**Review Paper**

# Functional Tests' Sensitivity and Specificity for Return to Sport After ACL Reconstruction: A Scoping Review

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## ABSTRACT

**Objectives:** Sports often witness high anterior cruciate ligament (ACL) injuries, which are common and tend to recur frequently. Functional tests are crucial for aiding athletes in their return to sports (RTS) after ACL reconstruction (ACLR). By understanding this injury through implementing functional tests, the potential for reinjury can be reduced. Additionally, this approach can decrease therapeutic costs and facilitate a smoother rehabilitation process, ultimately enabling successful RTS. This study aims to compile a comprehensive functional test and its sensitivity and specificity for RTS after ACL injury reconstruction.

**Methods:** This scoping review conducted an extensive survey of functional tests to assess the ability to RTS after ACL injuries. The search was performed on various databases, including Web of Science, PEDRO, Google Scholar, PubMed, ScienceDirect, SCOPUS, and CINAHL, covering the period from 2000 to January 2023. The purpose was to gather a comprehensive range of relevant studies and information on functional tests for evaluating RTS after ACL injuries. Furthermore, a manual search of the sources of articles was conducted and thoroughly examined.

**Results:** Of the 31 papers reviewed, 14 were included in this scoping review. The results of these selected papers were thoroughly examined, reported, and analyzed as an integral part of the review process. They were related to balance and postural control, agility, power, screening, and movement pattern tests. Functional tests for RTS after ACLR in terms of sensitivity and specificity included hop, shuttle run, vertical jump, carioca, and lower extremity functional test protocol (LEFT).

**Discussion:** An analysis of studies showed different functional tests. According to this study's results, the most common functional tests, the hop group tests may be more common functional tests for RTS after ACLR in terms of sensitivity and specificity, which were the main focus of this scoping review. We hope these tests will be useful for personal trainers, athletic trainers, practitioners, and clinicians when evaluating injured athletes.

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## Highlights

- Functional tests for RTS after ACLR were collected and categorized according to their sensitivity, specificity, and role.
- Functional tests provide indispensable knowledge for decision-making regarding RTS after ACLR.
- To date, functional tests, especially hop group tests, are the most common functional tests.

## Plain Language Summary

This review included 14 relevant and qualified studies out of 127 articles. The findings indicate that approximately 60% of the articles examined in this study revealed that hop group tests are the most commonly utilized functional tests by sports medicine physicians. This suggests that hop group tests have gained popularity in assessing the ability to return to sports (RTS) after anterior cruciate ligament (ACL) injuries.

## Introduction

One of the most common knee injuries is anterior cruciate ligament (ACL) injury, which occurs among patients aged 16-39 years [1-3]. ACL injuries can have short- and long-term consequences that encompass several factors. These consequences may include muscle weakness, physical deficits, decreased engagement in sports activities, an elevated risk of re-injury to the knee, and the potential development of osteoarthritis in the affected knee. These outcomes can significantly impact an individual's overall physical function and quality of life. It is essential to consider these factors when evaluating the effects of ACL injuries and determining appropriate interventions for rehabilitation and return to sports (RTS) [4-7]. Deciding when an athlete is ready to RTS can be difficult as a physician or clinician. Various elements must be considered, such as muscle strength, cardiovascular fitness, balance, and psychological readiness. By tracking progress in these areas, practitioners can make more informed decisions and increase the likelihood that the athlete will RTS at an optimal performance level [8]. Owing to the latest technological developments, medical, rehabilitation, and performance professionals can now easily gather data that can be utilized to enhance the care and development of athletes as they prepare for RTS. Nevertheless, understanding the significance and application of collected data remains challenging [8]. The success of RTS after ACL injuries often relies on a comprehensive biopsychosocial approach to rehabilitation. This approach considers the biological aspects of injury and recovery, as well as the psychological and social factors that can influence an individual's ability to RTS successfully. By addressing all these dimensions, including physical rehabilitation, psychological support, and social factors, the chances of a successful RTS can be significantly enhanced [9], and several factors likely affect its success. As a result, RTS assessments have become a vital and indispensable clinical and functional tool for determining readiness to RTS [10]. The selected papers and their results can be clinically crucial in advancing the RTS procedure and assessing the risk of reinjury after ACL reconstruction (ACLR). The findings from these studies can provide valuable insights and inform clinical decision-making to enhance the RTS process and minimize the chances of reinjury following ACLR [11]. The RTS process consists of several phases that pave the way and open the door for clinicians, practitioners, and trainers to focus on functional tests that play a crucial role in helping athletes after ACLR. Both clinical and functional tests are available. The term "sensitivity" is commonly used in medical testing and refers to the ability of a test to accurately identify individuals with the disease or condition being tested. In other words, a test's sensitivity measures its ability to correctly recognize individuals with errors [12]. An assessment with 100% sensitivity accurately identifies all individuals with the errors, whereas a test with 80% sensitivity can identify 80% of those with the error, leaving 20% of cases unnoticed [12]. To pinpoint a significant yet avoidable mistake, a high level of sensitivity is particularly crucial [12]. Conversely, the term "specificity" pertains to the test's capability to accurately exclude individuals who do not possess the disease or condition under examination [12]. Hence, a test with 100% sensitivity precisely identifies all individuals without errors [12]. An 80% specificity test correctly classifies 80% of individuals without errors as test negatives (true negatives), yet it erroneously categorizes 20% of error-free individuals as test positives (false positives) [12]. Herbst et al. [13] and Hildebrandt et al. as an example, [14] conducted seven functional assessments, which included the two-leg stability test, one-leg stability test, two-leg counter-movement jump, one-leg counter-movement jump, plyometric jumps, speedy test, and quick feet test. The results indicated that all the tests demonstrated moderate to substantial levels of reliability [15]. Although these functional tests' validity and test, re-test reliability have been investigated and verified, they have limitations when used as a standardized set of measurements. This is primarily due to their time-consuming and intricate testing procedures [14, 16, 17]. When assessing sports-related performance, it is crucial to consider factors beyond the reliability and validity of functional tests. Considerations, such as cost, user-friendliness, and portability, are also significant. The single-leg hop test, which has consistently been suggested, serves as a valuable tool for evaluating athletic outcomes after ACLR [18, 19]. Hence, this study aimed to explore functional tests and assess their sensitivity and specificity in RTS after ACLR.

## Materials and Methods

This scoping review was based on the preferred reporting items for systematic reviews and meta-analyses (PRISMA) guidelines.

### Search strategy

A thorough analysis of functional tests, encompassing their sensitivity and specificity for RTS after ACLR by searching the Web of Science, PEDRO, Google Scholar, PubMed, ScienceDirect, SCOPUS, CINAHL databases with the keywords using three groups of search terms: (group 1) "ACL RTS" OR "return to play" OR "return to competition" OR "return to activities" OR "return to participation;" AND (group 2) "lower extremity" OR "lower body" OR "lower limb" OR "ACL complex;" AND (group 3) "ACL functional tests" OR "ACL functional battery tests" OR "ACL functional assessment" OR "ACL functional evaluation." These combinations (involving three groups) were investigated in the titles, abstracts, and keywords of studies published in indexed journals from 2000 to January 2023. Manual searches were conducted to identify articles that might not have appeared in online searches, and a thorough review of article sources was performed.

### Eligibility criteria

The inclusion criteria included athletes or people who underwent rehabilitation programs, suffered ACL injuries, used functional tests to RTS; English-language articles, full-text studies were published, and also studies which were randomized control trial (RCT), cross-sectional, and cohort designs; other knee injuries, such as fractures of the proximal arm and articles that were published briefly in congresses and seminars. The exclusion criteria included non-English articles and tests that were not used for RTS.

### Study selection

English was used for this search. The researchers screened all the texts. Finally, 127 articles were received from databases using relevant keywords. At first, the titles of the articles were examined, and 12 duplicate articles were removed. In the next step, the abstracts of 115 articles were examined, and, 78 articles were excluded from the survey because they did not meet the inclusion criteria. Next, 37 articles were thoroughly examined in their entirety. Subsequently, 23 of these articles were eliminated from consideration because they did not meet the inclusion criteria. For example, articles in Chinese (9 articles) and Hindi (5 articles) that did not use performance tests for returning to sports after ACLR were deleted. Finally, 14 articles were included in the present review and their results were fully reported. The final compilation of the acquired articles was reviewed by another prominent researcher to ensure that they aligned with the study objectives. The process of obtaining study 2 is illustrated in Figure 1. The structure adheres to the population, intervention, comparison, outcomes, and study (PICOS) framework (Table 1), which is connected to the survey question below.

By searching databases, such as Web of Science, PEDRO, Google Scholar, PubMed, ScienceDirect, SCOPUS, and CINAHL, 127 papers were acquired. After removing duplicate titles, 115 abstracts were chosen for assessment. After reviewing these abstracts, 78 papers were excluded. Subsequently, 37 full-text papers were selected for further evaluation. After scrutinizing these full-text papers, 23 articles were disqualified, and 14 articles that met the criteria were included in the study. Table 2 shows the process of evaluating the quality of this study, and Figure 1 shows the process of evaluating and selecting research articles.

## Results

The study included ACL functional tests, and the results were compared with those of existing studies. Approximately, 31 tests, including balance and postural control, agility, power, screening, and movement pattern tests, were included, each explained separately. Tables 3, 4, 5 and 6 present the RTS functional tests and their specificities and sensitivities.

**Table 1.** PICOS framework

| Structure Components | Interpretation |
|---|---|
| Populace | Athletes or people with ACL injuries |
| Intervention | Performing functional tests to measure readiness to RTSs after ACL injuries |
| Comparison | A comprehensive report was generated encompassing the research incorporated into the survey. Subsequently, the outcomes of these studies were compared to ascertain the functional tests utilized to assess readiness for RTS after anterior ACL injuries. |
| Outcome | The primary aim of this review was to identify the existing functional tests used to evaluate RTS following ACL injuries. |
| Study type | Studies that were RCTs, cross-sectional, and cohort designs |

ACL: Anterior cruciate ligament; RTS: Return to sport.

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## Discussion

This review article was conducted to report the common functional tests and their sensitivity and specificity for RTS after ACLR. A significant finding of this review was that 60% of the articles showed that hop group tests are the most common functional tests after ACLR. Four tables were included: Balance and postural control, agility, power, screening, and movement pattern tests. The related explanation for each is discussed separately below.

Table 3 presents 20 tests of balance and postural control. Fifteen of 20 crucial tests were related to the hop group tests. The highest sensitivity was for the single-leg agility hop test and hopping obstacle course test (100% each) and the lowest sensitivity was for the balance error scoring system (BESS) test (34%). Also, the forward hop test and the hopping obstacle course test had the highest specificity (97% each), and the multiple single-leg hop stabilization test had the lowest specificity (63%). Finally, the sensitivity and specificity of the dynamic leap and balance (DLBT) test were unknown.

Table 4 presents the three agility tests. The shuttle run test had the highest sensitivity (80%), and the Illinois test had the lowest sensitivity (34%). Also, the shuttle run test had the highest specificity (68%), and the Illinois test had the lowest specificity (35%).

Table 5 presents three tests of power. The vertical jump test and the single-leg vertical jump test had the highest sensitivity (95% each), and the Carioca test had the lowest sensitivity (75%). Also, the Carioca test had the highest specificity (80%), while the vertical jump and single-leg vertical jump tests had the lowest specificity (46% each).

Table 6 presents six screening and movement pattern tests; one was a self-report questionnaire. The highest sensitivity was for the lower extremity functional test (LEFT) protocol (95%), and the lowest sensitivity was for the tuck jump test (52%). Also, the highest specificity was for the LEFT (95%), and the lowest specificity was for the tuck jump test (50%). Finally, the sensitivity and specificity of the self-report questionnaire adapted from de Bie et al. were unknown [20].

According to the above findings of each Table, it can be mentioned that the hop tests (Table 3), the shuttle run test (Table 4), the vertical jump tests and the Carioca test (Table 5), and the LEFT test may be more appropriate functional tests for RTS after ACLR in terms of sensitivity and specificity which were the main focus of this scoping review. Additionally, 10 of the 14 articles in this review assessed football players using hop tests, highlighting the importance of dynamic and static stability in football. However, others have focused on other components that are also crucial in sports. Considering the body as a whole and focusing on training principles, such as performing a task unilaterally in an open or closed kinetic chain with perturbation, along with dual tasks and focusing on movement pattern tests in terms of skill and movement quality, may effectively involve these components when assessing athletes [8]. As previously mentioned, these functional tests could offer a more time and cost-effective alternative to clinical tests. For instance, given the significance of the hop tests, they enable us to efficiently assess performance factors, such as speed, explosive force, acceleration, stability, and balance within a short timeframe [15]. Hop tests are vital in ACL injury prevention and RTSs [11]. Different hop tests include the single-leg hop test for distance, the stair-hop test, the 6-meter single-leg hop test for time, and the triple jump test, of which three are measured based on the distance and one is measured based on time [41, 42].

**Table 2.** The process of evaluating the quality of this study

| Items | | Criteria | Possible Answers |
|---|---|---|---|
| Reporting | 1 | Are the hypotheses and objectives of this study clearly and coherently expressed? | 1 |
| | 2 | Is there a clear description of the primary outcomes to be assessed in the introduction or methods section? Please do not answer this question unless the main results are mentioned in the results section. | 1 |
| | 3 | Have the clinical characteristics of these cases been adequately described? For cohort studies and trials, inclusion and the exclusion criteria should be provided. For case-control studies, the source of controls should be defined, and a clear case definition should be supplied. | 1 |
| | 4 | Are the interventions of interest comprehensively detailed? If applicable, the therapeutic interventions and placebo used for comparison should be clearly described. | 1 |
| | 5 | Are the distributions of potential confounders in each group of subjects to be compared clearly outlined? A list of essential confounders is provided. | 1 |
| | 6 | Has the primary outcome of the study been effectively communicated? Basic results data, including denominators and numerators, should be included for all significant findings, allowing readers to assess the main analyses and conclusions independently. It is essential to note that this question does not cover statistical tests described below. | 1 |
| | 7 | Do the study's main results include measures of random variability in the data? If the data were not normally distributed, the interquartile range of the results was specified. For data presented with a normal distribution, standard errors, standard deviations, and confidence intervals were provided. If there was no explicit description of the data distribution, it was assumed that the employed estimation was satisfactory, and a "yes" response was given. | 1 |
| | 8 | Have all significant adverse events that could result from the intervention been identified? If the study indicates a thorough endeavor to assess adverse occurrences, the answer should be "yes." (A list of potential adverse events is provided.) | 0 |
| | 9 | Has information regarding the characteristics of cases not followed up on been presented? Answer "yes" in cases with no follow-up loss or where the instances were negligible enough that the outcomes would not be affected by their inclusion. Answer "no" if a study fails to provide details about the number of cases lost to follow-up. | 1 |
| | 10 | Have actual probability values been provided (e.g. 0.035 instead of <0.05) for the primary outcomes, except in cases where the probability value is smaller than 0.001? | 0 |
| External validity | 11 | Were the participants invited to participate in the survey representative of the entire population from which they were selected? The survey should acknowledge the cases' source population and clarify the methodology for case selection. Cases were considered representative if they encompassed the entire source population, an unselected subset of consecutive cases, or a randomized sample. Random sampling is feasible only when a comprehensive list of all individuals in the relevant population exists. If a survey fails to specify the size of the source population from which the cases were drawn, the answer should be marked as "unable to determine." | 0 |
| | 12 | Were the individuals willing to participate representative of the entire population from which they were selected? The number of individuals who were approached and agreed to participate should be mentioned. To confirm that the sample was representative, there should be evidence that the key variables of interest distribution were similar between the survey sample and source population. | 1 |
| | 13 | Were the staff, facilities, and equipment where the cases received treatment representative of the typical care that most cases received? To answer "yes," the survey should demonstrate that the intervention aligns with the practices used in the source population. The answer should be "no" if, for instance, the intervention was provided in a specialized center that differs from the typical hospitals most of the source population would utilize. | 1 |
| Internal validity-bias | 14 | Was an attempt made to conceal the intervention they received from the survey participants? Participants who were unaware of the intervention to which they were assigned in the studies answered "yes." | 0 |
| | 15 | Was an attempt made to mask the individuals responsible for evaluating the primary outcomes of the intervention? | 0 |
| | 16 | If any of the outcomes in the study were the result of "data dredging,"was the process clearly explained? Any analyses not originally intended at the beginning of the study should be transparently presented. If no post hoc unplanned subgroup analyses were mentioned, answer "yes." | 0 |
| | 17 | Do the analyses account for varying follow-up durations among participants in prospective cohort studies and intervention trials? In case-control studies, is the period between the intervention and outcome consistent for both cases and controls? If the follow-up duration was the same for all study participants, the answer should be "yes." If varying follow-up durations were adjusted for, for instance, using survival analysis, the answer should also be "yes." If studies ignore differences in follow-up durations, the answer should be "no." | 1 |
| | 18 | Were the statistical methods employed to assess primary outcomes appropriate? The statistical techniques used should be well-suited to the characteristics of the data. For instance, non-parametric methods may be necessary for small sample sizes. If the study mentions appropriate statistical analysis, even if no bias documentation is provided, the answer should be "Yes." If the distribution of the data (whether normal or not) is not explicitly mentioned, it should be assumed that the chosen methods were appropriate, leading to an answer of "yes." | 1 |
| | 19 | Was adherence to the assigned interventions genuine? If there was noncompliance with the assigned treatment or cross-contamination between different groups, the answer should be "no." In studies where exposure misclassification could potentially introduce bias towards the null hypothesis (no effect), the answer should be "yes." | 1 |
| | 20 | Were the primary outcome measurements valid and reliable? If the outcome assessments are clearly and coherently defined, the answer should be "yes." For studies that refer to previous research or provide evidence that the outcome measurements are valid, the answer should also be "yes." | 1 |

| Items | | Criteria | Possible Answers |
|---|---|---|---|
| Internal validity-confounding (selection bias) | 21 | Were the individuals in different intervention groups (in trials and cohort studies) or the cases and controls (in case-control studies) recruited from the same population? For instance, cases for all comparison groups should ideally be selected from the same hospital or population. If no information is provided regarding the source of cases included in the study, the answer should be marked as "unable to determine" for cohort and case-control studies. | 0 |
| | 22 | Were the study participants in different intervention groups (in trials and cohort studies) or cases and controls (in case-control studies) enrolled over the same period? If a study does not specify when cases were recruited, the answer should be marked as "unable to determine." | 0 |
| | 23 | Were the cases in research studies randomized to different intervention groups? Studies that explicitly state that cases were randomized should be answered "yes," unless the randomization process was flawed and could not ensure true random allocation. For instance, if another form of allocation was used that was foreseeable, the answer should be "no." | 1 |
| | 24 | Was the random assignment of interventions concealed from participants and healthcare providers until recruitment was completed and irreversible? The answer to all non-randomized studies should be "no." If the allocation was concealed from participants but not from healthcare providers, the answer should also be "no." | 0 |
| | 25 | Was there adequate adjustment for confounding factors in the analyses from which the primary results were derived? This question should be answered "no" for trials if: The primary conclusions of the study were based on analyses of treatment rather than intent-to-treat; the distribution of recognized confounding factors among the different treatment groups was not documented; or the distribution of known confounding factors differed between treatment groups but was not considered in the analyses. In non-randomized studies, if the impact of key confounders was not examined or confounding was identified but not adjusted for in the final analyses, the answer should be "no." | 0 |
| | 26 | Were the losses of cases during follow-up taken into account? If the number of cases lost to follow-up is not provided, the answer should be marked as "unable to determine." If the number of cases lost to follow-up was minimal and wouldn't significantly affect the primary results, the answer should be "yes." | 1 |
| Power | 27* | Was the study adequately powered to detect a clinically significant effect when the probability value for a difference occurring by chance was less than 5%? The sample sizes were calculated to detect differences of x% and y%. | 1 |

*Items were adjusted.

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Note: Yes=1, No=0, Unable to discover=0. Adjusted downs and black checklist for the appraisal of the methodological quality of both randomized and non-randomized studies [21].

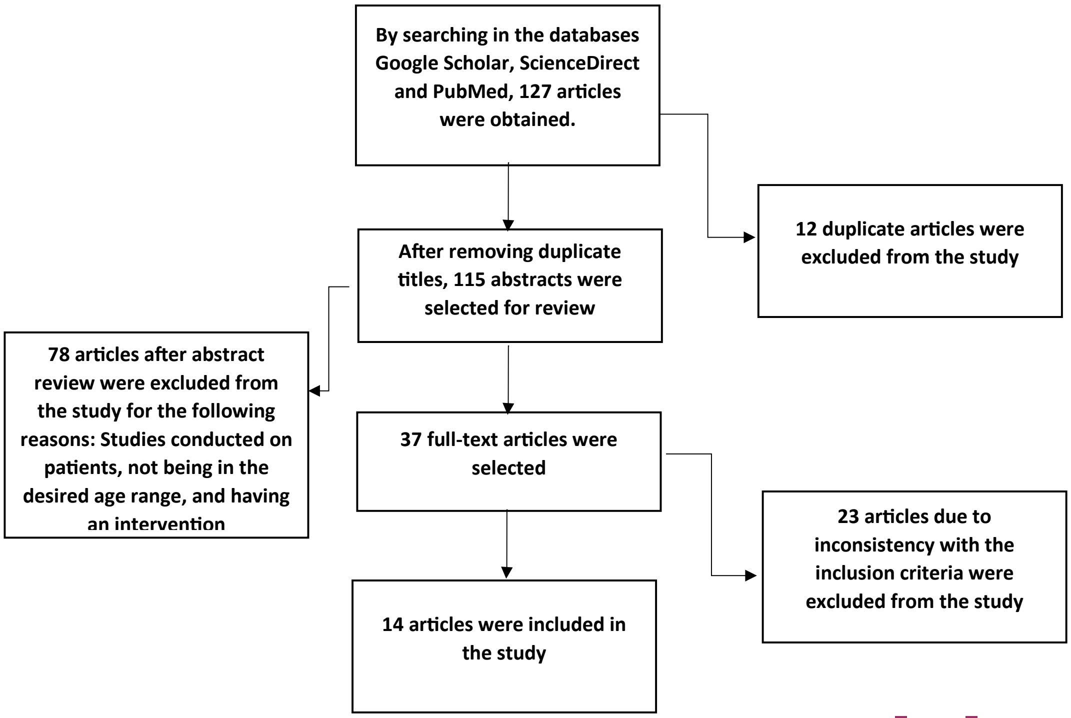


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**Figure 1.** The process of evaluating and selecting research articles (PRISMA)

**Table 3.** RTS functional tests and their specificity and sensitivity (balance and postural control tests)

| Return-to-sport Functional Tests | Target | Validity | Reliability | % | | Descriptions |
|---|---|---|---|---|---|---|
| | | | | Specificity | Sensitivity | |
| Multiple single-leg hop stabilization test [22] | Balance and postural control | 0.83 | 0.6 | 63 | 97 | This assessment aims to rapidly perform a one-legged jump while maintaining stability and landing securely. |
| Up-down hop test [22] | Balance and postural control | 0.86 | 0.69 | 77 | 86 | In this test, the participants performed 10 repeated jumps on one leg, up and down a platform with a height of 20 cm. |
| Figure of 8 hopping test [23] | Balance and postural control | 0.95 | 0.68 | 90 | 48/8 | The subject walks a 5-meter-long path in the shape of a figure of 8-shape with hopping. |
| Side hop test [23] | Balance and postural control | 0.84 | 0.69 | 70 | 48 | The subject performs 10 lateral jumps on their tested leg on a 30 cm path. |
| The square hop test [23] | Balance and postural control | 0.90 | 0.76 | 87 | 52 | A square with 40 cm side was marked on the ground using glue. The subject performed side jumps in and out of the square with the injured leg and returned to the starting point at the end. |
| Lateral hop test [24] | Balance and postural control | 0.96 | 0.72 | 83 | 86 | In this test, a person jumps three times laterally with the injured leg relative to a drawn line on the ground. |
| Forward hop test [24] | Balance and postural control | 0.94 | 0.69 | 97 | 52 | The procedure is similar to the lateral hop test, with the difference that the participant jumps forward. |
| 6-meter timed hop test [23] | Balance and postural control | 0.96 | 0.78 | 82 | 74 | This assessment aims to execute a swift one-legged jump across a span of 6 m, ensuring balance is maintained and a stable landing is achieved. |
| 30 m single-leg agility hop test [25] | Balance and postural control | 0.92 | 0.71 | 97 | 100 | In this test, a distance of 30 m was set, and four cones were placed in a zigzag pattern on the path. Then a person passes in a zigzag pattern on the injured leg. |
| Hexagon hop test [26] | Balance and postural control | 0.88 | 0.76 | 73 | 52 | In this test, six sides were drawn to a length of 60 cm, and a person jumped from inside the circle clockwise to the outside of each side in 10 s. |
| Hop-and-hold test [26] | Balance and postural control | 0.86 | 0.73 | 73 | 78 | In this test, three lines were drawn at angles of 120°, and a complete 360° was formed. The person is placed in the middle of the star, jumps in line with each line, and returns to the star's center. The test was performed in both clockwise and counterclockwise directions. |
| Hopping obstacle course test [27] | Balance and postural control | 0.92 | 0.64 | 97 | 100 | In this test, eight squares were drawn, four of which were placed at an angle of 15°. A person goes hopping on the injured leg consecutively, and after reaching the last square, repeats the route by hopping. |
| Agility hop test [28] | Balance and postural control | 0.95 | 0.74 | 88 | 89 | It is a combination of traditional hop tests and balance tests involving standing on one leg. In this test, the participant must jump in dissimilar directions in six squares. |
| Triple-crossover hop for distance test [29] | Balance and postural control | 0.96 | 0.69 | 85 | 80 | In this test, a 15 cm wide strip was stretched directly, and the person was placed behind the starting line. With the word "go," the person jumps three times in a row in a zigzag manner. |

| Return-to-sport Functional Tests | Target | Validity | Reliability | % | | Descriptions |
|---|---|---|---|---|---|---|
| | | | | Specificity | Sensitivity | |
| Star excursion balance test [24] | Balance and postural control | 0.91 | 0.93 | 86 | 87 | The assessment involved arranging a grid with eight lines extending at a 45-degree angle in both directions. These eight lines were defined based on their orientation about the foot placed on the ground. |
| YBT-LQ [30, 31] | Balance and postural control | 0.93 | 0.99 | 84 | 70 | For this test, three directions were configured in a Y-shape, with angles of 135°, 135°, and 90° between them. Participants could conduct up to six tests, each following this configuration. |
| Single-leg hop for distance [31] | Balance and postural control | 0.96 | 0.69 | 85 | 80 | The participants were motivated to propel themselves forward to the maximum extent possible, executing a jump and landing on the same foot. |
| BESS test [32] | Balance and postural control | 0.82 | 0.76 | 91 | 34 | To perform this test, three dissimilar standing positions, each on two hard and soft levels, were selected. Each position was held for 20 s, and the rest interval between repetitions was 15 s. |
| DLBT [33] | Balance and postural control | 0.93 | Unknown | Unknown | Unknown | This test is similar to the star test, with the difference that it is not performed in the entire 360-degree environment but in 180° and half of a circle. Five lines were drawn at an angle of 45°, and two points were marked on each line. |
| TTS [34] | Balance and postural control | 0.7 | Unknown | 73 | 67 | In this test, the participant's maximum vertical leap was computed by dividing 2 by 50% of their maximum height jump, which was determined through measurement using a Sargent's digital jumping device. Adjacent to the power panel is a scale bar with an indicator pointing toward the power panel. |

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Abbreviation: YBT-LQ: Y balance test for lower quarter; TTS: Time to stabilization test; DLBT: Dynamic leap and balance test; BESS: Balance error scoring system.

**Table 4.** RTS functional tests and their specificity and sensitivity (agility tests)

| Return-to-sport Functional Tests | Target | Validity | Reliability | Specificity (%) | Sensitivity (%) | Descriptions |
|---|---|---|---|---|---|---|
| Agility t-test [30] | Agility | 0.96 | 0.73 | 37 | 51 | The agility t-test measures movement in dissimilar directions. The participants moved in a T-shaped path, with the horizontal path 10 yards long (9.144 m). The normal soft for this test is approximately 8.9 to 13.5 s. |
| Illinois agility test [35] | Agility | 0.85 | 0.87 | 35 | 50 | An athlete sprints forward for 10 m, encircles a cone, returns the same 10-meter distance, and subsequently navigates a four-meter slalom course by moving back and forth. |
| Shuttle run test [28] | Agility | 0.97 | 0.92 | 68 | 80 | To perform the shuttle run test, two strips are drawn parallel to each other at a distance of 6.1 m from the ground. The person is asked to stand behind one of the bars. Then, with the word "go," the subject performs the test. The participant must walk the distance between the two bars four times. |

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**Table 5.** RTS functional tests and their specificity and sensitivity (power tests)

| Return-to-sport Functional Tests | Target | Validity | Reliability | Specificity (%) | Sensitivity (%) | Descriptions |
|---|---|---|---|---|---|---|
| Carioca test [15, 31] | Power | 0.90 | 0.72 | 80 | 75 | The test necessitated the subject to ambulate sideways for two stretches of 12 m each, incorporating an intermediate step. The participant completed the course by walking from the left side to the right and then in the opposite direction, allowing for a total movement of up to 24 m within a specified time frame. |
| Vertical jump test [30] | Power | 0.97 | 0.95 | 46 | 95 | The athlete stands next to the graded chart on the wall and performs a maximum vertical jump with a squat movement. |
| Single-leg vertical jump [15] | Power | 0.97 | 0.95 | 46 | 95 | The athlete stands next to the chart on the wall and performs a maximum vertical jump with a single-leg squat. |

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**Table 6.** RTS functional tests and their specificity and sensitivity (screening and movement patterns tests)

| Return-to-sport Functional Tests | Target | Validity | Reliability | % | | Descriptions |
|---|---|---|---|---|---|---|
| | | | | Specificity | Sensitivity | |
| FMS test [36] | Screening and movement patterns | 0.85 | 0.87 | 82 | 87 | The FMS is a screening tool for individuals without any preexisting pain or muscular injuries. It assesses seven fundamental movement patterns. |
| Tuck jump test [37] | Screening and movement patterns | 0.90 | 0.80 | 50 | 52 | In this test, the participants performed continuous tuck jumps for 10 s. The objective was to elevate the knees to the level of the hips and execute landings at the same location. |
| Drop jump test [38] | Screening and movement patterns | 0.92 | 0.95 | 60 | 55 | The drop jump, or depth jump or box jump, is a fitness assessment that evaluates leg strength and power. It involves the athlete jumping upward to achieve maximum height and landing on a mat with both feet touching down simultaneously. The athlete then returns to the initial take-off point. |
| LESS test [39] | Screening and movement patterns | 0.95 | 0.85 | 60 | 55 | This clinical test evaluates the biomechanics of landing during drop-jump tasks. In sports settings, performance indicators, such as jump height, velocity, contact time, and reactive strength index, are commonly employed for assessment. |
| LEFT test [40] | Screening and movement patterns | 0.96 | 0.66 | 95 | 95 | This test has four stations in the shape of a rhombus. It consists of eight components of agility tasks, each performed twice: Forward running, backward running, switch sides, carioca, and eight types of hopping, 45-degree cut, and 90-degree cut. |
| Self-report questionnaire adapted from de Bie et al. [20] | Screening and movement patterns | 0.86 | 0.64 | Unknown | Unknown | This questionnaire consists of five items: Pain, swelling, instability, walking pattern, and weight bearing, which are scored from zero to 100. The closer the score is to zero, the more unsuitable the person's condition. A higher score indicates that the subject has minimal problems with each item. |

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Abbreviation: FMS: Functional movement screen; LESS: Landing error scoring system; LEFT: Lower extremity functional test protocol.

Due to the complexity of identifying specific subjective and objective criteria for RTS after ACLR, a wide range of assessments were conducted to determine if individuals were prepared for a functional and quantifiable return to their previous levels of physical activity [14, 43, 44]. Most injury prevention protocols, such as 11+ and the Prevent Injury and Enhance Performance Program (PEP), include hop tests. Furthermore, hop tests are crucial and occupy a distinct position in the context of RTS after ACLR [11]. RTS outcomes following ACLR are disappointing [11]. Athletes who frequently experience ACL tears are often advised to undergo ACLR to ensure their fitness for sports [45]. RTS tests may include muscular strength and power, cardiovascular fitness, postural control, dynamic balance, movement quality, plyometric tests [8], and psychological readiness assessments using questionnaires [46, 47]. According to the studies, the RTS time has been reported as 6, 9, 12 months [48-50] and even more. Nevertheless, a significant disagreement is observed regarding the appropriate timeframe for safe return to competitive sports.

We hope that upcoming studies will focus on more up-to-date and effective functional tests that provide insights to clinicians, practitioners, and trainers so that they can better assess athletes for RTS after ACLR in the future.

## Conclusion

According to the results of this study, the most common functional tests were the shuttle run, vertical jump, Carioca, and LEFT tests, especially the hop tests. These tests may be more appropriate functional tests for RTS after ACLR in terms of sensitivity and specificity, which were the main focus of this scoping review. We hope these tests will be useful for personal trainers, athletic trainers, practitioners, and clinicians when evaluating injured athletes.

### Limitations

This review article's limitation included studies in non-English languages, such as Chinese and Hindi, unpublished studies, and studies in other motor searches. The authors hope that future research will address these gaps.

## Ethical Considerations

### Compliance with ethical guidelines

There were no ethical considerations to be considered in this research.

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### Authors' contributions

All authors contributed equally to the conception and design of the study, data collection and analysis, interpretation of the results, and drafting of the manuscript. Each author approved the final version of the manuscript for submission.

### Conflict of interest

The authors declared no conflict of interest.

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