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Literature Review

Comparison of functional outcome after early and delayed anterior cruciate ligament reconstruction: A systematic review

I Putu Dharma Kresna[1], Kukuh Dwiputra Hernugrahanto[2], Rr. Indrayuni Lukitra Wardhani[3], Dwikora Novembri Utomo[4*]

1) Faculty of Medicine, Airlangga University, Surabaya, Indonesia.
2) Department of Orthopedics and Traumatology, Faculty of Medicine, Airlangga University, Soetomo General Hospital, Surabaya, Indonesia.
3) Department of Physical Medicine and Rehabilitation, Faculty of Medicine, Airlangga University, Soetomo General Hospital, Surabaya, Indonesia.
4) Department of Orthopedics and Traumatology, Faculty of Medicine, Airlangga University, Soetomo General Hospital, Surabaya, Indonesia.

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Correspondence:

dwikora_utomo@yahoo.com

ABSTRACT

This study aims to find the optimal timing for Anterior Cruciate Ligament (ACL) reconstruction by comparing the outcome of early versus delayed ACL reconstruction, meniscus, and chondral damage. A systematic literature search was performed from February to March 2021 from 4 databases. Inclusion criteria were English language Randomized Control Trial (RCT) and observational studies published in 2000-2020, 20-50 years old patients with an isolated ACL tear with/without meniscal injury underwent ACL reconstruction. Early ACL reconstruction was estimated at less than six weeks post-injury, and delayed ACL reconstruction was estimated at more than six weeks. Tegner and Lysholm were the functional outcomes to compare early and delayed ACL reconstruction with a meniscus tear and chondral damage. The search yielded 3094 studies. After removing duplicates, titles and abstracts were screened, leaving 154 potential studies. The studies were selected, and eight studies were eligible. No statistically significant difference between early and delayed ACL reconstruction in Lysholm and Tegner score (p>0,05) was found. Both scores were similar regarding whether the patient performs early/delayed ACL reconstruction. Therefore, early ACL reconstruction could be an optimal timing for the patient who will undergo ACL reconstruction.

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INTRODUCTION

The anterior cruciate ligament (ACL) is the most common knee injury besides meniscus and, in most cases, needs surgical intervention. Therefore, in Orthopaedic Surgery, ACL reconstruction is the most common knee surgery as the ACL is injured more than any other structure in the knee (Gupton et al., 2021). It is estimated that 1 in 3000 people endures ACL injury in the United States of America, as 70% of these injuries result from sports activity. The injury of the ACL can be from contact or non-contact injury. 70% of the torn ACL cases occurred non-contact, without a direct blow to the knee joint, resulting from jumping landing and lateral cut maneuvers(S. Kim et al., 2011). These maneuvers usually occur in a sports activity with high movement frequency and high loadings of the knee, such as basketball, handball, soccer, and volleyball (Nessler et al., 2017). The mechanism of injury of the ACL can be multiple knee loadings. The ACL may be overloaded when quadriceps muscle forces are combined with the frontal plane and or transverse plane with insufficient hamstring muscle contraction especially when the knee is in the position of extension (Wetters et al., 2016). Other structures may also be injured, such as the meniscus, the chondral bone, PCL, and collateral ligament (Domnick et al., 2016).

ACL rupture is a common injury in active individuals. It can cause instability of the knee joint. This instability can make functional changes and other structural damage in the knee joint (Monk et al., 2016). If the tear of the ACL is not appropriately treated, it can lead to poor outcomes such as a higher rate of meniscus lesion and chondral damage (Friel & Chu, 2013).

In the treatment of the torn ACL, there are operative and non-operative treatments. The non-operative treatment has been an alternative; however, it can produce poor functional outcomes. In young adults with high demand for activity, the ACL reconstruction with grafting is the gold standard of treatment, replacing the damaged ACL with a new ligament using a harvesting graft. The ACL reconstruction with grafting regarding the results and the outcomes of the patient with high compliance shows good-long term outcomes and return-to-sport (Salmon et al., 2018). Each type of method of graft has its advantage and disadvantage; therefore, the surgeon needs to adapt the selection of the graft individually for each patient. The timing of reconstruction and rehabilitation also has an important role in obtaining an excellent outcome (Paschos & Howell, 2016).

Despite many studies of ACL anatomy and the development of surgical techniques for ACL reconstruction, the literature still debates the optimal timing for ACL reconstruction that deliver excellent outcome (Hetsroni & Marx, 2017). Many studies showed different terms for timing ACLR, which are acute or subacute instead of early, chronic instead of delayed ACL reconstruction. There is no clear term regarding the definition of acute because some authors use the terms early and acute interchangeably. Furthermore, there are no clear definitions regarding the cut of point in the timing of ACL reconstruction and the outcome of ACL reconstruction. According to Noyes et al., the average acute interval was six weeks, and the chronic operative period was three months after damage. (Noyes & Barber-Westin, 1997). Meanwhile, Chen et al. defined the acute ACL reconstruction as three to seven weeks, while the delayed ACL reconstruction lasted 6-11 months from injury to surgery. Manandhar et al. defined early ACL reconstruction as less than three weeks from injury to surgery, while delayed ACL reconstruction is defined as 42 until 60 days from injury to surgery (Chen et al., 2015; Manandhar et al., 2018).

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Some previous studies recommended early ACL reconstruction because delayed ACL reconstruction could increase the probability of chondral and meniscus injuries (Hetsroni & Marx, 2017). Moreover, inactive patients, due to surgical delaying, could cause a loss of muscle strength (Paschos & Howell, 2016). It was reported that there was a significantly higher incidence of involvement of other structure (meniscal/chondral) damage in the delayed surgery after three months (Ferguson et al., 2019). Another study showed a significantly higher incidence of meniscal tear when ACL reconstruction was performed eight weeks after injury than before eight weeks (Ghodadra et al., 2013).

Conversely, other studies reported that early ACL reconstruction resulted in stiffness, and arthrofibrosis and reduced the rate of return to work. Another reason for delaying reconstruction is to give the opportunity for the patient to regain normal knee function with non-operative treatment. Gage et al., advised that ACL reconstruction should be delayed until full passive extension with an average time of 18 days to achieve extension after an ACL injury to avoid arthrofibrosis post-operatively (Gage et al., 2019). Shelbourne recommended waiting at least three weeks to perform ACL reconstruction to avoid the risk of arthrofibrosis, which decreased when ACL reconstruction was delayed for 21 days, subsequently expanding rehabilitation time (Shelbourne et al., 1991). Conversely, Bottony et al., in their study, concluded that early ACL reconstruction did not develop in loss of motion or suboptimal clinical results when rehabilitation protocol pointed out in extension and early range of motion (Bottoni et al., 2008). Some studies reported no significant differences between early and delayed ACL reconstruction. Frobell et al. reported that a rehabilitation strategy plus early ACL reconstruction performed within ten weeks after an injury did not give a significant difference in results compared to rehabilitation plus optional delayed ACL reconstruction performed between 6.5 - 20 months after injury (Frobell et al., 2010). There is a lack of consensus regarding the timing of ACL reconstruction and its result that supports getting to work early.

This study aims to know whether early ACL reconstruction is more optimal for patients than delayed ACL reconstruction.

METHODS

The research was conducted using a systematic review consisting of three stages: data retrieval, data collection, and data interpretation. Before taking data, the right first step was to determine the PICO (Patient, Intervention, Comparison, Objective). The participant was a patient who had undergone ACL reconstruction. The intervention of the review was an ACL reconstruction, a surgery to reconstruct the injured ligament with a new ligament either by autograft or allograft. The comparison of the review was the timing of ACL reconstruction. Early ACL reconstruction was defined as less than six weeks after injury, while delayed ACL reconstruction was more than six weeks. The optimal timing for patients who undergo ACL reconstruction is still debatable. Still, most studies showed that ACL reconstruction should be performed within six weeks after injury with a well-planned rehabilitation program, such as quadriceps exercise. Conversely, above six weeks or delaying more than six weeks after injury could increase the risk of meniscus and cartilage damage to patients (Chen et al., 2015; Cipolla et al., 1995; Ferguson et al., 2019; Noyes & Barber-Westin, 1997; von Essen et al., 2020).

The outcome of the review was Tegner and/or Lysholm score. Tegner and/or Lysholm knee rating scores were applied to assess the functional outcome. The combination of Tegner and/or Lysholm scores is intended for

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a patient with ACL injury/ post-op of the ACL (Collins et al., 2011). The main benefit of the activity scale is that it can be used to monitor progress in activity level in the same person over time rather than comparing different patients. The pre-injury level and the current and desired activity levels can be determined using this scale. The Tegner score is a sports score that describes a typical daily activity of a patient; it consists of 10 distinct levels (1-10) of physical activity with 0 as a result from injury, 1-5 representing levels of work-related to activity and/or recreational sport, 6-9 representing a competitive/organized sport and 10 which represent the most elite athletes. The Lysholm score is widely and commonly used to assess the knee ligament injury and surgical outcomes; that consists of eight item scores that are proportional and scored up to 100 points on scales. The Lysholm score is described in some range of an interval and value such as 95 – 100 as excellent; 84 - 94 as good; 65 – 83 as fair; and <64 as poor (Lysholm & Tegner, 2007).

After determining the PICO, the authors (D.H, D.W, L.H) looked for screening in PROSPERO or the database whether there had been a systematic review with a similar title, and the results were not available. If similar title/results were found, then the differences in cut-off timing of reconstruction could be searched to distinguish among the reviews, so this research was continued. Data collection began with selecting keywords first. In this research, the keywords were as follows: ‘‘anterior cruciate ligament reconstruction’’ AND ‘‘surgery’’ AND ‘‘timing’’ OR “early” OR “delay’’.

From these keywords, the search results were summed from all search databases. Four databases were used in the study, namely Pubmed/MEDLINE, Science Direct, Scopus, and Google Scholar. The initial search was carried out, then the installation of automation tools could be started to focus the data obtained. Once the search results have been obtained, recording was performed, and duplication was removed because some studies might appear in more than one database. Duplication could be removed with the help of Mendeley. Furthermore, the data were selected according to the inclusion and exclusion criteria.

Selection was carried out in two stages by three authors (DK, DH, LW); the first stage was selection based on title and abstract. Excluded titles and abstracts were inappropriate with keywords or PICO that have been set at the beginning. In addition to the title and abstracts being screened for selection, full-text availability was also screened. The second stage of the selection was reading the full-text article to select studies that meet the inclusion and exclusion criteria requirements. The inclusion population of the journals was active people ranging 20-50 years old with an isolated tear of the ACL who underwent ACL reconstruction. The age criteria were chosen because surgery management which was ACL reconstruction, was usually a preferable treatment for younger athletes, those who have an occupation that requires a good physique or those who wish to return to their pre-injury sporting activities (Frobell et al., 2013; Smith et al., 2010) The diagnosis of the ACL injury can be through history taking, physical examination with Lachman or Anterior Drawer test, MRI scanning or diagnostic arthroscopy. Randomized control trials and observational studies were included in the selection of studies and were published from 2000-2020. The range of year was used in the studies because there were minimum studies that were published in the last 5-10 years; therefore, the study expanded the range of years from 2000 to 2020. Early ACL reconstruction was estimated less than six weeks after injury, while delayed ACL reconstruction was estimated more than six weeks post-injury to minimize the bias of

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journal selection and studies. Studies that met the criteria were called eligible. After obtaining eligible studies, the articles were assessed with Risk of Bias 2 (RoB2) for the RCT studies and Newcastle – Ottawa Quality Assessment Scale. RoB2 has been frequently used as a tool to assess the risk of bias for RCT studies. It was shown that RoB2 has been proven to be the appropriate tool to check the risk of bias tools as it is comprehensive and was approved by Cochrane (Sterne et al., 2019). Assessment consisted of 5 domains: randomization process (D1), deviations from the intended treatments (D2), missing the outcome data (D3), measurement of the outcome data (D4), and selection of the reported outcomes (D5). The end results from RoB2 were low quality, some concerns and high-quality study. For the observational studies, Newcastle – Ottawa Quality Assessment Scale was used to assess the quality of the observational studies which is one of the assessment tools that was approved by Cochrane. The observational studies were assessed with Newcastle – Ottawa Quality Assessment Scale by following the guidelines from 3 domains: selection of the participants, comparability, and outcomes (Wells et al., 2011). After the study assessment, articles could be read and extracted for each data in the study.

The first extracted data was the identity of the study, which was the author's name and time of writing. Furthermore, the data analyzed were types of studies. After that, it was done to be more specific, namely the data characteristics of the study sample. It consisted of the type of study, the country that had taken place in the study, number of patients in included studies and follow-up, injury to surgery time in either early or delayed ACL reconstruction, mean age of the patient, type of graft, each study's follow-up time, and surgical technique. The next was related to study variables: the Tegner score and/or Lysholm score and secondary data such as meniscus tears and chondral damage incidences. If there are data which are Tegner and/or Lysholm score that was presented in the form of the median, the methods from Hozo et al., were used to convert it to mean if possible (Hozo et al., 2005). The extracted data would be interpreted for retrieval conclusion. Should there be any disputes between authors, the fourth, the more senior author (DN) would aid in making the decision.

RESULTS

Figure 1 explains the collection and data selection which produced eight articles that fulfilled the eligibility criteria of the systematic review. The PRISMA chart started with collecting data using an electronic device from February to March 2021 from the database: Google Scholar, PubMed, Scopus, and ScienceDirect. From these databases, 3094 studies were obtained. Sometimes, articles were published in more than one database, so duplication selection was needed using Mendeley's application. Five hundred fifty-five studies obtained were duplicates which were then eliminated and ended with 2539 studies. Our first selection was based on the title, abstract, and full access to the article. The screening criteria used three points as in the plot: records excluded based on title, abstract, and full text of the studies. After eliminating the studies, there were 154 potential studies.

The Second Selection was based on the study's eligibility criteria, all English language articles of randomized control trial studies, and observational studies published from 2000 until 2020 that researched active people ranging from 20-50 years old who underwent ACL reconstruction. Early ACL reconstruction was defined as performing ACL reconstruction within six weeks post-injury, while delayed ACL reconstruction was more than six weeks post-injury. Early ACL reconstruction was performed within a few weeks of the injury

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to allow any joint effusion to subside, and a rehabilitation regimen focusing on quadriceps muscle and range of motion exercises was immediately implemented. In comparison, delayed ACL reconstruction was defined as an elective surgery with a pre-rehabilitation program such as quadriceps exercise, bracing, and others. From the 154 studies, only eight eligible studies fulfilled the criteria further analyzed for the risk of bias with RoB2 and

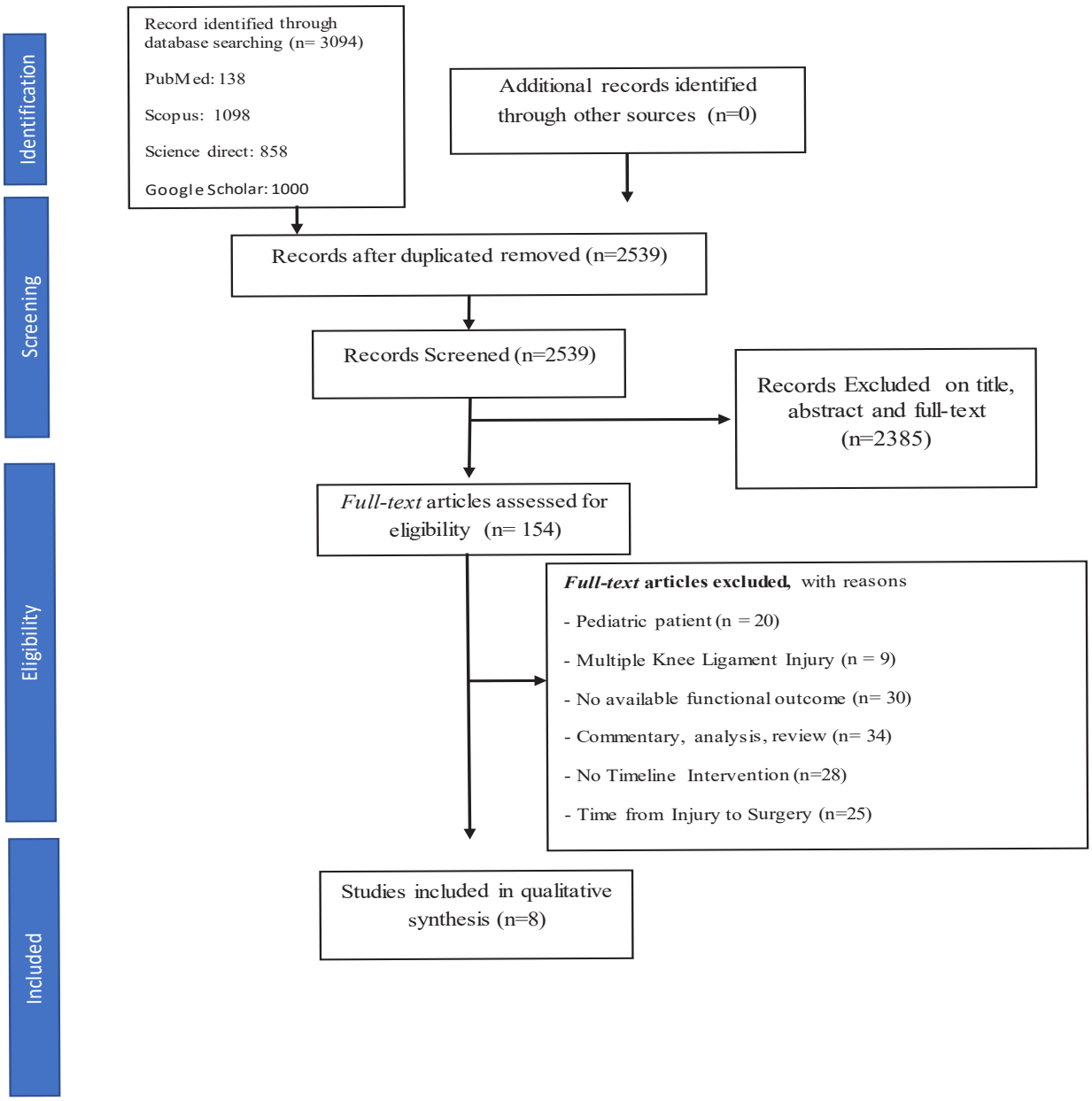

Figure 1

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Table 1. Risk of Bias 2 tools from 6 RCT studies.

Intention-to-treat	Unique ID	Study ID	D1	D2	D3	D4	D5	Overall
	1	(Meighan et al., 2003)	!	!	+	+	+	!
	2	(Bottoni et al., 2008)	!	+	+	!	!	!
	3	(Eriksson et al., 2018)	+	+	+	!	+	!
	4	(Manandhar et al., 2018)	!	+	+	!	+	!
	5	(Chen et al., 2015)	!	!	+	!	+	!
	6	(von Essen et al., 2020)	!	+	+	!	+	!

(Low Risk: + Some Concerns: !)

Table 2 . Risk of Bias 2 tools from 2 Observational studies.

No	Studies	Selection				Comparability	Exposure		
		Representatives of the exposed cased	Representatives of the non-exposed cased	Ascertainment of exposure	Selection of outcome parameters clearly specified in methods		Assessment of outcome?	Was observation period long enough for outcomes to occur?	Non-Response rate
1	(Hur et al., 2017)	*	*	*	*	*	*	*	*
2	(Herbst et al., 2017)	*	*	*	*	*	*	*	*

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Newcastle – Ottawa Quality Assessment Scale.

From table 1, six studies showed some concerns mainly because the process of randomization and allocation of the patient was unclear. There was also some unclear allocation as to whether the participant or the assessor knew what intervention the patient had. There were also some concerns regarding the outcome of some studies. There was also one study that had some concerns regarding the selection of reported results. From table 2, the two studies had a score of 8, which was good.

The study was conducted using a Systematic Review, and these were the results of data extraction from the eight following studies, which qualified the inclusion and exclusion criteria. There were nine tables, including the RoB2 table, Newcastle – Ottawa Quality Assessment Scale, demography table, Lysholm table, and Tegner table, meniscus tears tables, and chondral/cartilage damage tables.

Table 3 is the demography table of the eight following studies. The country of the studies was the place where the study had been conducted. Included studies were referred to all patients that underwent ACL reconstruction, and the follow-up was referred to all patients that underwent ACL reconstruction and could be followed up according to each outcome of the respective studies. There were patients who had lost contact during follow-up and could not be contacted. The injury to surgery time of the studies in early ACL reconstruction ranged from days to weeks, while the delay in ACL reconstruction ranged from weeks to a year. The mean interval of the age of the studies was 20-30 years old. The graft choices of the surgeon who did the surgery in the studies chose Hamstring as a graft, and only one study chose LARS. Follow-up times were varied, ranging from 2 weeks until five years. Two studies (Eriksson et al., 2018; von Essen et al., 2020) had the same initial patients but different follow-up times. One study (Herbst et al., 2017) differentiated between isolated ACL injury patients and ACL injury with the meniscal repair; they divided them into two groups. All studies used arthroscopy as their technical surgery.

Table 4 shows the Tegner and/or Lysholm score from 6 RCT and two observational studies. There were three RCT studies (Bottoni et al., 2008; Chen et al., 2015; Manandhar et al., 2018) and two observational studies (Herbst et al., 2017; Hur et al., 2017) reported the mean outcome of the Tegner score and five studies (Bottoni et al., 2008; Chen et al., 2015; Eriksson et al., 2018; Hur et al., 2017; von Essen et al., 2020) reported the mean outcome of the Lysholm score. Three studies (Eriksson et al., 2018; Meighan et al., 2003; von Essen et al., 2020) did not show the outcome of the mean Tegner score; they only showed the median Tegner score. There were also two studies (Manandhar et al., 2018; Meighan et al., 2003) that had no reference regarding the mean outcome of the Lysholm score. One Study (Herbst et al., 2017) did not explicitly state the mean Lysholm score. The study only revealed the chart follow-up of the score.

Meighan et al. defined early ACL reconstruction as less than two weeks from injury to surgery, while delayed ACL reconstruction is defined as eight until 12 weeks from injury to surgery. The delayed group had pre-operative physiotherapy from the intervention itself, while the early group did not have pre-operative physiotherapy. The differences in the pre-operative management could have different post-operative outcome, which could have a significant advantage on the functional outcome of the delayed group. However, after one year of follow-up, they concluded that whether the patient received early or delayed ACL reconstruction, both showed a reduced score in Tegner activity score

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Table 3 . Demography Table

No	Author	Type of Studies	Country	Number of Patients				Injury to Surgery Interval		Mean Age	Graft	Follow Up Time	Surgical Technique
				Included		Follow-up		Early	Delayed				
				Early	Delayed	Early	Delayed						
1	(Meighan et al., 2003)	Randomized Control Trial	Scotland	13	18	13	18	<2 weeks	8-12 weeks	21 (15-35 years)	HQ	2w. 6w, 3m, 6m, 1y	Arthroscopy
2	(Bottoni et al., 2008)	Randomized Control Trial	Hawaii, America.	35	35	34	35	2-17 days	42-192 days	27.3 (18-43 years)	HQ	6m – 2y	Arthroscopy
3	(Eriksson et al., 2018)	Randomized Control Trial	Swedish	34	35	32	32	8 days	6-10 weeks	26.9 (18-40 years)	HQ	3m, 6m	Arthroscopy
4	(Chen et al., 2015)	Randomized Control Trial	China	27	28	27	28	3-7 weeks	6-11months	Early: 29.4 Delayed: 31.9	LARS	1y and 5 y	Arthroscopy
5	(Manandhar et al., 2018)	Randomized Control Trial	India	110 (Not Stated)		53	51	4-21 days	42-60days	30 (18-55 years)	HQ	6m	Arthroscopy
6	(von Essen et al., 2020)	Randomized Control Trial	Swedish	33	35	28	29	8 days	6-10 weeks	26,9 (18-40 years)	HQ	6m, 1y,2y	Arthroscopy
7	(Hur et al., 2017)	Prospective Non-Randomized Control Studies	Korea	48	43	48	43	1-3 weeks	12-74 weeks	Early: 30.1 Delayed: 30	HQ	2y	Arthroscopy
8	(Herbst et al., 2017)	Prospective Non-Randomized Control Studies	Austria	50	50	50	50	1.2 days (average)	53.9 ± 68.4 days (average)	Early: 27.6 Delayed: 27.8	HQ	6m, 1y, 2y	Arthroscopy
				30	30	30	30	0.8 ± 0.8 days (average)	49.2 ± 86.3 days (average)	Early: 24.9 Delayed: 24.7			

(HQ: Hamstring Quadriple, LARS: Ligament Advanced Reinforcement System, w: weeks; m: months; y: year)

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Table 4. Results of both Tegner and Lysholm score in 8 eligible studies.

Author	Timing	Tegner	*P* Value	Lysholm	*P* Value
(Meighan et al., 2003)	Early ACL Reconstruction	NR		NR	
	Delayed ACL Reconstruction	NR		NR	
(Bottoni et al., 2008)	Early ACL Reconstruction	5.8 (Work related to activity and/or recreational sport)	0.34	80.6 (fair)	0.61
	Delayed ACL Reconstruction	4.9 (work related to activity and/or recreational sport)		83.4 (good)	
(Eriksson et al., 2018)	Early ACL Reconstruction	4.5* (work related to activity and/or recreational sport)	NR	76 (fair)	n.s
	Delayed ACL Reconstruction	4.25* (work related to activity and/or recreational sport)		79 (fair)	
(Chen et al., 2015)	Early ACL Reconstruction	6.3 (a competitive/organized sport)	0.413	93.37 (excellent)	0.164
	Delayed ACL Reconstruction	6.1 (a competitive/organized sport)		91.64 (excellent)	
(Manandhar et al., 2018)	Early ACL Reconstruction	4.15 (work related to activity and/or recreational sport)	0.064	NR	
	Delayed ACL Reconstruction	3.72 (work related to activity and/or recreational sport)		NR	
(von Essen et al., 2020)	Early ACL Reconstruction	7* (a competitive/organized sport)	NR	88.05 (good)	n.s

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	Delayed ACL Reconstruction	8.25* (a competitive/organized sport)		86.46 (good)	
(Hur et al., 2017)	Early ACL Reconstruction	6.0 (a competitive/organized sport)		94.5 (good)	
	Delayed ACL Reconstruction	5.6 (work related to activity and/or recreational sport)	0.27	96.3 (excellent)	0.28
(Herbst et al., 2017) (A)	Early ACL Reconstruction	6.7 (a competitive/organized sport)		Not Stated	
	Delayed ACL Reconstruction	6.3 (a competitive/organized sport)	n.s	Not Stated	n.s
(Herbst et al., 2017) (B)	Early ACL Reconstruction	6.6 (a competitive/organized sport)		Not Stated	
	Delayed ACL Reconstruction	6.3 (a competitive/organized sport)	n.s	Not Stated	n.s

(NR; No Reference) (NS: Not Significant) (*, Conversion from (Hozo et al., 2005))

compared to pre-injury activity rate on both groups with early and delayed groups showed similar outcomes. Meighan et al. preferred that the reconstruction could be done by delayed reconstruction because it was associated with a more rapid return of movement and muscle function.

According to Chen et al., the acute phase was described as the time required to properly manage rehabilitation and develop a positive mental attitude after the ACL ruptures. They categorized acute ACL reconstruction as reconstruction that occurred within 3-7 weeks after injury and delayed ACL reconstruction as reconstruction that occurred within 6-11 months after injury. Both the acute and delayed groups had a pre-operative rehabilitation. They believed that initiating rehabilitation earlier increased quadriceps and hamstring muscle strength, which was essential in determining knee function following ACL reconstruction in terms of flexion and extension. They reported that both Tegner and Lysholm score results were not statistically significant in the 1-year and 5-year follow-ups. The cut-off point for delayed ACL reconstruction was longer than any of the included studies, which might affect the outcome of the study. However, the study reported that patients in the delayed group that underwent ACL reconstruction for more than six months had a pre-operative rehabilitation to gain maximal ROM, which was the same

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criteria as the acute group. According to the study, 25% of patients had recurrent episodes of instability prior to surgery in the chronic group, and 32% of patients had persistent pre-operative pain. These symptoms persisted for six months before the patients had their first operation. The unpleasant series could be alleviated quickly with an acute intervention.

Manandhar et al. defined early ACL reconstruction as less than three weeks from injury to surgery, while delayed ACL reconstruction was defined as 42 until 60 days from injury to surgery. They stated that the mean Tegner score in early and delayed groups with a follow-up of six months was statistically not significant. Both early and delayed groups also had the same condition to undergo ACL reconstruction, which was the patient knee flexion with at least 120 degrees with or without pre-operative rehabilitation in the early group. In contrast, the delayed group had a pre-operative rehabilitation. They reported that even though the Tegner activity rating score did not differ statistically, it might be because the knee had to achieve a pre-operative 120 degree of flexion. That was why they concluded that patients should have surgery sooner rather than later, once they have restored 120 ° of knee flexion.

Both Eriksson et al., and Von Essen et al., had the same cut-off point of reconstruction, which was less than eight days from injury to surgery for early ACL reconstruction and six to 10 weeks from injury to surgery for delayed ACL reconstruction, and had the same sample population. The differences between the studies were that the patients' follow-up time with Eriksson et al. were followed up for 6 months while Von Essen et al., were followed up for 24 months. In a six-month follow-up, they reported that both groups' Tegner and Lysholm scores had improved. Surprisingly, the acute repair did not cause stiffness to rise. The acute group performed better on one-leg hop tests and improved in the subscales of pain, symptoms, and quality of life, but there were no significant differences after 24 months of follow-up.

Hur et al., defined early ACL reconstruction as the reconstruction of the ACL within three weeks after injury while delayed ACL reconstruction as the reconstruction of the ACL more than three months after injury. They excluded patients that underwent reconstruction more than three weeks until three months after an injury as they referred to the timing as an intermediate period, not acute or chronic. In the 24 months of follow-up, they reported that there were no significant differences in Tegner and Lysholm score. They also reported that there was a decreased Tegner score between pre-operative and post-operative in both groups as they assumed that the patients were reluctant to do more demanding activities. They hypothesized from their study that early ACL reconstruction had an advantage in muscle power and proprioception over delayed ACL reconstruction. However, in their study, they did not find any significant differences in the recovery of muscle power and proprioception between two groups.

Herbst et al., in their study, divided the patients into two groups which were patients who had an isolated tear of the ACL and patients who had an ACL injury with meniscus repair or meniscectomy. They defined early ACL reconstruction as the reconstruction of the ACL within 48 hours, while delayed ACL reconstruction was defined as reconstruction of the ACL after 6 weeks. They reported that in both groups, the Tegner score of early and delayed ACL reconstruction was not significant. For the Lysholm score, they only reported in the form of a graphic, and they concluded that there was no significant between early and delayed ACL reconstruction in both groups. Only 4.9 percent of patients with an isolated ACL reconstruction and 4.2 percent of patients with a combined ACL reconstruction and meniscus

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repair had a clinically relevant extension and flexion loss after acute surgery, according to this study. There was no discernible change in ROM between acute surgery within 48 hours and delayed surgery within the inflammation-free interval.

There were six studies (Bottoni et al., 2008; Eriksson et al., 2018; Hur et al., 2017; Manandhar et al., 2018; Meighan et al., 2003; von Essen et al., 2020) that reported the meniscus injury. Two of the eight studies (Chen et al., 2015) had no reference regarding the meniscus injury. Other studies (Eriksson et al., 2018; von Essen et al., 2020) reported the same outcome.

One study (Meighan et al., 2003) reported the meniscus injury without differentiating lateral meniscus or medial meniscus. Other studies (Bottoni et al., 2008; Eriksson et al., 2018; Hur et al., 2017; Manandhar et al., 2018; von Essen et al., 2020) differentiated the meniscal injury and reported that the total injury of the medial meniscus for early ACL reconstruction were 41 tears, while delayed ACL reconstruction was 61 tears. The lateral meniscus injury for early ACL reconstruction was 58 tears, while delayed ACL reconstruction was 36 tears. Early ACL reconstruction had fewer medial meniscus tears than delayed ACL reconstruction, while for lateral meniscus tears, early ACL reconstruction had more tears than delayed ACL reconstruction. Two studies (Hur et al., 2017; Manandhar et al., 2018) also reported bilateral tears, which were the lateral and medial meniscus injuries. The total tears of early and delayed ACL reconstruction in the two studies were 12 and 8 tears, respectively.

Our findings in these reviews about chondral damage showed that in three studies (Eriksson et al., 2018; Hur et al., 2017; Manandhar et al., 2018). Eriksson et al. reported greater chondral damage in early ACL reconstruction, while Manandhar et al. and Hur et al., reported a more serious chondral damage in delayed ACL reconstruction.

According to Eriksson and Von Essen, delaying ACL reconstruction surgery increases the risk of meniscal and chondral damage. However, both studies found no significant differences in terms of related injuries, even though the early group had a slightly higher accident rate. The insignificant differences were most likely due to a smaller sample size or a variation in time to surgery between the groups that were too low to affect subsequent injury outcomes.

Manandhar et al. also reported that the early group had a greater rate of lateral meniscus tears, and the delayed group had a higher rate of medial meniscus tears. The higher incidence rate of lateral meniscus tears in the early group from the study is possible not because of the time interval, but as mentioned in most journals, it is associated with the mode of injury (Briem & Snyder-Mackler, 2009; Lohmander et al., 2007; Simon et al., 2015). From the demography of the study, approximately 30% of the patient were in traffic accidents, while the rest were sport-related activity injuries. The traffic accident patient could predispose to the tears of meniscus and chondral damage. The patient could regain knee stability and reduce the chance of additional meniscal and chondral injury, leading to early degenerative joint change, if the ACL reconstruction was done sooner.

Hur et al., reported a higher incidence rate of meniscus tears and chondral damage in the delayed group than in an early group. They concluded that the patients that underwent early ACL reconstruction had a higher chance of repairment for the meniscus tears than delayed ACL reconstruction. For the chondral damage, they found that the insignificant differences between the two groups were more likely due to the time from injury to surgery, more than three months which might be too short as it did not influence the incidence rate of cartilage

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Table 5. Medial Meniscus tears from 4 eligible studies.

No	Author	Medial Meniscus Tear		*P* Value
		Early	Delayed	
1	(Bottoni et al., 2008)	14	15	1
2	(Eriksson et al., 2018)	7	2	NR
3	(Manandhar et al., 2018)	6	20	NR
4	(Hur et al., 2017)	14	24	0.06

Table 6. Lateral Meniscus tears from 4 eligible studies.

No	Author	Lateral Meniscus Tear		*P* value
		Early	Delayed	
1	(Bottoni et al., 2008)	18	9	0.025
2	(Eriksson et al., 2018)	13	10	NR
3	(Manandhar et al., 2018)	12	8	NR
4	(Hur et al., 2017)	15	9	0.06

Table 7. Meniscus Tears from 1 eligible RCT studies.

No.	Author	Meniscus Tears		*P* value
		Early	Delayed	
1	(Meighan et al., 2003)	3	4	NR

(NR: No Reference)

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Table 8. Chondral/Cartilage damage from 3 eligible studies.

No.	Author	Chondral/Cartilage Damage		*P* value
		Early (n)	Delayed (n)	
1	(Eriksson et al., 2018)	10	4	NR
2	(Manandhar et al., 2018)	10	28	NR
3	(Hur et al., 2017)	15	20	0.14

(NR: No Reference)

Table 9. Chondral/Cartilage damage from 1 eligible RCT study.

No	Types of Chondral damage (Bottoni et al., 2008)	Early ACLR (n)	Delayed ACLR (n)	*P* Value
1	Medial Femoral Condyle	0	4	0.11
2	Lateral Femoral Condyle	3	0	0.11
3	Patella	5	0	0.023
4	Femoral Trochlea	1	1	1

damage. The study concludes that early ACL reconstruction is more preferable as the torn of the meniscus in the early group increases the chance of repairment.

Bottoni et al. defined early ACL reconstruction as less than 21 days until three weeks from injury to surgery, while delayed ACL reconstruction was defined as more than six weeks from injury to surgery. They reported an increased incidence rate in lateral meniscus tears and the lateral femoral condyle in the early group, while the delayed group showed an increased incidence rate in the medial meniscus and medial femoral condyle. The increased incidence rate in the delayed group showed that when we delayed the injury to surgery, it could cause instability of the knee which resulted damaged in other structures, in this case, the medial meniscus and medial femoral condyle, because we know that the medial compartment of the knee represents the main weight-bearing of the knee (Briem & Snyder-Mackler, 2009). When there is an insufficiency of the ACL, the medial compartment, which is the medial meniscus and medial femoral condyle, is more stressed,

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which results in more prone to injury (Simon et al., 2015). From the demography of the studies, it was shown that several patients of both early and delayed groups had some traffic accidents that could affect the outcomes of the reconstruction and meniscal and chondral damage. Traffic accidents could cause massive damage/trauma to the knee joint's integrity, resulting in a severe arthrofibrosis and difficult rehabilitation (David Magit et al., 2007). Some patients also had different activity rates, such as active people, athletes, and soldiers, slightly affecting the outcomes. They also stated that meniscus tears in the early group are more manageable to heal than those in the delayed group, owing to the delay in surgery and the possibility of increased damage to the meniscus, which could predispose the inability to repair these tears. The conclusion of the study indicates that ACL reconstruction can be done in the early stage because the result of the functional outcome, Tegner dan Lysholm score, would give an insignificant difference compared to the delayed ACL reconstruction. However, the study stated that not all the reconstruction should be performed in the acute phase with the knee is still inflammation, swelling and having a limited ROM.

DISCUSSION

The main findings of this review show that the early ACL reconstruction has a higher score in both Tegner and Lysholm score than a delayed ACL reconstruction but are not statistically significant. There are three studies by (Bottoni et al., 2008; Chen et al., 2015; Manandhar et al., 2018) that use the Tegner score, and the others are two studies by (Bottoni et al., 2008; Chen et al., 2015) with Lysholm score that reported the probability score which was the statistically insignificant outcome with the value $P > 0.05$. The results obtained from this review show that there are no significant differences in the functional outcome as measured by Tegner and Lysholm.

Early ACL reconstruction is defined as performing ACL reconstruction within six weeks post-injury, while delayed ACL reconstruction is more than six weeks post-injury. This corresponds with previous studies. A study conducted by Goradia et al. showed that patients who had had early ACL reconstruction six weeks after injury had a higher score on the Lysholm scale; however, the difference was not statistically significant (Goradia & Grana, 2001). The mean acute pre-operative period was similarly established as six weeks by Noyes et al. (Noyes & Barber-Westin, 1997). Cipolla et al. also suggested that performing ACL reconstruction within 3-6 weeks after injury is well-timed (Cipolla et al., 1995). A meta-analysis by Smith could not identify any significant differences in functional outcomes score between early reconstruction performed within one month from injury and delayed reconstruction (Smith et al., 2010). They found that the severity of the injury, rather than the time interval between injury to surgery, is an essential aspect to consider when reconstructing the ACL.

The risk of performing early reconstruction is associated with arthrofibrosis development. The definition of arthrofibrosis is not generally acknowledged. Historically, it has been described as stiffness following a knee injury or reconstructive surgery. Past studies found an association between a pre-operative range of motion and arthrofibrosis development. For instance, Mayr et al.. found a correlation between limited pre-operative knee motion and stiffness after ACL reconstruction in a study. They noted that undergoing early ACL reconstruction during the inflammation stage could increase the risk of arthrofibrosis more than delayed ACL reconstruction and caused limited knee ROM. Mayr et al. reported that after ACL reconstruction in 223 patients with

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autologous BPTB graft (75%), the risk of arthrofibrosis incidence was increased when time injury to surgery was within four weeks; however, they also noted that the more crucial risk factors for the incidence of arthrofibrosis than the time between injury to surgery were inflamed knee (swelling, effusion, hyperthermia) and inadequate range of motion before surgery (Mayr et al., 2004) Pre-operative stiffness has been shown to be associated with past operative stiffness. Gage et al., recommended that ACL reconstruction should be delayed until full passive extension with an average time to achieve extension after 18 days after an ACL injury to avoid arthrofibrosis post-operatively (Gage et al., 2019). Arthrofibrosis remains a rare but potentially devastating complication after an ACL reconstruction, an estimation of 2% of patients who had post-operative stiffness required an intervention. Contrary, according to Sander et al., patients who underwent ACL reconstruction beyond four weeks of injury had a significantly higher risk of arthrofibrosis than patients treated surgically within four weeks (Sanders et al., 2017). A systematic review by Kwok et al., stated that when an ACL reconstruction was performed as early as possible, within one week after an injury, there is no increased risk of the knee stiffness if a modern surgical technique and an accelerated rehabilitation are used (Kwok et al., 2013).

An increase in the meniscus and the chondral lesion may be associated with delayed ACL reconstruction. The result of this review also found an increased incidence rate of the medial meniscus and medial femoral condyle. Ghodadra et al. evaluated 709 individuals who had their ACLs reconstructed. The time from injury to surgery was divided into three cut-offs which were less than four weeks, between 4 and 8 weeks, and more than eight weeks. They discovered that the chronic group (>8weeks) had a considerably higher rate of meniscal tears, particularly in the medial meniscus and medial chondral lesions than the early group (Ghodadra et al., 2013). In their study, Michalitsis et al. found that the risks of developing a high-grade cartilage lesion which was grade III and IV Outerbridge in an ACL-deficient knee repaired more than 12 months from injury to surgery were 5.5 and 12.5 times greater, respectively, as compared to knees that underwent ACL reconstruction less than three months and between 3 and 12 months from injury to surgery (Michalitsis et al., 2015). Chaddia et al. evaluated time to surgery in ACL reconstruction as one of the risk factors for meniscus and cartilage injury and concluded that the increased risk of the injured medial meniscus and decreasing repair rate had a strong relationship with the increasing time to surgery (Chhadia et al., 2011).

A retrospective study by Bierke et al., concluded that if an anatomical surgical technique was used and the patient was operated on in the acute phase without meniscus repair, there was no increased risk of arthrofibrosis. Early and forced movement should be considered while refixing the meniscus at the same time. Before surgery, symptoms of inflammation such as effusion, discomfort, and a motion deficit of fewer than 90 degrees should have resolved, although, in the study, aggressive rehabilitation should be evaluated in ACL reconstruction with simultaneous meniscus repair patients (Bierke et al., 2021).

The findings also showed an increased incidence rate in the lateral meniscus, lateral femoral condyle, and femoral trochlea in the early group compared to the delayed group. The possibility of the increased incidence rate is associated with the mode of injury rather than the time interval from injury to surgery. Feucht et al. retrospectively reviewed 268 patients who had undergone ACL reconstruction. The results indicate that the time interval between injury and surgery has

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no effect on lateral meniscus tears and that other factors other than surgical delay must be responsible for lateral meniscus tears in ACL-injured subjects. In contrast, delayed surgery increases the incidence of medial meniscus tears due to instability (Feucht et al., 2015).

From the previous systematic review that has been published, the majority of them (Deabate et al., 2020; Ferguson et al., 2019; Smith et al., 2010) concluded that the functional outcome of early and delayed ACL reconstruction, particularly Tegner and Lysholm score have no significant differences which are similar to the results of this systematic review although one of them (S. H. Kim et al., 2021) concluded that the Tegner and Lysholm score increased in the early group compared to the delayed group. Increased meniscus tears and cartilage were also found in two systematic reviews (Ferguson et al., 2019; S. H. Kim et al., 2021), although other systematic reviews (Deabate et al., 2020; Smith et al., 2010) stated that there were no significant differences between the two timings. The difference between this systematic review with others is that the cut-off point is six weeks from injury to surgery and the year of the publication.

The review suggests that the ACL reconstruction can be performed in the early phase. With the advance in surgical methods, understanding of grafts, and the anatomy of the knee for drilling structure and others, it can also be performed safely with rehabilitation and minimum side effects. With a proper and accurate diagnosis and immediate intervention, patients can return to sport or work sooner. Regardless of the timing of reconstruction, pre-operative management, early mobilization, and aggressive rehabilitation are important and should be done in both early and delayed ACL reconstruction.

The strength of the systematic review is that it mostly used RCT studies which are relatively objective in terms of bias compared to other studies. Another strength of the review is that the cut-off point in the timing of the studies is well defined as early ACL reconstruction is less than six weeks while delayed ACL reconstruction is more than six weeks. The studies can provide a better understanding of the cut-off timing of early and delayed ACL reconstruction. Unfortunately, the studies have some limitations. The limitation of this review is associated with the outcome of this review that only describes descriptively, not analytically, using a meta-analysis review which will be more objective. Second, there is a heterogeneous time regarding post-operative follow-up in each RCT study. Third, there is a limited amount of RCT studies published throughout the years, resulting in limited information regarding when the optimal time for surgery. Therefore, it is still debatable until now. Furthermore, some of the studies included in the systematic review have some bias concerns that still need improvement.

CONCLUSION

The review concludes that whether the patient performs early or delayed ACL reconstruction, the Tegner and Lysholm scores are similar. Therefore, early ACL reconstruction can be optimal for patients who will undergo reconstruction since delayed ACL reconstruction increases the risk of medial meniscus tears and medial femoral condyle damage. The following systematic review can be done with a meta-analysis approach as the analysis can be more objective.

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