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COMPARISON OF FUNCTIONAL OUTCOMES AFTER ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION

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ABSTRACT

Background. In competitive athletes undergoing anterior cruciate ligament reconstruction (ACLR), bone–patellar tendon–bone (BPTB) and hamstring tendon (HT) autografts are the most common options. Clinically meaningful differences likely appear in return-to-sport/performance, graft survival, knee stability, and donor-site morbidity.
Aim. To summarize 2021–2026 comparative evidence on BPTB versus HT in competitive/high-activity athletes after primary ACLR, focusing on return to sport/performance, patient-reported outcomes, function, stability, graft failure, and donor-site morbidity.
Materials and methods. Narrative literature review of PubMed and Scopus, including reviews, observational studies, and clinically relevant case series.
Results. Athlete-focused randomized and observational studies show generally similar outcomes between graft types at short- to mid-term follow-up. In professional/semi-professional soccer, RTS and knee-function scores were comparable at 2 years, but anterior knee pain was higher with BPTB (48.4%) than HT (22.6%). Large high-activity cohorts reported higher odds of return to preinjury activity with BPTB, though meta-analyses found no consistent difference across heterogeneous definitions. Instrumented laxity favored BPTB in athlete-focused syntheses and long-term cohorts, though surgical techniques may confound some findings. Several cohorts indicated higher ipsilateral graft failure/retear with HT in younger/high-risk athletes, while BPTB showed slower attainment of common early RTS strength/hop milestones.
Conclusions. In competitive/high-activity athletes, BPTB is associated with lower graft failure risk and modestly better stability, counterbalanced by higher anterior knee pain and potentially slower early functional recovery.

KEYWORDS

ACL Reconstruction, Competitive Athletes, Bone–Patellar Tendon–Bone, Hamstring Tendon, Return To Sport, Graft Failure, Anterior Knee Pain

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1. Introduction

Anterior cruciate ligament (ACL) rupture is a prevalent and potentially career-altering injury in competitive athletes participating in pivoting and cutting sports. Although contemporary rehabilitation paradigms and criteria-based return-to-sport (RTS) testing have improved postoperative decision-making, successful outcomes in this population are not captured by symptom resolution alone; rather, they depend on durable restoration of high-level performance (return to preinjury performance/level), maintenance of knee stability under high loads, and minimization of reinjury risk. Consequently, graft selection for primary ACL reconstruction (ACLR) remains a central clinical decision for athletes in whom failure or persistent functional limitation may have disproportionate professional and performance consequences.

Among autograft options, bone–patellar tendon–bone (BPTB) and hamstring tendon (HT) grafts are the most commonly compared constructs, reflecting a persistent trade-off between mechanical behavior, biologic integration, and donor-site morbidity. BPTB autografts offer bone-to-bone healing and have repeatedly been associated with slightly improved objective anterior stability compared with HT in pooled analyses, whereas HT grafts may reduce anterior knee symptoms at the potential cost of greater laxity and/or elevated failure risk in some high-demand cohorts. However, the extent to which these differences translate into athlete-relevant endpoints—such as return to preinjury activity levels, sustained weekly sport participation, and graft durability in young high-risk subgroups—remains incompletely resolved, in part because many studies aggregate heterogeneous "active" populations and use variable definitions of RTS and performance.

Evidence restricted to explicitly competitive cohorts provides important but still limited clarity. In a randomized controlled trial of professional or semiprofessional soccer players, patient-reported outcomes and clinical stability measures at 2 years were broadly similar between BPTB and HT; however, anterior knee pain was more frequent after BPTB, underscoring the clinical relevance of donor-site morbidity even in a sport that is not characterized by habitual kneeling. In contrast, larger observational datasets enriched for high-activity patients suggest that BPTB may confer advantages in returning to preinjury activity participation. Registry-based analyses have reported higher rates of return to preinjury activity levels (using activity scale–based definitions) following BPTB compared with HT, while also documenting patterns of ipsilateral versus contralateral ACL injury that may reflect differences in post-ACLR exposure to high-risk sport environments. In a cohort of high-level athletes defined by very high preinjury activity (Tegner 9), graft choice has also been examined in relation to return to preinjury performance and subsequent ACL injury, highlighting the importance of studying endpoints that approximate competitive performance rather than "any sport participation".

Systematic reviews and meta-analyses focused on athletes further illustrate both convergence and residual uncertainty. Syntheses targeting competing or high-level athletes have commonly found no large between-graft differences in broad patient-reported outcome measures or binary RTS outcomes, while reporting small but consistent differences favoring BPTB in instrumented laxity and activity scores (e.g., Tegner). More recent athlete-focused evidence syntheses that incorporate broader study designs similarly emphasize that RTS rates may be comparable while graft failure signals may differ by graft type, with several datasets suggesting higher retear risk in HT—particularly in younger, high-activity groups—despite similar reported rates of returning to sport participation. Notably, analyses that include strength and functional performance domains suggest that graft choice may influence the time course of recovery: patients reconstructed with BPTB may take longer to satisfy common RTS test thresholds (e.g., limb symmetry indices for quadriceps strength and hop performance), an observation that could be consequential for competitive timelines and for the interpretation of "early" RTS outcomes.

Taken together, the current literature suggests that, in competitive athletes, the BPTB-versus-HT decision is best framed not as a uniform superiority of one graft across all domains, but as a multidimensional optimization problem balancing (1) durability and objective stability, (2) return to preinjury activity/performance, and (3) donor-site morbidity and recovery kinetics. However, important gaps persist because many studies rely on heterogeneous athlete definitions, use inconsistent operationalizations of RTS and performance, and incompletely capture sport-specific functional limitations (e.g., anterior knee pain affecting jumping/landing tolerance versus hamstring-related deficits relevant to sprinting and deceleration). These limitations complicate translation to high-stakes decision-making in competitive settings, where small differences in stability, symptoms, or reinjury risk may meaningfully affect outcomes. Accordingly, the objective of the present study was to evaluate and compare outcomes after primary ACLR using BPTB versus HT autografts in a competitive athlete population, with a focus on athlete-relevant endpoints including RTS/return to preinjury performance, patient-reported knee function, objective functional performance and/or

readiness criteria, knee stability, graft failure or subsequent ACL injury, and donor-site morbidity. We hypothesized that BPTB would be associated with superior graft durability and/or stability-related endpoints, whereas HT would be associated with lower rates of anterior knee symptoms and potentially faster early recovery of selected functional milestones, consistent with the pattern reported across athlete-focused studies and syntheses.

2. RTS and RTPP

RTS and RTPP are key outcomes when evaluating ACLR in competitive athletes. Data from the New Zealand ACL Registry indicate that in high-activity patients BPTB reconstruction was associated with a higher rate of return to preinjury activity levels at 1–2 years compared with HT when assessed using the Marx activity score. An expanded registry analysis including more than 4000 cases further demonstrated higher odds of returning to weekly sport (Marx = 8) and returning to preinjury activity levels at two years in patients receiving BPTB grafts compared with HT grafts after multivariable adjustment. Similarly, a 2024 retrospective cohort of high-level athletes with a preinjury Tegner score of 9 reported that approximately 63% of athletes returned to their preinjury performance level; in multivariate models BPTB reconstruction was associated with higher RTP rates than HT, although exact adjusted effect sizes were not specified in the excerpt.

Sport-specific evidence provides additional perspective. In a prospective randomized controlled trial involving professional and semi-professional soccer players, no significant differences were observed between BPTB and HT grafts in terms of return to soccer participation or level of return two years after surgery; the primary difference between grafts in that study was the higher rate of anterior knee pain in the BPTB group. Evidence from mixed-level athlete cohorts, including both recreational and competitive participants, shows broadly similar RTS rates between graft types. In a large institutional cohort of athletes aged 13–24 years, the rate of return to the previous level of sport was approximately 91% for both HT and BPTB grafts, with graft retear rather than RTS representing the main differentiating outcome between the techniques. A randomized trial published in 2021 that included amateur athletes reported more nuanced differences: HT reconstruction appeared to favor returning to competitive-level sport, whereas BPTB reconstruction favored returning to the same preinjury level of sport activities.

Systematic reviews and meta-analyses focusing on athletes generally support the conclusion that overall RTS rates are similar between grafts. A 2024 systematic review involving competing and high-level athletes found no significant difference in return to preinjury sports participation between BPTB and HT grafts; however, Tegner activity scores were modestly higher in the BPTB group and instrumented laxity measured by KT-1000 favored BPTB. A 2025 meta-analysis of athletes similarly reported that overall RTS rates and return to previous activity levels were largely comparable between graft types, although the analysis emphasized lower retear rates with BPTB grafts; pooled RTS percentages were not detailed in the excerpt. Earlier meta-analytic work restricted to randomized controlled trials up to 2019 also found no substantial differences between BPTB and HT grafts in return to baseline sport participation.

Taken together, these findings suggest that crude RTS—defined as any return to sport—is generally similar between BPTB and HT grafts across athlete cohorts and randomized trials. However, when RTS is defined more strictly as return to the same preinjury activity level or to regular high-level sport participation, BPTB grafts tend to demonstrate somewhat higher rates in high-activity cohorts and registry-based datasets. Importantly, true elite-performance metrics such as match statistics, minutes played, or objective sport-specific performance outcomes remain sparsely reported in the literature; most studies rely on self-reported activity scales such as the Tegner or Marx scores rather than objective performance indicators. When comparing functional recovery and return to sport, the review indicates that successful RTS depends on multiple factors, including restoration of strength symmetry, neuromuscular control, and psychological readiness, rather than graft choice alone. Nevertheless, graft-specific differences may influence the quality and safety of return. BPTB grafts, due to their superior stability, may support a more reliable return to high-level performance, whereas HT grafts, although associated with reduced postoperative pain, may present limitations related to muscle strength deficits and increased laxity, which can affect performance in high-demand activities.

3. Patient-Reported Outcomes and Objective Knee Function

Patient-reported outcome measures (PROMs) and objective knee function represent additional critical domains in the comparison of graft types. In the randomized trial involving professional and semi-professional soccer players, no significant differences were observed between BPTB and HT grafts in modified Cincinnati, IKDC (subjective or objective), or Lysholm scores at two-year follow-up. Consistent findings were reported in a systematic review focusing on competing and high-level athletes, in which pooled Lysholm and IKDC subjective scores did not differ significantly between graft types. Nevertheless, Tegner activity scores were statistically higher among patients receiving BPTB grafts, indicating a greater likelihood of returning to higher activity levels despite similar knee symptom and function scores.

Longer-term cohort data also demonstrate modest differences favoring BPTB in certain populations. In a cohort of young men with sports-related ACL injuries followed for five to ten years, IKDC subjective scores were higher in the BPTB group (88 ± 10) compared with the HT group (82 ± 13; $p < 0.01$), and both Tegner and Marx activity scores were also higher in patients receiving BPTB grafts. In a registry cohort of young women aged 15–20 years, KOOS and Marx activity scores were recorded as secondary outcomes; however, the primary differences between graft types in that cohort related more strongly to failure risk than to symptomatic outcomes. Meta-analytic evidence further supports the overall similarity of PROMs between graft types. A meta-analysis including only randomized controlled trials reported no clinically meaningful differences between BPTB and HT grafts across Tegner, Cincinnati, IKDC, and Lysholm outcome measures. A network meta-analysis similarly concluded that PROM differences are generally modest and that the most consistent symptomatic distinction between graft types is the higher frequency of anterior knee pain associated with BPTB grafts rather than differences in global functional scores. Overall, across competitive and high-activity populations, global PROMs such as IKDC, Lysholm, and KOOS appear very similar between BPTB and HT grafts, with occasional small advantages for BPTB in IKDC or activity subscores that likely reflect higher activity levels rather than major differences in knee symptoms or functional capacity.

Objective measures of function and muscle strength provide additional insights. A rehabilitation milestone study including 410 patients compared recovery trajectories following BPTB and HT reconstruction and found that patients receiving BPTB grafts required more time to achieve greater than 90% limb symmetry in isokinetic quadriceps and hamstring strength as well as in hop tests, including horizontal, crossover, and vertical jump assessments. These findings suggest slower early functional recovery after BPTB reconstruction, consistent with quadriceps donor-site morbidity associated with patellar tendon harvesting. Supporting this observation, a network meta-analysis reported lower peak extension torque in patients treated with BPTB grafts compared with HT grafts, reflecting the impact of quadriceps tendon harvesting on extensor mechanism strength. Although the excerpt does not detail hamstring-specific torque patterns, previous literature suggests that HT harvesting may lead to persistent hamstring deficits, particularly at high flexion angles. In a randomized trial involving amateur athletes that included isokinetic strength testing using CYBEX dynamometry, both graft groups demonstrated overall strength improvement over time; however, the study primarily emphasized the higher rerupture rate observed in the HT group and did not provide detailed between-graft comparisons of strength asymmetry in the excerpt. Overall, these findings indicate that early functional recovery—particularly in terms of strength symmetry and hop performance—may occur somewhat faster following HT reconstruction, whereas longer-term activity levels and stability may favor BPTB grafts, with PROM scores typically converging between groups by one to two years after surgery.

The emerging Quadriceps Tendon (QT) graft presents a compelling option, offering similar functional outcomes to other autografts but with lower rates of complications, such as anterior knee pain or significant short-term muscle strength deficits.Allografts and synthetic options serve as secondary interventions for specific populations. Allografts are particularly advantageous for older, low-demand patients (typically over 40 years old) due to shorter surgery times, a lack of donor site morbidity, and a faster recovery period; however, they are associated with slower restructuring and a higher risk of graft tearing in younger, active patients under 25. Synthetic grafts, such as the Ligament Advanced Reinforcement System (LARS), currently have limited use due to a lack of long-term evidence regarding their safety and clinical superiority. While they allow for rapid recovery and high availability, they are generally reserved for specific cases where quick recovery is essential or for elderly patients where functional outcomes are sufficient.

4. Knee Stability and Graft Failure / Retear

Mechanical knee stability and graft integrity are central considerations in high-demand athletic populations. In the randomized soccer trial, clinical stability tests including the Lachman, pivot-shift, and anterior drawer examinations revealed no significant differences between graft types at two years, although the sample size limited statistical power. In contrast, a systematic review involving competing athletes reported that instrumented laxity measured with the KT-1000 arthrometer was significantly greater in the HT group compared with the BPTB group, indicating more anterior tibial translation with HT grafts. Similar findings were reported in a long-term cohort of young men, in which KT side-to-side differences and clinical laxity measures favored BPTB reconstruction; in that cohort, lower laxity was associated with higher Tegner, Marx, and IKDC scores. Network and randomized-trial meta-analyses also demonstrate a consistent pattern in which BPTB grafts show slightly less anterior laxity—typically less than 1 mm difference—and marginally better pivot-shift results than HT grafts. Although these differences in laxity are relatively small, they appear consistent across studies and may be particularly relevant for athletes participating in high-demand pivoting sports, where even small improvements in stability can influence confidence and risk of reinjury.

Graft failure and retear risk represent one of the most important distinctions between graft types in young athletes. Evidence from prospective and retrospective cohorts indicates higher rerupture rates with HT grafts. In a randomized trial involving amateur athletes, six reruptures or revisions occurred in the HT group compared with one in the BPTB group ($p = 0.044$). Similarly, a cohort of athletes aged 13–24 years reported ACL retear rates of 12.0% for HT grafts compared with 3.1% for BPTB grafts and 5.1% for quadriceps tendon grafts; after statistical adjustment HT grafts remained significantly more likely to fail than BPTB grafts. A registry cohort of young women aged 15–20 years also found higher graft failure rates associated with HT grafts, quantified using hazard ratios in Cox regression models. Registry-based data from high-activity populations further demonstrate that BPTB autografts have lower ipsilateral graft failure rates but higher rates of contralateral ACL injury compared with HT grafts. The increased contralateral injury incidence in the BPTB group is often interpreted as a marker that these athletes return more fully to high-demand activities. Meta-analytic evidence supports these findings: a 2023 network meta-analysis in young adults reported lower graft failure rates with BPTB compared with both two- and four-strand HT constructs, and an athlete-focused RTS meta-analysis also highlighted lower retear rates with BPTB while reporting similar RTS rates between graft types. Overall, among competitive and high-risk young athletes, HT grafts consistently demonstrate a higher risk of ipsilateral graft failure or revision than BPTB grafts, often by a factor of approximately two to four in youth cohorts, making graft durability one of the most decisive factors in graft selection.

5. Donor-Site Morbidity: Anterior Knee Pain vs Hamstring Deficits

Donor-site morbidity represents another key difference between graft types. Anterior knee pain and kneeling discomfort are well-recognized complications associated with BPTB graft harvesting. In the randomized soccer trial, anterior knee pain at two years was significantly more frequent in the BPTB group (48.4%) compared with the HT group (22.6%; P =.03) [4]. Patellar tendinitis and kneeling pain were also reported, although the excerpt does not provide detailed numerical values; the overall direction of these outcomes favored HT reconstruction. A network meta-analysis similarly reported that BPTB grafts were associated with the highest rate of anterior knee pain among grafts studied and with lower peak extension torque, findings consistent with disturbance of the extensor mechanism following patellar tendon harvest. Systematic reviews focusing on athletes generally acknowledge the increased prevalence of anterior or kneeling pain following BPTB reconstruction, although many lack detailed athlete-specific quantitative data. Clinically, this increased burden of anterior knee symptoms may be particularly relevant for sports requiring frequent kneeling or high patellofemoral loading, such as wrestling, certain positions in American football, or volleyball.

Hamstring-related morbidity after HT graft harvest has been less clearly quantified in modern athlete-focused studies. In the soccer trial by Guglielmetti et al., subjective loss of kicking power was reported by 25.8% of HT patients and 29% of BPTB patients, while loss of sprinting power was reported by 19.4% of HT patients and 12.9% of BPTB patients; these differences were not statistically significant. However, the trial was likely underpowered to detect meaningful performance differences and relied on self-reported outcomes. Indirect evidence from meta-analyses indicates lower extension torque following BPTB reconstruction but does not clearly specify hamstring torque deficits after HT graft harvest within the excerpt. Earlier literature suggests that persistent hamstring strength deficits at high knee-flexion angles may occur following HT harvest, which could influence sprinting and deceleration performance, although this phenomenon has not

been thoroughly quantified in modern cohorts of competitive athletes. Overall, the classical trade-off between graft types—greater anterior knee pain with BPTB and greater hamstring weakness with HT—remains broadly supported, although direct sport-specific performance data are limited.

However, these advantages are counterbalanced by a higher burden of donor-site morbidity. BPTB autografts are associated with substantially higher rates of anterior knee pain and kneeling discomfort, with up to 40–60% of patients reporting donor-site symptoms. In contrast, HT autografts demonstrate a more favorable morbidity profile, with less anterior knee pain and fewer issues related to kneeling, making them more comfortable in activities involving patellofemoral loading.

6. Rehabilitation Milestones and Time to RTS Criteria

Differences in rehabilitation milestones and time to meet RTS criteria have also been investigated. A 2024 study by Steiner et al. compared the time required to reach RTS criteria defined as greater than 90% limb symmetry index in strength and hop tests in 232 patients treated with BPTB grafts and 178 treated with HT grafts. Patients receiving BPTB grafts required more time to achieve these functional benchmarks, particularly for quadriceps strength and several hop test measures. Cox proportional hazards modeling confirmed slower progression toward rehabilitation milestones in the BPTB group. For competitive athletes this finding has practical implications: although long-term RTS outcomes and graft durability may favor BPTB reconstruction, rehabilitation timelines may need to be extended or more carefully managed when criteria-based RTS protocols emphasizing limb symmetry are applied. In contrast, HT grafts may allow earlier attainment of objective readiness criteria, although this advantage must be balanced against the higher graft failure risk observed in young high-demand populations. Recent findings indicate that aggressive, criterion-based rehabilitation not only facilitates a successful return to sport but also positively influences knee biomechanics, potentially mitigating the long-term risk of post-traumatic osteoarthritis (PTOA). The integration of diverse exercise modalities, including both open and closed kinetic chain exercises, is recommended to optimize muscle strength and function.Crucially, the review underscores that physical recovery is inextricably linked to psychological readiness. Barriers such as fear of reinjury and low self-confidence can adversely affect outcomes, while higher self-efficacy is directly correlated with better functional recovery and successful return to pre-injury activity levels. Consequently, the study concludes that a multidisciplinary approach—synthesizing advanced anatomical surgical techniques, evidence-based biological enhancements like stem cell therapies or Platelet-Rich Plasma (PRP), and integrated psychological support—is essential for improving the overall quality of life for patients undergoing ACL reconstruction.

7. Gaps and Future Research Perspectives

Despite the growing body of literature comparing BPTB and HT autografts in anterior cruciate ligament reconstruction, several important gaps remain in the evidence base, particularly with respect to competitive and elite athletic populations. One significant limitation of the current literature is the scarcity of sport-specific performance metrics following reconstruction with different graft types. While many studies rely on activity scales such as Tegner or Marx scores to evaluate return to sport, objective measures of athletic performance—such as sprint times, agility and cutting performance, or match statistics—are rarely reported, especially in true elite cohorts. Consequently, the extent to which graft selection influences real-world athletic performance remains insufficiently understood.

Another key area requiring further investigation involves detailed graft-specific neuromuscular assessments in competitive athletes. Current research provides limited information regarding the differential effects of BPTB and HT graft harvesting on neuromuscular control, muscle function, and movement quality. Advanced biomechanical analyses, including three-dimensional motion analysis and comprehensive neuromuscular testing, would allow for more precise quantification of quadriceps and hamstring function and could clarify how graft choice influences movement patterns, dynamic knee stability, and injury risk during sport-specific tasks.

Psychological readiness to return to sport represents another critical yet underexplored factor in graft comparison studies. Instruments such as the ACL–Return to Sport after Injury (ACL-RSI) scale have demonstrated the importance of psychological factors in the decision-making process surrounding return to sport. However, relatively few studies have examined whether psychological readiness differs according to graft type or how such differences might influence return-to-sport timelines, confidence in knee function, or long-term athletic participation.

Finally, there is a need for comprehensive longitudinal datasets that integrate multiple dimensions of recovery following anterior cruciate ligament reconstruction. Future research would benefit from study designs that simultaneously examine graft type, objective return-to-sport criteria, psychological readiness, and actual on-field performance outcomes over extended follow-up periods. Such longitudinal analyses would provide a more complete understanding of how graft selection influences not only clinical outcomes but also athletic durability and sustained performance at competitive levels.

8. Conclusions

In competitive athletes undergoing anterior cruciate ligament reconstruction, the choice between BPTB and HT autografts involves a complex balance between performance outcomes, mechanical stability, postoperative symptoms, and rehabilitation timelines. Evidence from recent literature indicates that each graft type presents distinct advantages and disadvantages that should be carefully considered in relation to the athlete's sport-specific demands, risk profile, and performance goals.

BPTB autografts demonstrate several advantages in high-demand athletic populations. Studies consistently report a higher probability of returning to preinjury activity levels or weekly sport participation in high-activity cohorts when BPTB grafts are used. In addition, BPTB reconstruction is associated with lower rates of ipsilateral graft failure and improved anterior knee stability compared with HT grafts. Long-term outcomes in high-demand cohorts also suggest that activity-related outcome measures, including Tegner and Marx scores, as well as IKDC scores, may be slightly higher following BPTB reconstruction. Despite these advantages, BPTB grafts are associated with notable disadvantages. One of the most consistently reported limitations is the higher prevalence of anterior knee pain and kneeling discomfort, which has been documented even among professional soccer players. Furthermore, quadriceps recovery following BPTB harvest may be slower, resulting in a longer time required to meet objective RTS criteria during rehabilitation protocols.

Hamstring tendon autografts offer a different risk–benefit profile. A major advantage of HT reconstruction is the lower incidence of anterior knee pain, which often results in greater comfort during activities involving kneeling or substantial patellofemoral loading. Rehabilitation progression may also occur more rapidly in the early postoperative period, with faster attainment of functional milestones such as strength symmetry and hop test performance. Additionally, overall patient-reported outcome measures and crude RTS rates appear comparable to those observed following BPTB reconstruction in many studies. However, HT grafts are associated with several disadvantages that are particularly relevant in young, high-demand athletes. These include higher ipsilateral graft failure and revision rates, which have been consistently reported in both cohort studies and meta-analyses, particularly among young high-activity athletes and young women. HT reconstruction is also associated with slightly greater anterior knee laxity compared with BPTB grafts, a factor that may be especially important in sports requiring frequent pivoting and cutting movements. In addition, the potential for hamstring strength deficits exists following HT harvest, although the magnitude and long-term functional significance of these deficits remain less clearly quantified in contemporary athlete-specific research.

In the cohort of athletes aged 13–24 years, graft choice was associated with measurable differences in RTS outcomes and reinjury risk. Athletes reconstructed with BPTB autografts demonstrated a tendency toward higher rates of return to previous level of sport and return to competition compared with those receiving HT grafts, suggesting a potential advantage of BPTB in achieving preinjury performance levels. In contrast, HT grafts were associated with comparable but not superior RTS clearance timing, indicating that faster clearance does not necessarily translate into higher-level return. With respect to reinjury outcomes, HT autografts showed a higher incidence of graft retear compared with BPTB, particularly in younger and higher-risk athletes, whereas BPTB grafts demonstrated greater durability in this regard. Meniscal reinjury outcomes were also assessed, with differences observed between graft groups, further supporting the influence of graft choice on joint integrity after RTS. Overall, these findings indicate that BPTB grafts may provide more robust return-to-performance outcomes and lower retear risk, whereas HT grafts, although widely used, may be associated with a higher likelihood of reinjury in this young athletic population.

The clinical decision regarding graft selection may therefore depend on the specific context in which the athlete competes. Current evidence suggests that BPTB grafts may be particularly advantageous in young athletes under the age of 25 who participate in high-risk pivoting sports such as soccer, basketball, handball, or rugby, where graft failure represents a substantial threat to athletic performance and career continuity. BPTB reconstruction may also be preferable in situations where maximal rotational stability and long-term durability of RTS are prioritized over rapid early rehabilitation or avoidance of anterior knee symptoms. This

consideration may be particularly relevant in high-level female athletes in their late teenage years or early twenties, as HT grafts have been associated with higher failure rates in this population.

Conversely, HT grafts may represent a reasonable or preferred option in certain clinical and sporting scenarios. Athletes participating in sports where kneeling and high patellofemoral loads are integral—such as wrestling, some positions in football, or occupations that require frequent kneeling—may benefit from the lower incidence of anterior knee pain associated with HT reconstruction, provided they accept the possibility of a higher graft failure risk. HT grafts may also be considered in older or less extreme competitive athletes, or in individuals for whom slightly reduced stability and a somewhat increased failure risk are acceptable trade-offs in exchange for reduced anterior knee morbidity and potentially faster functional recovery. Additionally, HT reconstruction may be more suitable in cases where supplementary stabilizing procedures, such as lateral extra-articular tenodesis, are performed to mitigate the increased laxity associated with hamstring grafts.

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