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Revision anterior cruciate ligament reconstruction: clinical outcome and evidence for return to sport

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Abstract
Purpose An increasing number of patients undergo revision anterior cruciate ligament (ACL) reconstruction, with the intention of returning to sport being a major indication. The aim of this study is to assess the available evidence for clinical improvement and return to sport, to understand the real potential of this procedure in regaining functional activity, and to facilitate improved counselling of patients regarding the expected outcome after revision ACL reconstruction.
Methods The search was conducted on the PubMed database. Articles reporting clinical results for revision ACL reconstruction were included. A meta-analysis was performed on return to sport, and results were compared to the literature on primary ACL reconstruction. Other specific clinical outcomes (Lysholm, Tegner, IKDC Objective scores) were also included in the meta-analysis.
Results Of the 503 identified records, a total of 59 studies involving 5365 patients were included in the qualitative data synthesis. Only 31 articles reported the rate of return to sport. Whereas 73 % of good objective results and satisfactory subjective results were documented, 57 % of patients did not return to the same level of sport activity, significantly inferior to that of a primary procedure.
Conclusion The real potential of revision ACL reconstruction should not be overestimated due to the low number of patients able to return to their previous activity level, significantly inferior with respect to that reported for primary ACL reconstruction. This finding will help physicians in the clinical practice providing realistic expectations to the patients. Future studies should focus on participation-based outcome measures such as return to sport and in strategies to improve the results in terms of return to previous activities after revision ACL reconstruction.
Level of evidence Systematic review and meta-analysis including Level IV studies, Level IV.

Keywords Revision ACL · Meta-analysis · Clinical outcome · Return to sport

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Introduction

The anterior cruciate ligament (ACL) plays a key role in knee stability by limiting anterior tibial translation on the femur and restraining rotation, as well as by resisting varus and valgus joint forces [77]. ACL tears are common and affect mostly young active patients, i.e. athletes aged under 25 years involved in high school, collegiate, or league sports [6]. It has been suggested that patients aiming to return to sports participation, in particular those active in organized competition or pivoting sports, should undergo ACL reconstruction [5]. The goals of this surgery are to maximize joint stability and increase functional capacity to prevent further trauma and allow a safe return to their previous activity level while reducing deleterious forces that may lead to the early osteoarthritic changes observed in instable knees [40].

Although significant advances in ACL reconstructive surgery have been made in the past decade, graft failure continues to occur, with a reported rate of about 2 % of patients in the first 2 years [4] and 11.9 % at 10 years [15]. Several factors can account for reinjuries, including young patient age, high sports activity level, prior meniscectomy, or errors in surgical technique such as improper graft placement, tensioning, fixation [6]. Regardless of the reason, graft failure is a devastating outcome for patients undergoing ACL reconstruction, making revision ACL reconstruction an important orthopaedic procedure to restore joint stability and knee function. In fact, the rate of revision has increased over the last few decades and, due to the increasing emphasis in our culture on sports participation and fitness, it is likely to continue on an upward trend in the future [88].

Although the results of revision ACL reconstruction are generally considered to be inferior to primary ACL reconstruction, the overall body of the literature is sparse [88]. A systematic review suggested that this procedure results in a worse outcome, with patient-reported outcome scores inferior to those published on primary ACL reconstruction, even if some questions were raised on the clinical significance of the observed differences [97]. Moreover, stability evaluations or average outcome scores reported by most of the studies may not reflect the real clinical benefit experienced by the patients [71]. There is increasing awareness that greater emphasis should be placed on the use of participation-based outcomes to assess the effectiveness of this surgery. Furthermore, the patient's intention to return to sport following ACL reinjury is a major indication for surgical intervention. Thus, returning to sport is a key outcome (RTS), as restrictions to participation in sport or previous activities are likely to be of greater importance to the patient than measurements of impairments such as muscle strength or knee range of motion.

The aim of this meta-analysis is to assess the available evidence for clinical improvement and RTS, to understand the real potential of this procedure in regaining functional activity and to give to the patient's realistic expectations regarding the outcome after revision ACL reconstruction.

Materials and methods

A systematic review and meta-analysis were performed on revision ACL reconstruction, to analyse the documented evidence. The primary purpose was to investigate the rate of RTS. The secondary purpose was to analyse the other clinical outcome measurements reported in the literature.

Search strategy and screening criteria

The search was conducted on the PubMed database on 14 July 2014 using the following parameters: [(revision) OR (revision surgery) OR (revision reconstruction)] AND [(ACL) OR (anterior cruciate ligament)]. The guidelines for Preferred Reporting Items for Systematic Reviews and Meta-analysis (PRISMA) were used [57]. A flow chart of the study selection for the qualitative and quantitative data synthesis is reported in Fig. 1.

Screening process and analysis were conducted separately by two independent observers (LA and MR). In the first step, the articles were screened by title and abstract. The following inclusion criteria for relevant articles were used during the initial screening of titles and abstracts: clinical reports of any level of evidence, written in the English language, on revision ACL reconstruction. Exclusion criteria were articles written in other languages, preclinical studies, and reviews. In the second step, the full texts of the selected articles were screened, with further exclusions according to the previously described criteria. Moreover, the articles not reporting clinical results were excluded. Reference lists from the selected papers were also screened, and all selected studies were included in the qualitative data synthesis. Relevant data (year, type of study, no. of patients, grafts, sex, age, aetiology, follow-up, interval between primary and revision reconstruction, type of results reported, scores reported, RTS rate, and no. of failures) were then extracted and collected in a database with consensus of the two observers, to be analysed for the purposes of the present study.

RTS, the primary study purpose, was specifically analysed. The selected studies were assessed using a six-item checklist developed for an analysis on primary ACL RTS outcomes [5]. The six items assessed were: selection criteria described, representative population selected, participants' preinjury sports participation level reported, data collected prospectively, demographic data reported, and postoperative sports participation level compared with preinjury level. Items were scored dichotomically (1 = criterion satisfied, 0 = criterion not satisfied). All articles were assessed independently by two assessors, with disagreements resolved by consensus. The articles reporting the rate of RTS were included in the quantitative analysis: the meta-analysis focused on the number of participants returning to any sport regardless of the level of participation and those returning to their preinjury level. Data regarding RTS were reported as dichotomous variables. To assess whether revision ACL reconstruction outcomes were different compared to primary ACL reconstruction, the rates of RTS were compared with those obtained in a previous meta-analysis on primary ACL [5].

Finally, as a secondary study purpose, the articles reporting specific clinical outcomes (Lysholm, Tegner,

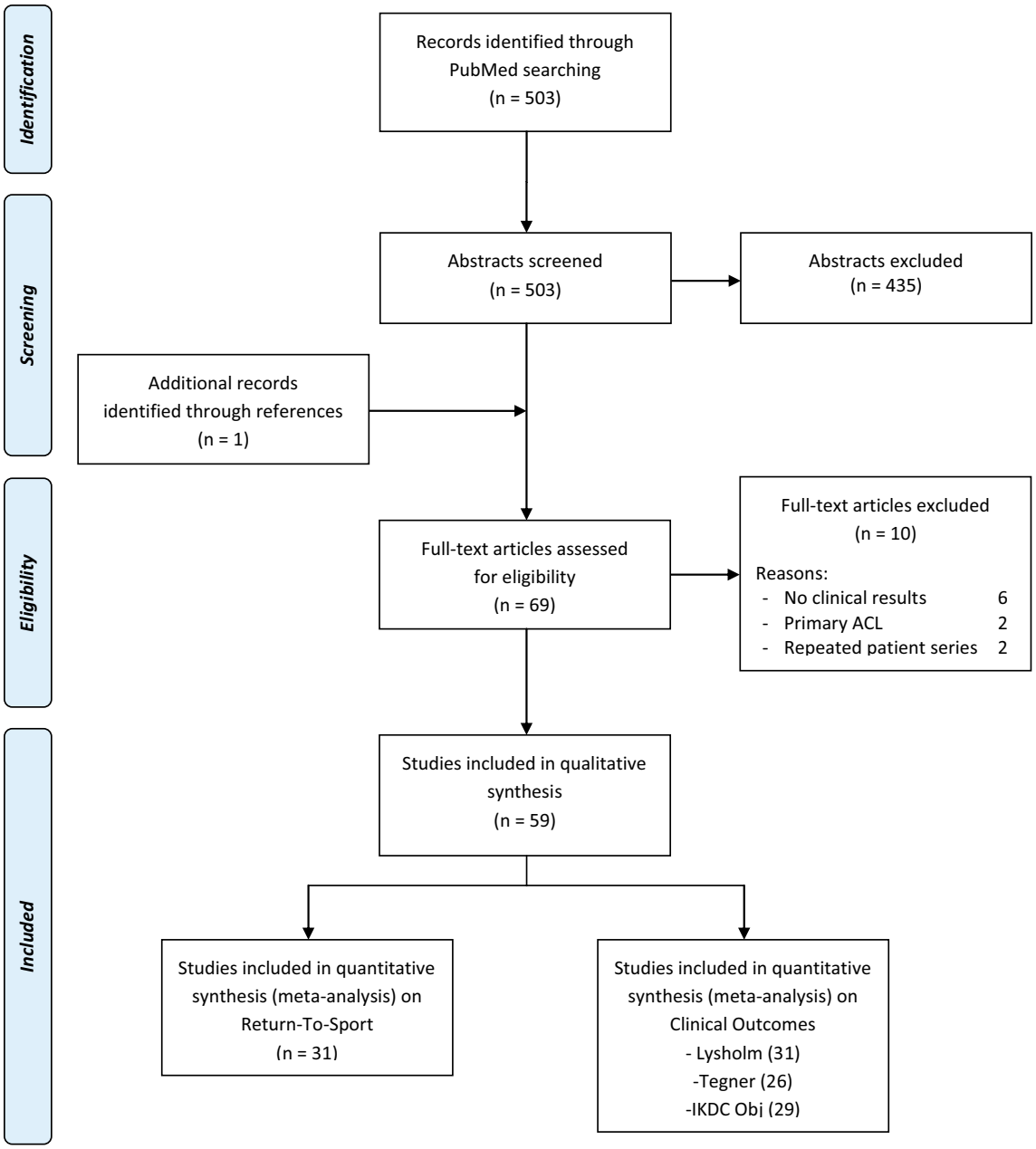

Fig. 1 PRISMA flow chart of the systematic literature review

IKDC Objective scores) were selected and included in a meta-analysis. The Lysholm score [52] was analysed as a preoperative score (if available) and postoperative score; the Tegner score [82] was analysed as preinjury score (if available) and postoperative score; the International Knee Documentation Committee (IKDC) objective score [39] was analysed as the rate of normal/nearly normal scores at follow-up. The KT-1000 scores had to be excluded because of the heterogeneity in the way in which the articles reported the data (mean, range, cut-off, etc.).

Statistical analysis

Return to preinjury activity level was treated as a dichotomous variable, with patients either returning or not returning at the time of follow-up. For overall IKDC results, patients classified as normal (A) or nearly normal (B) were in one group, while those classified as abnormal (C) or severely abnormal (D) were in another group. For each dichotomous variable, the number of patients in each group was summed. For continuous variables (Lysholm Tegner, scores), a mean score was calculated.

Table 1 Characteristics of the articles included in the qualitative data synthesis, with study quality assessment

References	Type of study (level of evidence)	No. of patient for FU	Follow-up (m)	Sport outcome measures	Quality checklist	Focus of study	Most important finding
Sonnery-Cottet [78]	Case series (4)	5	31.6	RTS	5	Evaluation of RACL with associated surgery	Good results for combined ACL rerevision with proximal tibial anterior closing wedge osteotomy in patients with recurrent ACL ruptures and an associated increased posterior tibial slope
Reverte-Vinaixa [69]	Retrospective case series (4)	19	12	–	4	Graft type comparison	Results obtained with allograft are comparable with BPTB in revision ACL reconstruction
Mahmoud [53]	Case series (4)	20	30	–	4	RACL survey evaluation	Good outcomes, regardless of the graft types used, did not affect the outcome of the procedure
Shelbourne [74]	Comparative study (2)	259	7.2	RTS	5	RTS evaluation	High rate of RTS in athletic population after RACL with BPTB autograft, better results for high school and college athletes compared with recreational-level adults. Low reinjury rates
Pascual-Garrido [66]	Case series (4)	47	55	–	3	RACL survey (<40) evaluation	Good clinical results in patients younger than 40 years old
Ventura [87]	Case series (4)	14	51	–	3	Failed artificial ACL survey evaluation	Autologous revision ACLR not recommended in patients with initial osteoarthritis after artificial graft ACLR
Dauty [17]	Comparative study (3)	39	12	–	4	Muscular isokinetic strength evaluation	Isokinetic muscle strength deficits after ACL revision seem similar to primary ACL reconstruction with the same surgical technique
Ra [67]	Case series (4)	17	32	RTS, Tegner	5	Surgical technique evaluation	Good results in patients treated with one-stage revision surgery and an impacted bone graft
Chen [12]	Registry study (3)	1200	24	Marx score	4	Single- and multiple-revision ACL comparison	Patients with multiple-revision ACL reconstructions had lower activity levels, more chondral injuries and high rate of a nontraumatic, recurrent injury of their graft
Flanigan [27]	Retrospective comparative study (3)	12	12	RTS	5	Psychological factors influencing RTS	Persistent knee symptoms are more influencing RTS compared to job, family demands or lack of interest. Fear of reinjury is present in half of the patients who did not return to sport
Franceschi [29]	Case series (4)	30	80	RTS	5	Surgical technique evaluation	Good results with two stage procedure at 5-year follow-up
Griffith [33]	Case series (4)	15	60	Tegner, RTS	5	Repeat RACL evaluation	Repeat revision ACL reconstruction may improve functional without gaining prior activity level
Enad [23]	Retrospective case series (4)	19	48	RTS (military duty)	5	Primary vs revision comparison	Lower rate to return to full duty after RACL compared with primary ACL reconstruction
Kievit [44]	Retrospective comparative study (3)	25	64	Tegner	4	Primary vs revision comparison	Revision reconstruction patients have more signs of osteoarthritis and worse QOL than primary reconstruction patients
Buda [10]	Case series (4)	24	40	RTS	6	Surgical technique evaluation	Nonanatomic over-the-top ACL reconstruction and lateral extra-articular plasty technique allow results comparable with other ACL revision series
Gifstad [33]	Comparative study (3)	56	90	RTS, Tegner	5	Primary vs revision comparison	Significantly inferior scores for revision group compared with the primary group and more severe radiological osteoarthritis

Table 1 continued

References	Type of study (level of evidence)	No. of patient for FU	Follow-up (m)	Sport outcome measures	Quality checklist	Focus of study	Most important finding
Ferretti [26]	Case series (4)	12	36	Tegner	4	Surgical technique evaluation	The use of hamstring tendons harvested from the unaffected knee represents a valid option for revision surgery
Lind [48]	Registry study (2)	203	12	–	2	RACL survey evaluation	Higher risk of rerevision for younger patients and allograft. Lower results compared with primary ACL reconstruction
Mayr [56]	Retrospective comparative study (3)	29	68.8	Tegner	3	Surgical technique evaluation	Functional results with allografts were comparable to those with autografts in ACL revision surgery
Trojani [84]	Retrospective case series (4)	163	44	–	3	Surgical technique comparison	Lateral tenodesis allows a better rotation control
Lind [48]	Retrospective case series (4)	128	70	Tegner	3	Long-term RACL survey evaluation	Subjective scores indicate significant knee impairment with low scores in sport and QOL and a rerevision rate of 6 % after 6 years
Shino [76]	Case series (4)	17	38	–	2	Surgical technique evaluation	The rectangular tunnel ACLR technique provided acceptable results after one-stage revision ACLR
Reinhardt [68]	Case series (4)	21	36	RTS	5	RACL survey (<18) evaluation	Revision ACL reconstruction in young, active patients restores knee stability but only half of patients return to prior level of activity or sport
Wright [95]	Registry study (2)	29	24	Marx score	3	Primary vs revision comparison	Revision ACL reconstruction resulted in significantly worse result than primary
Ahn [2]	Retrospective case series (4)	40	76	–	3	RACL survey evaluation	Improvement in scores, with severities of degenerative changes which correlates with clinical results
Niki [59]	Comparative study (3)	20	33	Tegner	4	Failed artificial ACL survey evaluation	Revision ACLR with BPTB after synthetic ligament failure yielded favourable results, but inferior and with more OA sings in comparison with primary ACL reconstruction
Muneta [58]	Case series (4)	21	40	RTS, Tegner	6	Surgical technique evaluation	Comparable stability but better isokinetic result and subjective results for primary versus revision
Wegrzyn [90]	Retrospective case series (4)	10	38	RTS	5	Repeat RACL evaluation	Outcome of repeat revision ACL reconstruction was good in 70 % of the cases, although decreased after second revision. Meniscal and articular cartilage lesions are more common with recurrent laxity
Lind [49]	Registry study (2)	93	12	Tegner	3	Primary versus revision comparison	Lower postoperative score compared with primary evaluating a national ACL reconstruction registry
Denti [19]	Case series (4)	60	41.9	RTS, Tegner	5	Surgical technique evaluation	Comparable results between revision ACL reconstruction and primary reconstructions, with a little less satisfactory results
Ahn [3]	Comparative study (3)	55	48.7	–	4	Primary vs revision comparison	Revision ACL reconstruction could improve clinical and stability results, regardless of graft choice, but the clinical results were inferior to those of primary reconstruction
Diamantopoulos [20]	Case series (4)	107	72.9	RTS, Tegner	5	Surgical technique evaluation	Satisfactory midterm results, but with a significant progression of osteoarthritis
Wright [96]	Registry study (4)	39	24	–	4	RACL survey evaluation	Improvement in physical scores and 15 % additional surgery following revision ACL reconstruction in patients with high amount of cartilage lesion

Table 1 continued

References	Type of study (level of evidence)	No. of patient for FU	Follow-up (m)	Sport outcome measures	Quality checklist	Focus of study	Most important finding
Battaglia [8]	Case series (4)	63	72.7	RTS	5	RACL survey evaluation	Revision ACL surgery allowed approximately 60 % of patients to go back to sports, but at lower levels. Instrumented laxity < 3 mm was associated with better results. Radiographic arthritis was associated with duration of instability symptoms after primary failure
Weiler [91]	Comparative study (2)	50	30	–	4	Primary versus revision comparison	Primary ACL reconstruction showed significantly better results in subjective score compared with revision group, although objective score and knee stability showed no difference between the groups
Ferretti [25]	Case series (4)	30	60	RTS, Tegner	5	Surgical technique evaluation	Satisfactory functional outcomes, with a failure rate of 10 % at 5 years
Salmon [72]	Case series (4)	50	89	RTS	5	Surgical technique evaluation	Good objective results can be obtained, but subjectively, the results appear inferior to those of primary anterior cruciate ligament reconstruction in the literature, which may be related to the high incidence of articular surface damage in this patient population
Garofalo [63]	Case series (4)	28	51	RTS	5	Surgical technique evaluation	Satisfactory results after ACL revision surgery using quadriceps tendon at a minimum 3-year follow-up
Noyes [63]	Case series (4)	21	49	RTS	5	Surgical technique evaluation	Good results in a group of complex knees compounding problems of articular cartilage damage, meniscectomy, varus malalignment, or additional ligamentous injury that most likely affected the results
Liden [47]	Case series (4)	11	115	Tegner	3	Surgical technique evaluation	Poor clinical results for reharvested patellar tendon, with no normalization of MRI signal after 10 years. Signs of mild degenerative changes in all patients
Thomas [83]	Comparative study (3)	49	75	–	4	Surgical technique evaluation	Lower subjective scores and more cartilage degeneration, but with similar stability, for revision ACL group compared with primary ACL group
Grossman [36]	Retrospective case series (4)	29	67	RTS, Tegner	5	RACL survey evaluation	Good results for revision ACL reconstruction at long-term follow-up with inferior stability for allograft versus autograft
O'Neill [65]	Case series (4)	48	90	RTS	6	Surgical technique comparison	Previously unharvested ipsilateral autografts proved reliable in improving function and stability in revision ACL reconstruction with 6 % failures and 37 % progressive degenerative findings
Fox [28]	Retrospective case series (4)	32	57	Tegner	4	Surgical technique evaluation	Results of revision ACL reconstruction with a nonirradiated patellar tendon allograft at medium follow-up were less favourable than those of a primary ACL reconstruction
Carson [11]	Retrospective case series (4)	43	24	RTS	5	RACL survey evaluation	Overall results of revision ACL surgery are encouraging in providing symptomatic relief and restoring stability; however, they are significantly lower than primary ACL surgery
Taggart [81]	Retrospective case series (4)	20	41	RTS, Tegner	6	Surgical technique evaluation	Good subjective results with poor correlation between the physical examination (objective) and the patient's perception (subjective)

Table 1 continued

References	Type of study (level of evidence)	No. of patient for FU	Follow-up (m)	Sport outcome measures	Quality checklist	Focus of study	Most important finding
Fules [30]	Retrospective comparative study (4)	29	50	Tegner	4	Surgical technique evaluation	Results in nonmultiply operated knees are comparable to primary reconstruction
Shelbourne [75]	Case series (4)	52	42	RTS	5	Surgical technique evaluation	Overall good results with outcome depending on cartilage status at the time of revision
O'Shea [75]	Case series (4)	11	51.2	–	3	Surgical technique evaluation	Reliable stability and strength with a reharvested patellar tendon for revision ACL reconstruction
Colosimo [14]	Case series (4)	13	39.4	RTS, Tegner	5	Surgical technique evaluation	Reharvested central-third patellar tendon is a viable option for revision ACL reconstruction with good subjective results
Noyes [61]	Case series (4)	55	33	RTS	5	Surgical technique evaluation	Less favourable results and higher failure rate for revision surgery than primary operations, with 93 % revised knees affected by articular cartilage damage, prior meniscectomy, loss of secondary ligament restraints, or varus malalignment
Harilainen [37]	Comparative study (4)	12	24	–	4	RACL survey evaluation	Results of the revision operations are not as good as those of well-executed primary reconstructions
Woods [94]	Case series (4)	10	49	RTS	5	Surgical technique evaluation	Revision ACL reconstruction with lateral third of the ipsilateral patellar tendon after failure of a central-third graft provides comparable results with other techniques
Eberhardt [21]	Retrospective case series (4)	44	41.2	RTS, Tegner	6	Surgical technique evaluation	Good results with autogenous BPTB graft but OA progression in knees with major cartilage lesion and long-term extensive synovitis due to previous ACL reconstruction using synthetic grafts
Kartus [43]	Case series (4)	24	26	Tegner	4	Graft type comparison	Reharvesting the ipsilateral patellar tendon resulted in lower functional scores and a higher rate of complications than revision with the contralateral patellar tendon or primary reconstruction
Uribe [85]	Case series (4)	54	30	RTS, Tegner	6	RACL survey evaluation	Overall improved outcome, with significantly worse results depending on the degree of articular cartilage degeneration
Wirth [92]	Case series (4)	87	96	–	2	RACL survey evaluation	Low rate of satisfaction in patients with revision ACL reconstruction compared with primary reconstruction
Johnson [42]	Case series (4)	25	28	RTS	6	RACL survey evaluation	High rate of satisfaction after revision ACL reconstruction, but 36 % instability and 88 % abnormal knee rated with IKDC guidelines
Noyes [64]	Case series (4)	65	42	RTS	6	Surgical technique evaluation	Revision ACL reconstruction with BPTB allografts provide improvement in all scores

Table 2 List of the different scores used in the articles included in the qualitative data synthesis

References	Subjective scores							Sport scores		
	Lysholm	IKDC subj	KOOS	Noyes	Cincinnati	EQ5D	SF36	Tegner	Marx	RTS
Sonnery-Cottet [78]	x	x						x		x
Reverte-Vinaixa [69]	x	x					x			
Mahmoud [53]	x	x	x							
Shelbourne [74]		x			x					x
Pascual-Garrido [66]	x	x								
Ventura [87]			x							
Dauty [17]										
Ra [67]	x	x						x		x
Chen [12]									x	
Flanigan [27]										x
Franceschi [29]	x									x
Griffith [35]	x	x						x		x
Enad [23]										x
Kievit [44]	x		x			x		x		
Buda [10]		x								x
Gifstad [33]	x		x					x		x
Ferretti [26]	x	x						x		
Lind [48]			x					x		
Mayr [56]	x	x						x		
Trojani [84]										
Lind [48]			x					x		
Shino [76]										
Reinhardt [68]		x								x
Wright [95]		x	x						x	
Ahn [2]	x	x								
Niki [59]	x							x		
Muneta [58]	x							x		x
Wegrzyn [90]										x
Lind [49]			x					x		
Denti [19]	x							x		x
Ahn [3]	x	x								
Diamantopoulos [20]	x							x		x
Wright [96]							x			
Battaglia [8]										x
Weiler [91]	x									
Ferretti [25]	x	x						x		x
Salmon [72]	x									x
Garofalo [63]	x							x		x
Noyes [63]					x					x
Liden [47]	x							x		
Thomas [83]		x								
Grossman [36]	x	x						x		x
O'Neill [65]										x
Fox [28]	x	x	x	x				x		
Carson [11]										x
Taggart [81]	x							x		x
Fules [30]	x							x		

Table 2 continued

References	Subjective scores							Sport scores		
	Lysholm	IKDC subj	KOOS	Noyes	Cincinnati	EQ5D	SF36	Tegner	Marx	RTS
Shelbourne [75]				x						x
O'Shea [75]				x						
Colosimo [14]	x							x		x
Noyes [61]					x					x
Harilainen [37]	x							x		
Woods [94]										x
Eberhardt [21]	x							x		x
Kartus [43]								x		
Uribe [85]	x							x		x
Wirth [92]	x									
Johnson [42]					x					x
Noyes [64]				x	x					x
	31	18	9	4	5	1	2	26	2	31

References	Objective scores							
	IKDC Obj	KT2000	KT1000	Lachman	Pivot shift	ROM	Single-leg hop	Isokinetic testing
Sonnery-Cottet [78]	x		x		x			
Reverte-Vinaixa [69]				x	x			
Mahmoud [53]								
Shelbourne [74]			x					
Pascual-Garrido [66]	x		x		x			
Ventura [87]	x		x	x		x		
Dauty [17]								
Ra [67]		x						
Chen [12]								
Flanigan [27]								
Franceschi [29]	x		x	x	x	x	x	
Griffith [35]				x	x			
Enad [23]								
Kievit [44]			x		x			
Buda [10]	x	x				x		
Gifstad [33]			x					
Ferretti [26]	x		x	x	x			
Lind [48]								
Mayr [56]	x		x	x		x		
Trojani [84]	x		x					
Lind [48]	x		x		x			
Shino [76]	x		x			x		
Reinhardt [68]				x	x			
Wright [95]								
Ahn [2]	x	x		x	x			

Table 2 continued

References	Objective scores							
	IKDC Obj	KT2000	KT1000	Lachman	Pivot shift	ROM	Single-leg hop	Isokinetic testing
Niki [59]	x	x						
Muneta [58]			x	x	x	x		x
Wegrzyn [90]	x		x	x	x			
Lind [49]								
Denti [19]	x		x	x				
Ahn [3]	x	x						
Diamantopoulos [20]	x		x					
Wright [96]								
Battaglia [8]			x	x		x	x	
Weiler [91]	x		x	x	x			
Ferretti [25]	x		x	x	x	x		
Salmon [72]	x		x	x	x		x	
Garofalo [63]	x		x	x	x	x		
Noyes [63]	x	x			x			
Liden [47]	x		x				x	
Thomas [83]	x	x						
Grossman [36]	x		x				x	x
O'Neill [65]	x	x				x		x
Fox [28]			x	x	x	x	x	
Carson [11]			x	x	x			
Taggart [81]			x	x	x	x		
Fules [30]	x	x						
Shelbourne [75]			x			x		x
O'Shea [75]			x			x		x
Colosimo [14]			x	x	x		x	
Noyes [61]					x	x		
Harilainen [37]								
Woods [94]	x		x	x	x		x	x
Eberhardt [21]	x		x	x	x	x		
Kartus [43]			x				x	
Uribe [85]			x	x	x			
Wirth [92]								
Johnson [42]	x		x		x	x	x	
Noyes [64]								
	29	9	34	21	26	17	10	6

Data analysis was performed according to Lipsey and Wilson [51]. A fixed-effect method was adopted for the pooling of results when the data had homogenous distribution; a random-effect method was used otherwise. The heterogeneity of the distribution was assessed by the Q statistic and the calculation of the I^2 index with significance set at $P < 0.10$. In situations where the standard deviations were not reported, the mean of the standard deviations from the other trials that reported this statistic was imputed [31].

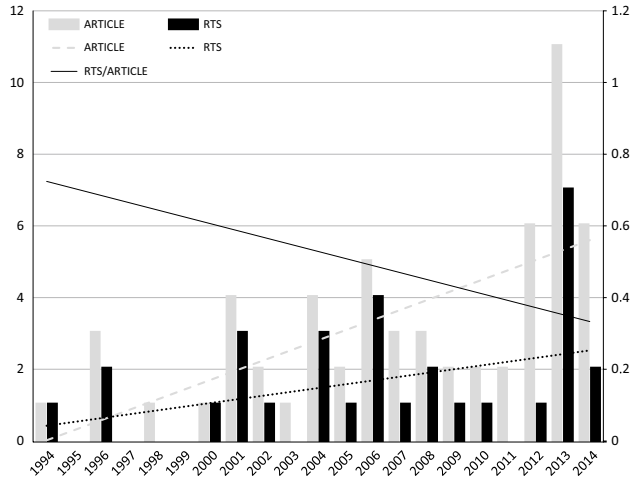

Fig. 2 Number of articles per year and trends of publications dealing with revision ACL reconstruction and RTS in revision ACL reconstruction surveys. The *continuous line* shows the trend of the ratio between articles reporting RTS and articles about revision ACL reconstruction published per year

Results

The PubMed search identified 503 records, and the abstracts were screened and selected according to the inclusion/exclusion criteria (Fig. 1): a total of 435 abstracts were excluded, and one article [82] was identified through the reference lists, which gave a total of 69 full-text articles assessed for eligibility. Ten full-text articles were also excluded for the following reasons: six articles did not report clinical results [38, 41, 47, 54, 79, 93], two articles reported outcomes of primary ACL reconstruction surveys [1, 7], and two articles [60, 61] reported the results of the same patients included in a larger survey subsequently analysed in another manuscript at a longer follow-up [62]. Thus, a total of 59 studies were included in the qualitative data synthesis (Table 1) [2, 3, 8, 10–12, 14, 17, 19–21, 23, 25–30, 32, 33, 35–37, 42–44, 47–50, 53, 56, 58, 59, 62, 63, 65–69, 72, 74–76, 78, 81–85, 87, 90–92, 94–96]. The scores used to assess the results in these articles are summarized in Table 2. Among these, only 31 articles reported the rate of RTS [8, 10, 11, 14, 19–21, 23, 25, 27, 29, 32, 33, 35, 36, 42, 58, 62, 63, 65, 67, 68, 72, 74, 75, 78, 81, 82, 85, 90, 94] and were included in the RTS meta-analysis. Twenty studies reported the number of participants returning to some sport activity [8, 10, 11, 14, 19, 25, 29, 42, 58, 62–64, 67, 68, 72, 75, 78, 81, 90, 94], and 28 studies reported the number of participants returning to sport at their preinjury participation level [10, 11, 14, 19–21, 23, 25, 27, 29, 32, 33, 35, 36, 58, 62–65, 67, 68, 74, 75, 78, 81, 85, 90, 94]: these two types of RTS score were analysed separately for the primary outcome meta-analysis.

Further meta-analysis of secondary outcome measures was performed. Among the different scores used in the literature (Table 2), we selected the most common ones for every specific outcome type (Lysholm for subjective scores, Tegner for sport scores, IKDC for objective scores) for the meta-analysis focused on the secondary purpose of this study: 31 articles reported subjective outcome evaluated with the Lysholm score [2, 3, 14, 19–21, 25, 26, 28–30, 32, 33, 35–37, 44, 53, 56, 58, 59, 66, 67, 69, 72, 75, 78, 81, 85, 91, 92], 26 articles evaluated Tegner score activity level [14, 19–21, 25, 26, 28, 30, 32, 33, 35–37, 43, 44, 48–50, 56, 58, 59, 67, 75, 78, 81, 85], and 29 articles assessed objective results with the IKDC objective score [2, 3, 10, 19–21, 25, 26, 29, 30, 32, 36, 42, 48, 56, 59, 63, 65, 66, 72, 75, 76, 78, 83, 84, 87, 90, 91, 94].

Qualitative data synthesis

Published articles

Among the 59 articles included in the qualitative data synthesis, the evaluation of study type showed five registry studies, eight prospective comparative studies, four retrospective comparative studies, 31 prospective case series, and 11 retrospective case series (Table 1). A growing publication trend over time was found by analysing the articles published in the last 20 years, with 17 articles on revision ACL reconstruction published between 1994 and 2004 and 17 articles published just in 2013 and the first half of 2014 (Rho = 0.691; $p = 0.001$; Fig. 2). An increase in the number of articles reporting the rate of RTS was also noticed (n.s.). However, a further analysis showed that the ratio between the articles reporting RTS data and the overall number of published articles has actually decreased over time, although not significantly (Rho = 0.408; n.s.).

Patient data

A total of 5365 patients were treated with ACL revision reconstruction, but outcomes of only 3803 patients were reported (a detailed description of the analysed data, with the number of patients and the specific data available, is provided in Table 3). Patients were evaluated at a mean of 37.8-month follow-up, using a wide range of heterogeneous scores (Table 2): the study results were evaluated in the meta-analysis. The overall failure rate was 8.9 % (133 patients failed among the 1502 described in 35/59 studies which reported the failure rate) [8, 10, 11, 14, 21, 25, 26, 28, 30, 32, 35, 36, 45, 48, 50, 53, 56, 62, 63, 65–69, 72, 75, 76, 78, 81, 83, 84, 91, 96].

Table 3 Demographic data of the patients analysed in the articles included in the qualitative data synthesis

	Data reported		Available data	
	n	(%)	No. of patients with available data	No. of studies reporting data
No. of patients	5365			
No. of patients at follow-up	3803			
Study design (pts reported)			3803	59
Registry study	1564	41.1		5
Comparative studies	540	15.2		8
Retrospective comparative studies	95	2.5		4
Case series	1057	27.8		31
Retrospective case series	547	14.4		11
Follow-up (m, mean)	37.8		3803	59
Primary–revision interval (m, mean)	47.1		1598	34
Graft (pts reported)			2524	53
Allograft	539	21.4		25
BPTB	1125	44.6		37
Hamstring	707	28.0		29
Quadriceps tendon	122	4.8		11
Other	31	1.2		3
Sex			4834	55
Men	2909	60.2		
Women	1925	39.8		
Age (years)	28.5		3452	54
Aetiology			2836	37
Traumatic	1097	38.7		
Technical error	842	29.7		
Biological	137	4.8		
Multifactorial/other/unknown	760	26.8		
Failures	133	8.9	1502	35

BPTB bone-patellar tendon-bone

Return to sport meta-analysis

Return to sport at any level

In the 20 articles reporting this outcome, 496/634 patients returned to some level of sport participation, for a cumulative rate of RTS at any level of 75 % (95 % CI 75–82 %, $I^2 = 2.9$ %). Compared to the rate of RTS at any level reported for primary ACL reconstruction (82 %, 95 % CI 73–90 %, $I^2 = 98$ %) [5], no significant difference was found (n.s.) (Fig 3).

Return to sport at the same level

In the 28 articles reporting this outcome, 670/1167 patients returned after the revision ACL reconstruction at their preinjury participation level, for a cumulative rate of RTS at the same level of 43 % (95 % CI 39–48 %, $I^2 = 76.1$ %). A significant difference was found ($p \leq 0.05$) with respect to the rate of RTS at the preinjury level reported for primary ACL reconstruction (63 %, 95 % CI 54–71 %, $I^2 = 98$ %) [5] (Fig. 4).

Clinical scores meta-analysis

Mean Lysholm scores at the latest follow-up (59.1 months from revision ACL reconstruction) were available for 1067 patients reported in 31 studies. The preoperative values were calculated from the data reported in 17 studies. Overall, the Lysholm score increased significantly ($p < 0.05$) from 61.5 points preoperatively (95 % CI 60.6–62.3, $I^2 = 90$ %) to 87.5 points at the latest follow-up (95 % CI 86.9–88.1, $I^2 = 94$ %; Fig. 5).

The sport activity evaluated with the Tegner score at the latest follow-up (45.1 months from revision ACL reconstruction) was available for 1117 patients in 26 studies. The preinjury values were obtained from the data reported in 16 studies. Overall, the patients reached a 5.0 score (95 %

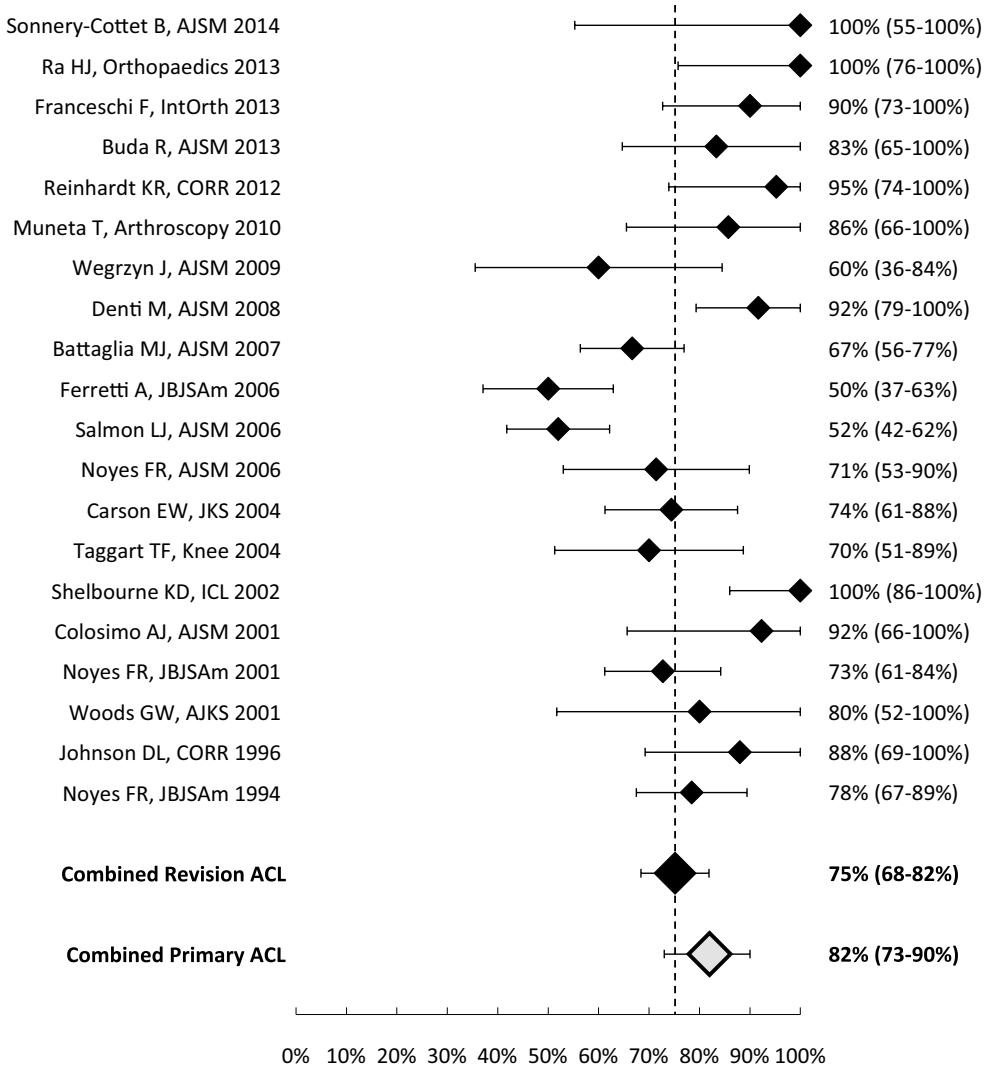

Fig. 3 Forest plot of rate of return to any sports participation. The mean proportion and 95 % CI data from individual studies in addition to the pooled proportion are presented ($Q = 19.6$, $I^2 = 2.9$ %)

CI 4.9–5.1, $I^2 = 94$ %), which was significantly lower ($p < 0.05$) with respect to their preinjury Tegner score (6.8; 95 % CI 6.7–7.0, $I^2 = 95$ %; Fig. 6).

The IKDC objective score values were available for 1185 patients in 29 studies, at a follow-up of 58.2 months after revision ACL reconstruction. The rate of patients having the operated knee evaluated as normal or nearly normal at the latest follow-up was 73 % (95 % CI 62–83 %, $I^2 = 79$ %; Fig. 7).

Discussion

This study documented the available clinical evidence on revision ACL reconstruction outcome, allowing for interesting conclusions to be drawn not only on the RTS after this surgical approach (primary purpose), but also on the clinical results evaluated with different types of scores (secondary purpose). Interestingly, the meta-analysis showed that different outcome measures may lead to different conclusions with regard to the success of this treatment, with RTS showing a less satisfactory outcome with respect to the primary or revision ACL reconstruction comparison based on other findings. In fact, the overall outcome documented by the most commonly used scores present overall good results, not matched by an equal success in RTS.

According to the research criteria, 59 studies describing 5365 patients were identified and analysed. Among these, 31 evaluated the clinical outcome after revision ACL reconstruction with the Lysholm score, and they were included in a meta-analysis which demonstrated a significant improvement, with 1067 patients reaching 87.5 points at a mean 5 years of follow-up. It was not possible to compare these results statistically with the published data about primary ACL reconstruction, since no meta-analysis on the subjective outcome evaluated with Lysholm score has been reported, to our knowledge. Nevertheless, considering that the results documented in the literature for

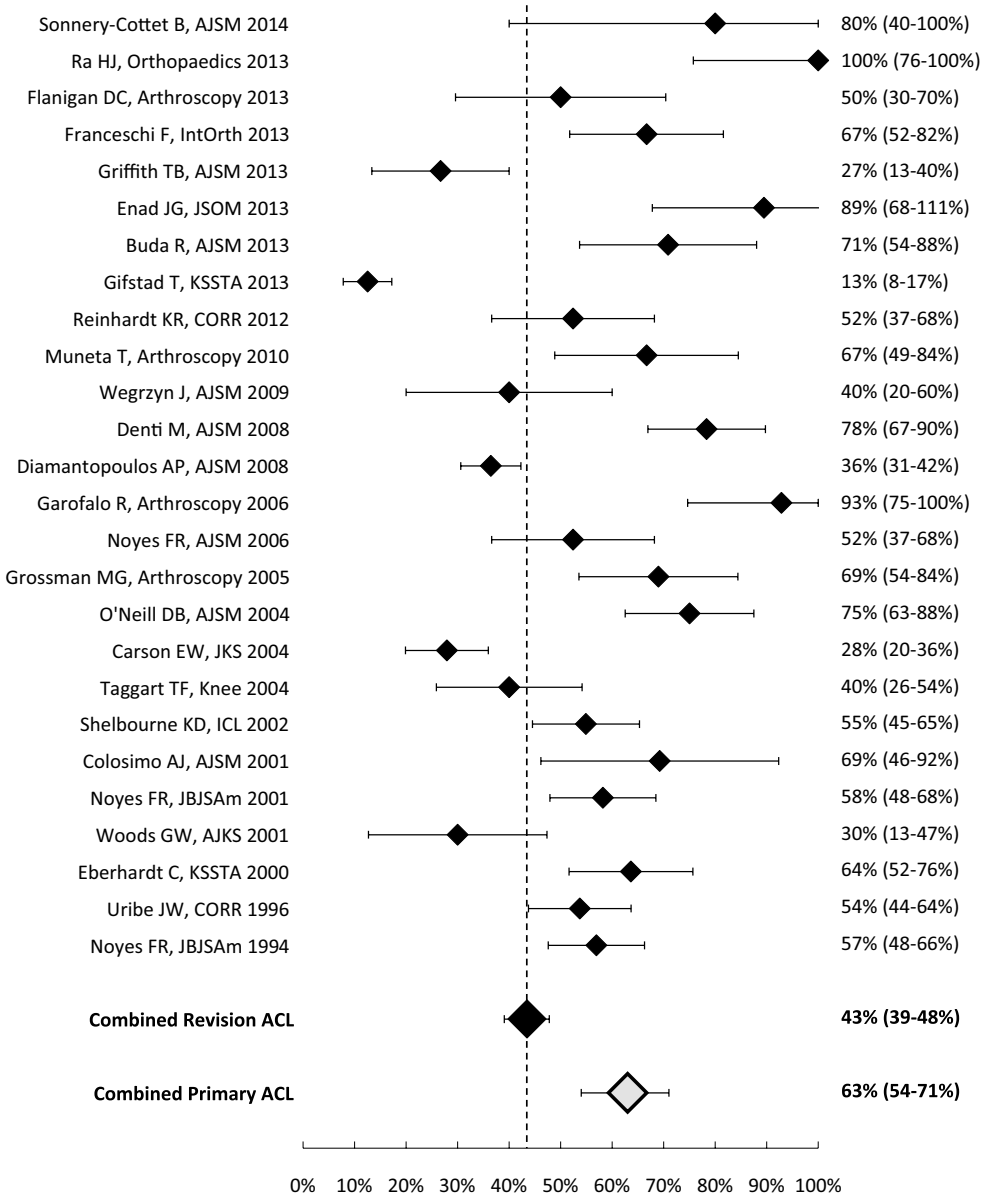

Fig. 4 Forest plot of rate of return to preinjury sports participation level. The mean proportion and 95 % CI data from individual studies in addition to the pooled proportion are presented ($Q = 104.8$, $I^2 = 76.1$ %)

primary ACL reconstruction range from 85 to 95 [22, 24, 45, 46, 73] and that a 10.1-point minimal clinically important difference was established for the Lysholm score [9], it is reasonable to conclude that primary and revision ACL reconstructions do not present a clinically significant difference for this outcome measure. Also for the IKDC objective score, it is not possible to perform a statistical comparison with the literature, but some conclusions can be drawn. In the 29 evaluated articles on 1185 patients, 73 % knees were normal or nearly normal. This outcome does not appear to be as successful as the same score reported for primary ACL reconstruction (80–90 % IKDC grade A or B) [45, 46], but might be still considered successful since the evaluated knees had already undergone multiple trauma and surgeries.

A different picture can be drawn when analysing the sport-related outcomes.

In fact, the 1117 patients evaluated with the Tegner score in 26 studies reached a mean of 5.0 points almost 4 years after revision ACL reconstruction, significantly lower than the preinjury level, and lower than the score reported for primary ACL reconstruction (with average value always above 6) [22, 24, 45]. Moreover, a Tegner score of 5 corresponds to low demanding activities such as cycling, cross-country skiing, or jogging on uneven ground. Concerning this, the importance of sport activities in patients undergoing ACL reconstruction should be underlined. The ACL is commonly injured during sports participation, particularly in sports involving highly demanding activities such as jumping, pivoting, and cutting manoeuvres [34, 55], and the will to

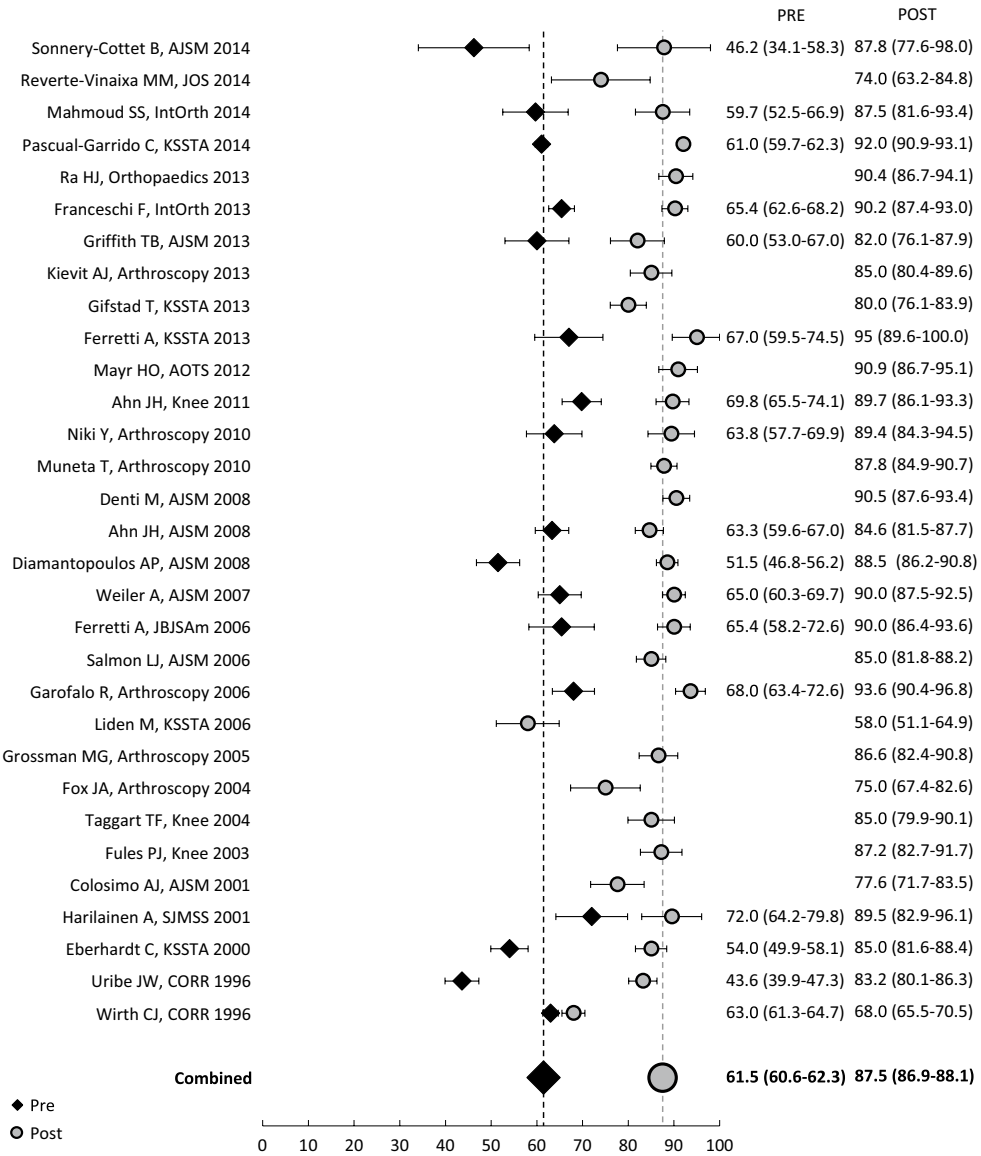

Fig. 5 Forest plot of the preinjury and postoperative mean Lysholm scores. The mean proportion and 95 % CI data from individual studies in addition to the pooled proportion are presented (PRE: $Q = 168$, $I^2 = 90$ %; POST: $Q = 464$, $I^2 = 93.5$ %; MD: $Q = 27{,}889$, $I^2 = 99.9$ %)

return to such sports activities is still the most typical indication for ACL reconstruction. In fact, the aim of surgery is to maximize stability and functional capacity in the ACL-deficient knee [13], thus facilitating a return to preinjury activity levels and sports participation [16, 70, 89].

Thus, it appears evident how important it is to focus on sport-related outcomes when evaluating the benefit obtained by this surgical treatment. The chances in going back to previous activities are of major interest for a patient undergoing revision ACL reconstruction, and the ratio of patients able to return to sport activity should be the main outcome of a revision ACL procedure. The meta-analysis on the rate of RTS showed precisely that, whereas 75 % of patients returned to some kind of sport, only 43 % were able to return to the same level of sport activity. This results is significantly lower with respect to that reported in a meta-analysis on primary ACL reconstruction (63 %) [5], confirming the limits of the revision reconstruction to obtain results comparable to the primary reconstruction in terms of RTS.

In the light of these results, care should be taken in reporting RTS when evaluating revision ACL reconstruction surveys. As argued by Ardern et al. [5], for many patients the use of a specific participation measure such as the ability to return to the preinjury level of sports participation is appropriate and its use should be encouraged. RTS is of greater importance to the patient than measurements of impairments such as muscle strength or knee range of motion [86]. However, this is not the direction the literature is heading for. In fact, the recent increase in scientific interest on this surgical approach, with more than one-third of the papers published just in the last 3 years, has not been

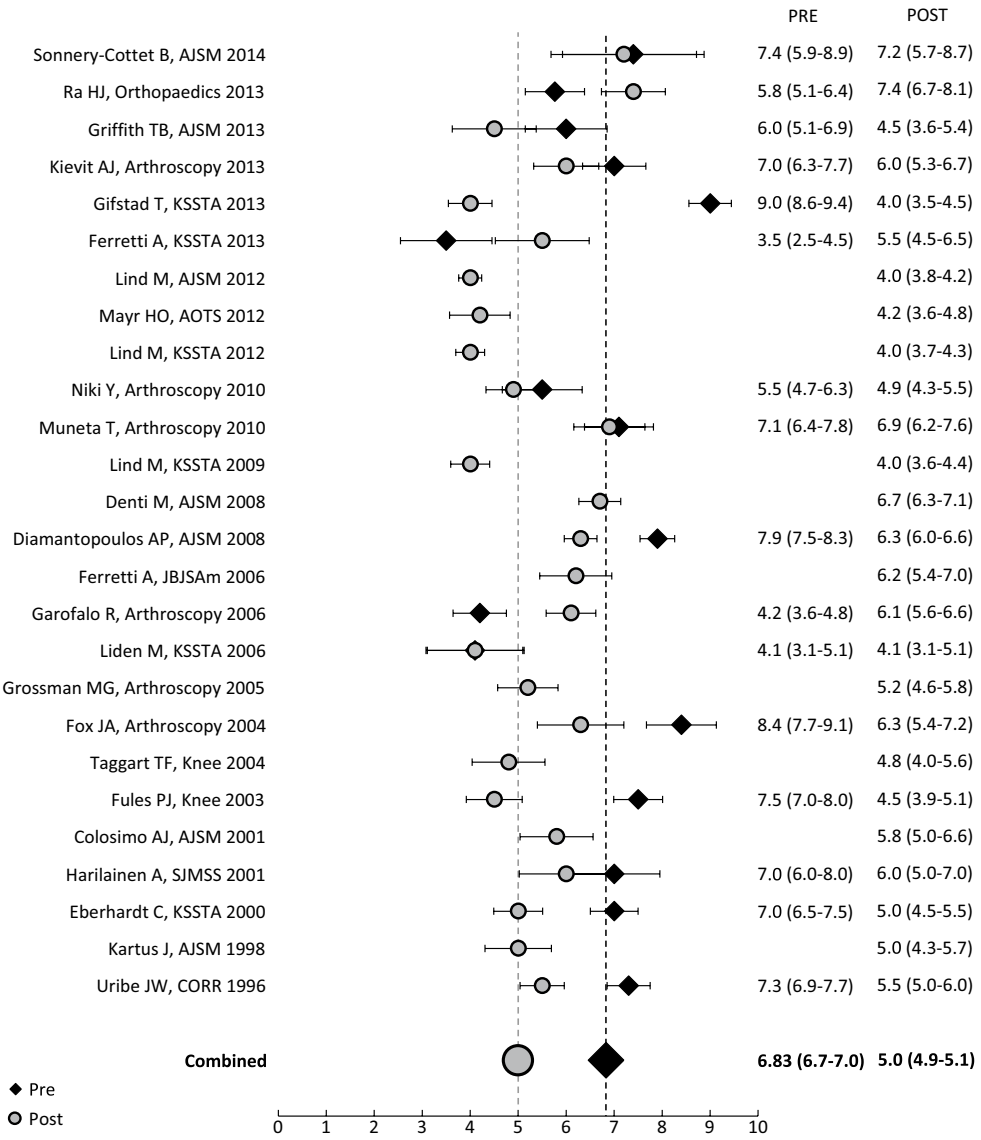

Fig. 6 Forest plot of the preinjury and postoperative mean Tegner scores. The mean proportion and 95 % CI data from individual studies in addition to the pooled proportion are presented (PRE: $Q = 310$, $I^2 = 95.2$ %; POST: $Q = 413$, $I^2 = 94.2$ %; MD: $Q = 3003$, $I^2 = 99.5$ %)

coupled with an increase in studies reporting the rate of RTS: only 31 out of 59 papers reported RTS, and the RTS/article ratio is decreasing over time (Fig. 2). Moreover, there are different definitions of RTS, thus generating confusing data (Table 4). An agreed definition of RTS, widely applied in studies on this topic, would help to better investigate this important outcome.

The study presents some limitations. Due to the limited number of studies on revision ACL reconstruction, no study selection has been made based on the level of evidence or the sample size for this meta-analysis. Although this might be seen as a limitation, it allowed us to combine the results of 59 studies and 5365 participants. The current literature on revision ACL is composed of relatively low-level studies with heterogeneous methodology and only a few of them reporting RTS. Thus, the inclusion of all of them allowed us to obtain enough data to perform a strong meta-analysis on different types of outcome and demonstrated the importance of RTS. With regard to RTS, it might be argued that not all patients aim at sport participation when undergoing ACL revision, thus influencing the study findings. However, this is a limiting factor also in case of primary surgery, thus not affecting the comparison between results obtained after primary and revision ACL surgery. Moreover, the results of our study suggest that also in the case of patients undergoing surgery for reasons other than the intention of returning to sport, a participation measure encompassing participation in occupation, leisure pursuits and societal roles may be more appropriate and should be applied to evaluate the success of the procedure.

The results of the current meta-analysis reinforce the view that greater emphasis should be placed on the use of sport participation-based outcomes to assess

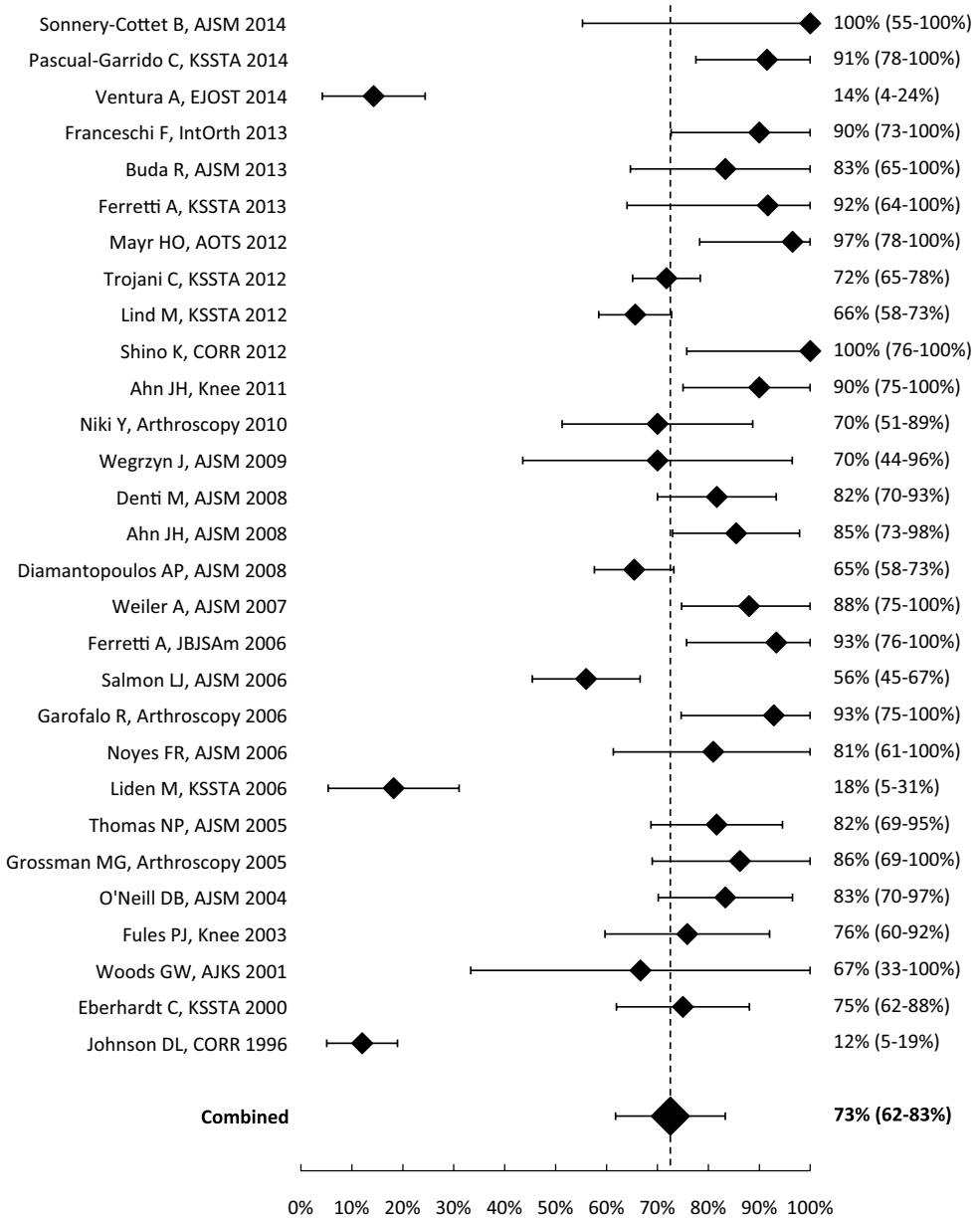

Fig. 7 Forest plot of the percentage of normal/nearly normal IKDC objective scores. The mean proportion and 95 % CI data from individual studies in addition to the pooled proportion are presented ($Q = 134.2$, $I^2 = 79.1$ %)

the effectiveness of revision ACL reconstruction surgery rather than on outcomes based on clinical scores. This is in accordance with the work by Ross et al. [71] who showed the absence of a direct correlation between objective measures of knee function and patient participation in a range of activities including sport. The World Health Organization recommendations on health-outcome measurement are reflected as well [80]. In fact, regardless of 73 % good objective results and satisfactory subjective results being only slightly inferior compared to primary reconstruction, 57 % of patients did not return to the same level of sport activity, which shows that the benefit of a revision ACL procedure is actually low and significantly inferior to that of a primary procedure. A reinjured knee presents a more damaged articular environment and increased chances of residual instability [40, 77], and psychosocial factors such as fear of reinjury, motivation, and sports confidence may play a role as well [27]. Therefore, orthopaedic surgeons should provide to patients undergoing a revision procedure realistic expectations and should motivate them to perform an extensive rehabilitation programme focused on the recovery of the specific sport skills to optimize the return to previous activities [18].

Table 4 Different definitions of RTS reported in the articles included in the qualitative data synthesis

Definition of return to sport	References
Return to preinjury activity level	[20, 21, 27, 29, 32, 33, 67, 94]
Resume sports activity at the same level as before first ACL reconstruction	[10, 65, 74, 90]
Return to the same sport and level at the time of follow-up	[19, 25, 75]
Return to the same activity level at the last follow-up	[35, 78]
Return to unrestricted sporting activities	[8, 11]
Return to same sport activity level at last follow-up without symptoms	[63, 64]
Return to pre-primary ACL reconstruction activities	[36, 81]
Resume preinjury activity level at the time of follow-up	[14]
Return to the same activity/sport level as before original injury at latest follow-up	[68]
Return to sporting activities at athletic levels equal to preinjury levels	[58]
Participation in strenuous or moderate sport activity	[72]
Return to sports without symptoms	[62]
Return to the same degree of activity as before the original ACL injury	[85]
Return to previous occupation specialty without physical restrictions	[23]
Participation in sports more than one time per week	[42]

Conclusion

The current systematic review is the first one to evaluate the RTS and the clinical outcome following revision ACL reconstruction with a meta-analysis. The study combines the results of 59 studies and 5365 participants, allowing some clarification in the outcomes of this surgical procedure. Although 73 % of good objective results and satisfactory subjective results have been reported, only slightly inferior compared to primary reconstruction, the real potential of this procedure should not be overestimated. Of the 75 % of patients who returned to some kind of sport, only 43 % were able to return to the same level of sport activity, with significantly poorer results with respect to those reported for primary ACL reconstruction. Future studies should focus on participation-based outcome measures such as RTS and strategies to improve the results and return to previous activities after revision ACL reconstruction.

Compliance with ethical standards

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