent that the test may be predictive in runners.[24,26] Although only 5 athletes in our sample failed the wall sit task, all 5 experienced a lower extremity injury. Few athletes failing the task and all experiencing injury resulted in a wide CI, so more research on this task

Table 5. Likelihood of Injury and Running Readiness Scale (RRS) Results in Division III Track and Field and Cross Country Student-Athletes

	Total ($n = 113$)			
Classification	N	Percent Inj	AOR[a]	95% CI
RRS score of $\leq$3	38	55.3	4.8[b]	2.1, 11.3
RRS score of $\geq$4	75	21.3	1.0	Ref
Individual Tasks of RRS				
Double-leg hop FAIL	15	60.0	4.5[b]	1.4, 14.7
Double-leg hop PASS	98	28.6	1.0	Ref
Plank FAIL	18	50.0	2.4	0.9, 6.6
Plank PASS	95	29.5	1.0	Ref
Step-up FAIL	19	47.4	2.1	0.8, 5.8
Step-up PASS	94	29.8	1.0	Ref
Single-leg squat FAIL	87	33.3	1.1	0.4, 2.9
Single-leg squat PASS	26	30.8	1.0	Ref
Wall sit FAIL[c]	5	100.0	25.9[b]	1.4, 482.0[c]
Wall sit PASS[c]	108	29.6	1.0	Ref

Abbreviations: AOR, adjusted odds ratio; CI, confidence interval; Inj, injured; N, number at risk; Ref, reference group (higher scores/passed test); RRS, Running Readiness Scale.
[a] Adjusted for prior injury $\geq$7 days in the past year.
[b] $P < .05$, significantly different from the reference group.
[c] Not adjusted for prior injury.

in runners is recommended. Of note is that, although Wilkerson et al initially used the double-leg wall sit task in their study, consistent with the RRS, they later updated their testing to a unilateral wall sit assessment with the intent of assessing athletes' ability to avoid excessive hip adduction and knee valgus.[25] The unilateral wall sit reduced the duration of the test "while maintaining the discriminative power of the test."[25] More recent evidence linking shorter wall sit holds with increased risk of injury in basketball players has used the unilateral version of the test.[27] In summary, although the double-leg task is reflective of muscle endurance, the unilateral version adds more control and balance demands, so further research is recommended to determine if the unilateral version could be more appropriate to use in a future version of the RRS in collegiate track and cross country runners.[25]

In our study, the plank task was not significantly related to lower extremity injury. This is consistent with a prior study in which plank hold times were not associated with injury in a combined group of track and field and cross country athletes.[28] Longer plank hold times have been correlated with less dynamic knee valgus during a step-down task in prior research, suggesting that trunk endurance may influence lower limb kinematics, and prone plank performance has been linked to lower extremity overuse injuries in active college students.[29,30] Differences in results of the studies may be attributed to the pass/fail classification based on form and the 60-second cut-point for the RRS as well as the different activity levels of participants.

The step-up task was not a significant indicator of lower extremity injury risk in our sample. The literature supports that the motions of step-up tasks are comparable with those used during running.[31] Schreiber et al observed that the kinematics during a step-down task for hip internal rotation, knee valgus, and rearfoot eversion were predictive of the kinematics observed during running in highly trained runners.[31] Similarly, in novice runners, the kinematics of the step-up test as part of the RRS were significantly correlated with frontal plane pelvis, hip, and knee as well as transverse plane knee running kinematics.[9] The relationships between step-down and step-up motions with running kinematics may be useful in a clinical setting, particularly when examining frontal and transverse plane running mechanics that may contribute to injury because no apparent knee collapse toward midline is required to pass the step-up task.

Although we expected that athletes with poorer performance on the single-leg squat assessment would experience a higher likelihood of lower extremity injury, we did not observe a significant relationship. Our expectations were based on findings from Eckard et al who reported that trunk/hip shift, knee valgus, and hip drop/hike were common movement deviations in Division I athletes from several sports with poor execution of the single-leg squat and that in these athletes, poor movement quality for single-leg squats was associated with a higher risk of lower extremity injury.[32] Contrasting results may be attributed to the different population samples or that Eckard et al used a scoring system tallying the number of deviations to reflect single-leg squat performance rather than the pass/fail rating used for the RRS.[32] Specific kinematics were not analyzed for our rating, rather, passing the task required level hips, no apparent knee collapse toward midline, and no excessive forward or lateral trunk lean. These form elements for the RRS single-leg squat task correlate to contralateral pelvic drop and dynamic genu valgum during running.[9] In the current study and that of Payne et al, the single-leg squat was the RRS task with the highest failure rate.

A notable strength of this study is the prospective design, which reduces measurement bias of the RRS scale, and demographics at the start of the athletic seasons as well as athletic training staff being blinded to these measures. Second, the sample size was sufficiently large enough to meet a priori values to appropriately test our primary hypothesis. Third, to our knowledge, this is the first study that has reported examining the relationship between RRS scores and lower extremity injury in collegiate track and field and cross country athletes, providing novel information to sports medicine personnel about a tool that may help them identify runners at greater likelihood of lower extremity injury.

Several limitations of the study are noteworthy. Although the study was adequately powered for the overall sample and RRS scores, the analysis of the wall-sit individual RRS task resulted in a wide CI. Thus, this analysis should be interpreted with caution. We included track and field athletes in different events and cross country runners; studying a more homogenous group, like only distance runners, may result in smaller CIs. Another potential limitation is that some athletes may have experienced a time-loss lower extremity injury but did not report the injury to the athletic training staff. This may have affected the true relationship between the RRS and injury. As we used a time-loss definition of injury, athletes who experienced physical complaints but continued to participate fully were not considered injured. Of clinical importance, though, is that nontime-loss physical complaints often precede a time-loss injury in athletes; thus, symptoms that may not initially limit running warrant the attention of the athletic trainer and athlete.[33]

In summary, we observed that track and field and cross country athletes with poorer performance on the RRS at the start of their season were more likely to incur a lower extremity injury during the season. Athletes who failed the double-leg hop or wall sit tasks of the RRS were more likely to experience a lower extremity injury. Key form elements associated with passing the dynamic tasks of the RRS include keeping the hips level and no apparent knee collapse toward midline. These relate to contralateral pelvic drop and dynamic genu valgus during running stance, whereas the static RRS tasks assess trunk and lower extremity muscle endurance. The RRS may serve as a clinical assessment tool to help identify running athletes at risk of developing a lower extremity injury. Future work is needed to determine whether interventions to improve performance on RRS tasks in those identified at risk based on preseason screening reduce subsequent injury.

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REFERENCES

1. NCAA sports sponsorship and participation rates database (data visualization dashboard). National Collegiate Athletic Association. Accessed February 2023. http://www.ncaa.org/about/resources/research/ncaa-sports-sponsorship-and-participation-rates-database
2. Roos KG, Marshall SW, Kerr ZY, et al. Epidemiology of overuse injuries in collegiate and high school athletics in the United States. *Am J Sports Med*. 2015;43(7):1790–1797. doi:10.1177/0363546515580790

3. Kerr ZY, Kroshus E, Grant J, et al. Epidemiology of National Collegiate Athletic Association men's and women's cross-country injuries, 2009–2010 through 2013–2014. *J Athl Train*. 2016;51(1):57–64. doi:10.4085/1062-6050-51.1.10
4. Yang J, Tibbetts AS, Covassin T, Cheng G, Nayar S, Heiden E. Epidemiology of overuse and acute injuries among competitive collegiate athletes. *J Athl Train*. 2012;47(2):198–204. doi:10.4085/1062-6050-47.2.198
5. Hotta T, Nishiguchi S, Fukutani N, et al. Functional movement screen for predicting running injuries in 18- to 24-year-old competitive male runners. *J Strength Cond Res*. 2015;29(10):2808–2815. doi:10.1519/JSC.0000000000000962
6. Ruffe NJ, Sorce SR, Rosenthal MD, Rauh MJ. Lower quarter- and upper quarter Y Balance Tests as predictors of running-related injuries in high school cross-country runners. *Int J Sports Phys Ther*. 2019;14(5):695–706. doi:10.26603/ijspt20190695
7. Christopher SM, Donnelly G, Brockwell E, et al. Clinical and exercise professional opinion of return-to-running readiness after childbirth: an international Delphi study and consensus statement. *Br J Sports Med*. 2024;58(6):299–312. doi:10.1136/bjsports-2023-107489
8. Christopher SM, Gallagher S, Olson A, Cichowski S, Deering RE. Rehabilitation of the postpartum runner: a 4-phase approach. *J Womens Health Phys Therap*. 2022;46(2):73–86. doi:10.1097/JWH.0000000000000230
9. Harrison K, Williams DSB, Darter BJ, et al. The Running Readiness Scale as an assessment of kinematics related to knee injury in novice female runners. *J Athl Train*. 2023;58(2):120–127. doi:10.4085/1062-6050-404-21
10. Crossley KM, Zhang WJ, Schache AG, Bryant A, Cowan SM. Performance on the single-leg squat task indicates hip abductor muscle function. *Am J Sports Med*. 2011;39(4):866–873. doi:10.1177/0363546510395456
11. Whatman C, Hing W, Hume P. Physiotherapist agreement when visually rating movement quality during lower extremity functional screening tests. *Phys Ther Sport*. 2012;13(2):87–96. doi:10.1016/j.ptsp.2011.07.001
12. Rees D, Younis A, MacRae S. Is there a correlation in frontal plane knee kinematics between running and performing a single leg squat in runners with patellofemoral pain syndrome and asymptomatic runners? *Clin Biomech (Bristol)*. 2019;61:227–232. doi:10.1016/j.clinbiomech.2018.12.008
13. Whatman C, Hume P, Hing W. Kinematics during lower extremity functional screening tests in young athletes—are they reliable and valid? *Phys Ther Sport*. 2013;14(2):87–93. doi:10.1016/j.ptsp.2012.06.001
14. Noehren B, Hamill J, Davis I. Prospective evidence for a hip etiology in patellofemoral pain. *Med Sci Sports Exerc*. 2013;45(6):1120–1124. doi:10.1249/MSS.0b013e31828249d2
15. Noehren B, Davis I, Hamill J. ASB clinical biomechanics award winner 2006 prospective study of the biomechanical factors associated with iliotibial band syndrome. *Clin Biomech (Bristol)*. 2007;22(9):951–956. doi:10.1016/j.clinbiomech.2007.07.001
16. Payne SS, D'Errico J, Blaise Williams D. An examination of step frequency and the Running Readiness Scale as predictors of running-related injury in collegiate cross-country athletes. *J Sports Med Allied Health Sci*. 2019;5(2):4. doi:10.25035/jsmahs.05.02.04
17. Chow S-C, Shao J, Wang H, Lokhnygina Y. *Sample Size Calculations in Clinical Research*. 3rd ed. CRC Press; 2017.
18. Rauh MJ, Macera CA, Marshall SW. Applied sports injury epidemiology. In: Magee DJ, Manske RC, Zachazewski JE, Quillen WS, eds. *Athletic and Sport Issues in Musculoskeletal Rehabilitation*. Elsvier Saunders; 2010:730–772.
19. Rauh MJ, Macera CA. Athletics. In: Caine DJ, Harmer PA, Schiff MA, eds. *Epidemiology of Injury in Olympic Sports*. Wiley-Blackwell; 2009:26–48.
20. Rauh MJ, Koepsell TD, Rivara FP, Rice SG, Margherita AJ. Quadriceps angle and risk of injury among high school cross-country runners. *J Orthop Sports Phys Ther*. 2007;37(12):725–733. doi:10.2519/jospt.2007.2453
21. van Poppel D, van der Worp M, Slabbekoorn A, et al. Risk factors for overuse injuries in short- and long-distance running: a systematic review. *J Sport Health Sci*. 2021;10(1):14–28. doi:10.1016/j.jshs.2020.06.006
22. Yamato TP, Saragiotto BT, Lopes AD. A consensus definition of running-related injury in recreational runners: a modified Delphi approach. *J Orthop Sports Phys Ther*. 2015;45(5):375–380. doi:10.2519/jospt.2015.5741
23. Meardon S, Klusendorf A, Kernozek T. Influence of injury on dynamic postural control in runners. *Int J Sports Phys Ther*. 2016;11(3):366–377.
24. Nussbaum ED, Gatt CJ II, Bjornarra J, Yang C. Evaluating the clinical tests for adolescent tibial bone stress injuries. *Sports Health*. 2021;13(5):502–510. doi:10.1177/1941738120988691
25. Wilkerson GB, Colston MA. A refined prediction model for core and lower extremity sprains and strains among collegiate football players. *J Athl Train.* 2015;50(6):643–650. doi:10.4085/1062-6050-50.2.04
26. Wilkerson GB, Giles JL, Seibel DK. Prediction of core and lower extremity strains and sprains in collegiate football players: a preliminary study. *J Athl Train*. 2012;47(3):264–272. doi:10.4085/1062-6050-47.3.17
27. Plummer HA, Wilkerson GB, Bruce JR, Lamour RJ, Ostrander RV III. Preliminary findings of lower extremity injury risk categorization through lumbopelvic-hip endurance screening of high school basketball players. *Athl Train Sports Health Care.* 2020;12(3):127–134. doi:10.3928/19425864-20190507-01
28. Luedke LE, Rauh MJ. Plank times and lower extremity overuse injury in collegiate track-and-field and cross country athletes. *Sports (Basel).* 2022;10(3):45. doi:10.3390/sports10030045
29. Burnham JM, Yonz MC, Robertson KE, et al. Relationship of hip and trunk muscle function with single leg step-down performance: implications for return to play screening and rehabilitation. *Phys Ther Sport*. 2016;22:66–73. doi:10.1016/j.ptsp.2016.05.007
30. De Blaiser C, De Ridder R, Willems T, Vanden Bossche L, Danneels L, Roosen P. Impaired core stability as a risk factor for the development of lower extremity overuse injuries: a prospective cohort study. *Am J Sports Med*. 2019;47(7):1713–1721. doi:10.1177/0363546519837724
31. Schreiber C, Becker J. Performance on the single-legged step down and running mechanics. *J Athl Train*. 2020;55(12):1277–1284. doi:10.4085/1062-6050-533-19
32. Eckard T, Padua D, Mauntel T, et al. Association between double-leg squat and single-leg squat performance and injury incidence among incoming NCAA Division I athletes: a prospective cohort study. *Phys Ther Sport*. 2018;34:192–200. doi:10.1016/j.ptsp.2018.10.009
33. Whalan M, Lovell R, Sampson JA. Do niggles matter?—Increased injury risk following physical complaints in football (soccer). *Sci Med Football.* 2020;4(3):216–224. doi:10.1080/24733938.2019.1705996

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