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The influence of graft choice on isokinetic muscle strength 4-24 months after anterior cruciate ligament reconstruction.

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Abstract

Purpose: Regaining adequate strength of the quadriceps and hamstrings after anterior cruciate ligament (ACL) reconstruction is important for maximizing functional performance. However, the outcome of muscle strength after either BPTB or hamstrings autograft is unclear given the plethora of published studies that report post-operative muscle strength. The purpose of this study was to systematically compare the muscle strength of patients who have undergone ACL reconstruction using either Bone Patellar Tendon Bone (BPTB) or Hamstrings (HST) autograft.

Methods: The databases of MEDLINE, Cinahal and EMBASE were systematically searched for articles that report muscle strength outcome following ACL reconstruction. The quality of the studies was evaluated and a meta-analysis of the muscle strength outcomes was conducted on reported data.

Results: Fourteen studies were included in this systematic review; eight Randomized Control Studies (RCT) and six non-Randomized Control Studies (non-RCT). A meta-analysis was performed involving eight of the included studies (4 RCTs & 3 non-RCTs). At 60^0/sec and 180^0/sec, patients with BPTB graft showed a greater deficit in extensor muscle strength and lower deficit in flexor muscle strength compared with patients with HST.

Conclusion: This systematic review of Level III evidence showed that isokinetic muscle strength deficits following ACL reconstruction are associated with the location of the donor site. These deficits appear to be unresolved up to two years after ACL reconstruction.

Keywords: ACL reconstruction, isokinetic muscle strength, systematic review, meta-analysis.

Level of evidence; III

Introduction

Rupture of the Anterior Cruciate Ligament (ACL) is one of the most common athletic injuries of the knee [17, 60, 14]. Lyman et al recently estimated that the frequency of ACL reconstruction is increasing in the United States and that younger patients are at a higher risk for re-rupture of the ACL graft [4|]. The consequences of an ACL rupture to the function of the involved limb are multifaceted and possibly include a decrease in joint stability, muscle weakness, meniscal damage, pain and, in the long term, development of osteoarthritis [61, 30, 72, 66, 54, 29, 46, 51, 58, 47, 50]. In an attempt to prevent these deficits in joint function, reconstruction of ACL has become one of the most common orthopaedic interventions. Although many different surgical techniques and an increasing number of graft types have been described in the literature, autograft reconstruction using Bone Patellar Tendon Bone (BPTB) or Hamstrings Tendon (HST) appear to be the most popular grafts choices [4, 12, 23, 24, 26, 53, 45].

Despite, a plethora of recently published comparative studies, the relative effectiveness of the different grafts used for the reconstruction of ACL remains unclear [4, 6, 7, 11, 12, 15, 23, 24, 27, 33]. Maximizing knee stability after ACL reconstruction is one of the most important criteria for the choice of graft. Postoperative stability allows the performance of rehabilitation protocols that aimed to restore normal function and thus safe and fast return to pre-injury activity level [48]. The superior post-operative stability afforded by BPTB autograft is likely to be related to enhanced healing from bone-to-bone attachments [3, 59, 71]. However, increased donor- site morbidity has been reported after harvesting BPTB autograft. Specifically, anterior knee pain, quadriceps weakness and worse results in functional tests along with an increased rate of patellar fractures have been observed [43, 44, 40, 27, 49]. Harvesting of the HST autograft may avoid some of these post-operative problems, but is associated with hamstring muscle weakness and slower healing of the graft attachment site that may predispose patients to higher risk of re-rupture [69, 2, 65]. Thus, both of these graft choices are limited in the their ability to restore knee function for people with ACL rupture, and there is consequently an ongoing debate concerning the superiority of one graft over the other. An imporant aspect of this debate is the outcome of lower limb muscle strength following either of these graft types.

Evaluation of muscle stength can be accomplished by using functional tools (incorporating hop or twisting) or single joint evaluation tools [52, 9, 2]. One of the most commonly used tools that is reliable in assessing single-joint muscle strength is isokinetic dynamometry [56, 19]. In comparison to other measures of strength, isokinetic dynamometry allows quantification of muscle strength deficit through the assesement of specific parameters like work per unit, torque at spefici joint angles and the widely used peak torque value [56, 19, 66, 22]. In the majority of studies, that investigate muscle strength following ACL recontruction, the strength of the operated limb is recorded as a deficit or gain in comparison to the contralateral healthy limb.

Restoration of similar muscle strength between reconstructed and healthy knee, is considered to be a critical factor for a safely return back to dynamic activities [48]. Thus, the restoration of muscle strength ratio between the operated and contralateral limbs for both the quadriceps and the hamstrings is crucial αfter an ACL reconstruction for a fast an uneventful return to pre-injury activities [48]. There is evidence that muscular recovery is closely related to pre-operative muscle strength the time between injury and reconstruction and the pre and post surgery rehabilitation [22, 55, 8]. In addition, changes in the sensory system with ACL reconstruction, such as alterations in the somatosensory evoked potentials or the development of inconsistent postural synergies, may also influence muscle [18].

Although many authors have compared lower limb muscle strength in patients with ACL reconstruction after either BPTB or HST grafts, the plethora of information is difficult to interpret. Therefore, a systematic review of the literature is warranted to synthesize reported findings of the isokinetic muscle strength in studies comparing ACL reconstruction using either BPTB or HST autografts. Clarification of muscle strength recovery after ACL reconstruction using either graft type will enhance decision-making with regards to graft choice and rehabilitation.

Material and methods

A thorough search of the databases MEDLINE, Cinahal and EMBASE for articles that compared muscle strength using isokinetic dynamometry between patients that had undergone ACL reconstruction with either BPTB or HST autograft was completed in September 2009. Full text articles published in English were searched using variations and combinations of the following terms: anterior cruciate ligament reconstruction, knee reconstruction, dynamometry, strength, weakness, and torque.

To be included in this review, articles must have:

- compared two groups of patients that had undergone ACL reconstruction - one of the groups must have received BPTB autograft and one HST autograft
- evaluated knee flexor and extensor isokinetic muscle strength between 4 and 24 months after ACL reconstruction surgery
- been published in English language.

The following criteria were used to exclude articles from the systematic review Studies were not included if:

- studies did not include original data.
- any participants had undergone revision of ACL
- participants had undergone multiple-ligament reconstruction.

Studies of different methodological design were included in this systematic review and are subject to different biases. Therefore, multiple tools were used to assess the quality of included studies. Randomized Control Trials (RCT) were assessed for quality using the PEDRO scale [20] which assesses the quality of studies based on 11 criteria. All other study designs were assessed using the tool described by Downs and Black [21]. The assessment of methodological quality was completed by 2 reviewers independently. Disagreement was resolved by discussion with a 3rd reviewer.

Extraction of Data

Two independent reviewers read all of the articles in the final yield and systematically extracted pre-defined relevant data. Demographic details of participants were extracted from all articles in addition to the descriptive variables of isokinetic strength assessment at all speeds.

A meta-analysis was conducted on the findings of isokinetic evaluations at testing speeds of 60^0/sec and 180^0/sec an average of 12 months after ACL reconstruction surgery. To be included in the meta-analysis, the mean and measures of variability must have been reported. Wherever the outcomes were not presented in a form suitable for direct inclusion in the meta-analysis, the corresponding authors were contacted by email in an attempt to obtain the data required for meta-analysis (numbers of participants, mean scores and SDs).

Statistical Analysis

Muscle strength of the operated limb was extracted when reported either as a percentage of the uninvolved limb (i.e Limb Symetry Index), or as a percentage deficit of the uninvolved limb (100 X deficit of injured leg/deficit of uninjured leg).

Mean differences and 95% confidence intervals were calculated from the extracted data. Random-effects models was used to pool data. Review Manager 5 (Version: 5.0.24) software was used for the calculation of effect sizes.

Results

A total of 1532 published studies were identified in the original search of databases. Following the application of inclusion and exclusion criteria a final yield of 14 studies were included in this systematic review as presented in the flow chart (Appendix 1). Of the 14 included studies eight were RCT, and six non Randomized Control Trials – (non-RCT).

The study design and the characteristics of each study included in this review are presented in Table 1.

Quality assessment of the RCTs and the non- RCTs are presented in table 2 and 3. Inadequate randomization may allow the introduction of bias, however only 3 of the 8 RCTs reported the process of patient randomization. Although blinding of the patient and surgeon is not always possible in this field of research, only 2 studies reported that assessors were blinded to the group allocation of patients.

Muscle strength outcomes

The muscle strength outcomes that were reported from all studies are presented in Tables 4 (for RCTs) and 5 (for non-RCTs).

Six studies [5, 11, 12, 7, 16, 68] found no significant difference between BPTB and HST for isokinetic muscle strength for knee extensors or knee flexors at follow up times between 4 and 24 months after reconstruction.

Four studies [26, 10, 42, 35] found significant extensor muscle strength deficit in the operated limb in the BPTB group compared to the HST group at different follow up times between 4 and 24 months. In addition six studies [10, 26, 42, 31, 70, 13] found significant deficits of the flexor muscles in the operated limb in HST group compared to the BPTB group at different follow-up times between 4 and 24 months.

Sufficient data were provided in only four of the RCTs [11, 16, 26, 42] and three of the non-RCTs [13, 68, 70] to conduct a meta-analysis on findings 12 months after ACLR.

Figures 1 and 2 show forest plots that summarize quadriceps and hamstring strength for patients at a speed of 60°/sec. There were 3 articles where muscle strength of the operated limb was reported as a percentage of the uninvolved limb. For patients with HST graft, quadriceps strength was an average of 9% stronger and hamstrings strength was 8% weaker than patients with BPTB graft. Two articles reported muscle strength of the operated limb as percentage deficit of the uninvolved limb. Similarly, patients with HST graft showed a 3% lower deficit in quadriceps strength and 9% greater deficit in hamstrings strength than patients with BPTB.

Figures 3 and 4 show forest plots that summarize quadriceps and hamstring strength for patients at a speed of 180°/sec. There were 2 articles where muscle strength of the operated limb was reported as a percentage of the uninvolved limb. For patients with HST graft, quadriceps strength was an average of 7% stronger and hamstrings strength was 9% weaker than patients with BPTB graft. Two articles reported muscle strength of the operated limb as percentage deficit of the uninvolved limb. Similarly, patients with HST graft showed a 1% lower deficit in quadriceps strength and 20% greater deficit in hamstrings strength than patients with BPTB.

Discussion

The most important finding of the present study was the apparent trend for muscle weakness that is specific to the graft donor site following ACL reconstruction. The meta-analysis performed showed that extensor muscle strength deficit exists in ACL reconstructed knees using BPTB autograft and that flexor muscle strength deficit exists in ACL reconstructed knees using HST autografts, 12 months post operatively.

Not all studies reported muscle weakness in one group of patients or the other. Six studies [5, 11, 12, 7, 16, 68] did not find significant differences in extensor or flexor muscle strength between BPTB or HST group, at any testing speed (60°/sec, 120°/sec, 180°/sec, 240°/sec, 300°/sec). In contrast, eight studies found differences between groups. Significant quadriceps muscle strength deficit in BPTB group was observed in four studies [10, 42, 26, 35] and six studies found significant hamstrings muscle deficits in HST group [10, 42, 26, 13, 31, 70]. All of the studies evaluated patients between 4 and 24 months after surgery and muscle weakness was found to persist throughout this period. These findings are in agreement with other reviews [57, 19], that have concluded that the graft site affects muscle strength.

There is an obvious trend for quadriceps deficit at BPTB group compared to HST group and a trend for hamstrings deficit in HST group compared to BPTB group at 12 months post-operative. The results of the meta-analysis showed that difference between BPTB and HST group for extensor muscle strength was nearly 10% at the speed of 60^0/sec and 180^0/sec and that for flexor muscle strength was 20% at 180^0/sec. It is clinically accepted that anything less than a 10% difference between limbs is considered inconsequential [39]. Although the difference in quadriceps strength between sides was not greater than 10%, the difference in hamstring strength exceeded this clinical limt. It is difficult to know what the implications for this asymmetry between limbs are, given that most research has focused on investigating asymmetrical quadriceps weakness. Further research is therefore needed to establish whether such a large hamstring weakness in the operated limb of patients with HST graft has any clinical relevance.

The apparent trend for muscle strength weakness related to the donor site may be explained by previous research. It seems that harvesting the patellar tendon autograft during the ACL reconstruction may alter the length-tension relationship of the extensor mechanism [32] and consequently contribute to extensor muscle strength deficit. It is also described that muscle function might be altered due to the attenuation of the gamma loop function caused by the initial ACL injury and that is not restored after the ACL reconstruction. The mechanoreceptors located within the ACL play an important role in enhancing the activity of gamma motor neurons (contributing, to a normal muscle function) [36, 62, 38], however this mechanism is not restored with ACL reconstruction, and may therefore also play a role in the extensor muscle weakness seen after harvesting the BPTB graft. Furthermore, knee pain and effusion have been documented up to 12 months following ACL reconstruction and could alter the neural control of the quadriceps [64, 37, 67].

Strength deficits in the knee flexor muscles may be more easily explained. There is evidence that tendon fibers can regenerate following harvesting of the hamstring tendon to become similar to healthy and non harvested fibers [25, 28]. However, Hioki et al [34] found an atrophy of hamstrings' muscle fibers as well as hypertrophy of the semimembranosus and biceps muscles, after harvesting the hamstrings tendon. Moreover, they demonstrated that after harvesting the hamstrings tendon the semitendinosus muscle assumes different shapes and movements and that each pattern was related to different knee flexor strength. It is not clear how these changes in morphology affects muscle and knee function.

Regardless of the physiological explanations for muscle weakness, it is clear that restoration of muscle strength must focus on increasing muscle strength following ACL reconstruction to maximize functional outcomes. In particular, it appears that patients with different graft types may be susceptible to muscle strength that is specific to graft type. These findings suggest that rehabilitation that addresses muscle weakness specfic to graft type may enhance strength outcomes after ACL reconstruction.

The findings of muscle weakness related to graft donor site were not consistent throughout all of the studies included in this review. There were some methodological differences between these studies that may explain this inconsistency. The method of randomization was not reported or was insufficient for the most of the RCTs. Only three [11, 26, 42] used a specific random allocation, which verifies that allocation was concealed. This allows for a bias that potentially could alter the findings of these studies. Although almost all RCTs assessed patients with the same activity level, three did not report the sex of the patients despite the plethora of information that gender influences outcome after ACL reconstruction. Therefore, the generalizability of the findings reported in these studies may be limited [1, 63]. Although blinding is one of the most important factors to limit bias in a RCT, no patients or therapist and only 2 studies reported that assessors were blinded to patient group allocation. Only in the trials of Aglietti et al [5] and Maletis et al [42] the assessors were blinded. Again, the potential for bias in the findings of those studies that did not blind assessors needs to be considered. The studies that were not RCTs were subjected to different biases. Because patients in these studies were not randomized to receive either a BPTB or HST graft, it is important that both groups be similar at baseline on factors that may confound muscle strength findings. However, 3 studies did not adequately describe that groups were similar on important demographic characteristics such as height and weight. These limitations need to be considered when interpreting the findings of this review. Future work that compares the muscle strength outcomes between patients with either BPTB and HST ACL reconstruction need to consider these factors when designing future research.

There are some limitations that need to be considered when interreting the findings of this review. The meta-analysis was limited to only half of the studies included in the review because of disparity in the parameters of isokientic testing (for example, the speed of testing, and the time since surgery). Nevertheless, studies that did not evaluate muscle strength according to the strict criteria were still included in the systematic review and contribute significantly to the information that details recovery of muscle strength following ACL reconstruction.

Conclusions

Although not all studies reported muscle strength differences between patients with either BPTB or HST graft ACL reconstruction, there was an obvious trend towards greater muscle weakness that was dependent on the graft donor site. Rehabilitation that is specific to this difference in muscle strength between graft types is needed.

Furthermore, more high quality studies need to be conducted assessing the muscle strength recovery after the reconstruction of the torn ACL, in order to reveal a potential superiority of a graft type over the other graft options.

Table 1. Characteristics of the included studies. (RCT-> Randomized Control StudyNon RCT -> non, Randomized Control Study, BPTB-> Bone Patella Tendon Bone, HST-> Hamstring (when is not specified if the graft was semitendinosus or somitndinosus/gracilis), ST -> Semitendinosus, ST/G-> semitendinosus/Gracilis, PT-> Patella tendon, IKDC→ International Knee Documentation Committee, KOOS→ Knee injury and Osteoarthritis Outcome Score, VAS scale→ Visual Analog Scale, FL→ Flexion, EX→ Extension, ATT→ Anterior Tibial Translation, ROM→ Range Of Motion, * → We communicated with the author about the sex)

AUTHOR YEAR NATION	STUDY DESIGN	PATIENTS SEX	REHAB PROTOCOL	OUTCOMES	ISOKINETIC MUSCLE STRENGTH OUTCOMES	POST-OPERATIVE FOLLOW UP
Aglietti 2004	RCT	120p 60BPTB (46M/14F) 60 HAST (46M/14F)	Description of the program	KT-1000 IKDC KOOS VAS scale for analyzing subjective knee complaints ROM Functional knee score for anterior knee pain. Radiography	FL/EX Isokinetic at 60 °/sec. 120°/sec. 180°/sec	4, 12 and 24 months
Andersson 2002	Non RCT	45p 22BPTB 23HST No sex mentioned	Shelbourn and Nitz (1990)	-	FL/EX Isokinetic 60°/sec concentric /eccentric	6 and 12 months
Aune 2001	RCT	72P 35BPTB (19M/16F) 37HST (21M/16F)	Shelbourn and Nitz (1990)	KT-1000 VAS scale for patient satisfaction VAS scale for kneeling problems Cincinnati knee score system Stairs Hopple test Single-legged hop test	FL/EX Isokinetic at 60 °/sec, 240°/sec	6, 12, and 24 months
Beard 2001	RCT	45p 22BPTB (18M/4F) 23HST (15M/8F) *	Shelbourn and Nitz (1990)	KT1000 IKDC ATT Lysholm score, Tegner activity score,	FL/EX Isokinetic at 60°/sec	6 and 12 months
Bizzini 2006	Non RCT	153p 87BPTB (54M/ 33F) 66HST (45M/21F)	Description of the program	KT 1000	FL/EX Isokinetic at180°/sec, 300°/sec	11 months

Beynnon 2002	RCT	52p 26BPTB (18M/10M) 26HST (13M/15F)	Description of the program	KT 1000, Pivot Shift, IKDC ROM Tegner, One-leg-hop, duckwalking, squat.	FL/EX Isokinetic at 60°/sec 180°/sec, 240°/sec	2,4,6,12 and 36 months
Carter 1999	RCT	l06p 38 PT, 33 ST 35 ST/G No sex mentioned	Description of the program	-	FL/EX Isokinetic at 180°/sec, 300°/sec	6 months
Feller 2003	RCT	65p 34BPTB (8F/23M) 31HST (10F/24M)	Shelbourn and Nitz (1990)	KT-1000, Lachmann IKDC Cincinnati Scores Anterior knee pain	FL/EX Isokinetic at 60°/sec, 240°/sec	4, 8, and 12 months
Gobbi 2003	Non RCT	80p 40BPTB 40HST No sex mentioned	Description of the program	CA 4000 IKDC Tegner scale Noyes scale Lysholm VAS scale for pain ROM	FL/EX Isokinetic at 60°/sec, 180°/sec, 300°/sec	3, 6, 12 and 36 months
Jansson 2003	RCT	99p BPTB 51 HST 48 No sex mentioned	Description of the program	CA 4000 IKDC Lachman and pivot shift Lysholm knee score Tegner activity level Kujala patellofemoral score MRI	FL/EX Isokinetic at 60°/sec, 180°/sec	12 and 24 months
Maletis 2007	RCT	99p 46BPTB (31M/15F) 53 HAST (45M/8F)	Description of the program	Kt1000 IKDC Lysholm Tegner Physical examination ROM Single hop test Short form SF 36	FL/EX Isokinetic at 60°/sec 180°/sec ,300°/sec ABD/ADD 60°/sec 180°/sec 300°/sec INT/EXT rot 60°/sec 180°/sec 300°/sec	6,12 and 24 months
Two 2005	Non RCT	68p 34HST 34BPTB No sex specified	Description of the program	KT 1000 IKDC	FL/EX Isokinetic at 60°/sec 240°/sec	3, 6, and 24 months
Webster 2005	Non RCT	34p 17BPTB (16M/1F) 17HST (16M/1F) 17 CONTROL	Description of the program	IKDC KT 1000 Kinematic walking up/down Kinetic walking up/down	FL/EX Isokinetic at 60°/sec	BPTB-11 months HST-9.3 months
Witvrouw 2001	Non RCT	34p17BPTB (10M/7F) 32HST (17M/15F)	Description of the program	ROM KT 1000 Lysholm, Tegner, Kujala scales	FL/EX Isokinetic at 60°/sec 240°/sec	6weeks 3,6 and 12 months

Table 2. Results from the methodological assessment of the eight RCTs using the Pedro scale. (Y: Yes N: No)

Pedro Criteria	Item no.1	Item no.2	Item no.3	Item no.4	Item no.5	Item no.6	Item no.7	Item no.8	Item no.9	Item no.10	Item no.11
	Eligibility criteria specified	Subjects randomly allocated to groups	Concealed allocation	Baseline data	Blinding of subjects	Blinding of therapists	Blinding of assessors	Key outcome obtained from > 85% of the subjects	Intention to treat	Appropriate statistics	Measures of variability
First author (year)											
Agglieti et al 2004	Y	N	N	Y	N	N	Y	Y	Y	Y	N
Aune et al 2001	Y	N	N	Y	N	N	N	Y	Y	Y	N
Beard et al 2001	Y	Y	Y	Y	N	N	N	Y	Y	Y	Y
Beynnon et al 2002	Y	N	N	Y	N	N	N	Y	Y	Y	N
Carter et al 1999	N	N	N	N	N	N	N	Y	N	Y	Y
Feller et al 2003	Y	Y	Y	Y	N	N	N	Y	Y	Y	Y
Jansson et al 2003	Y	N	N	Y	N	N	N	Y	Y	Y	N

Maletis et al 2007	Y	Y	Y	Y	N	N	Y	Y	Y	Y	N

Table 3. Results from the methodological assessment of the six non-RCTs using the Downs and Black scale. (Y: Yes N: No)

Downs & Black criteria	***Item no. 1***	***Item no. 2***	***Item no. 3***	***Item no. 5***	***Item no. 6***	***Item no. 7***	***Item no. 12***	***Item no. 16***	***Item no. 18***	***Item no. 25***	***Item no. 27***
	Clear aim	Outcomes described	Patients described	Confounders described	Findings clearly described	Measures of random variability	Patients represent population	Planned analysis	Appropriate statistics	Modification for confounders	Power calculation
First author (year)											
Anderson 2002	Y	Y	Y	Y	Y	Y	Y	X	Y	X	N
Bizzini 2006	Y	Y	Y	Y	Y	Y	Y	X	Y	X	N
Gobbi 2003	Y	Y	N	N	Y	N	Y	X	Y	X	N
Tow 2005	Y	Y	N	N	Y	N	Y	X	N	X	N
Webster 2005	Y	Y	Y	Y	Y	Y	Y	X	Y	X	N
Witvrow 2001	Y	Y	Y	Y	Y	Y	N	X	Y	Y	N

Table 4. Muscle strength outcomes of the included RCT, at the time between 4-24 months. (ND: no difference between groups (BPTB vs HST) for flexion/extension strength, - : No evaluated)

RCT	Isokinetic-Flexion/Extension					
AUTHOR YEAR	4 months	6 months	8 months	11 months	12 months	24 months
Aglietti 2004	ND between groups at 60°/sec, 120°/sec, 180°/sec	—	—	—	ND between groups at 60°/sec, 120°/sec, 180°/sec	ND between groups at 60°/sec, 120°/sec, 180°/sec
Aune 2001	—	Extension deficit in BPTB group at 60°/sec, 240°/sec Flexion deficit in HST group at 240°/sec	—	—	Flexion deficit in HST group at 60°/sec 240°/sec	Flexion deficit in HST group at 60°/sec 240°/sec
Beard 2001	—	ND between groups at 60°/sec	—	—	ND between groups at 60°/sec	—
Beynnon 2002	—	—	—	—	ND between groups at 60°/sec, 180°/sec, 240°/sec	—
Carter 1999	—	ND between groups at 180°/sec, 300°/sec	—	—	—	—
Feller 2003	Extension deficit in BPTB group at 240°/sec	—	Extension deficit in BPTB group at 60°/sec, 240°/sec	—	Flexion deficit in HST group at 60°/sec	—
Jansson 2003	—	—	—	—	Extension deficit in BPTB group at 60°/sec	ND between groups at 60°/sec, 180°/sec
Maletis 2007	—	Extension deficit in BPTB group at 60°/sec, 180°/se, 300°/sec Flexion deficit in HST group at 180°/sec	—	—	Extension deficit in BPTB group at 60°/sec, 180°/se, 300°/sec Flexion deficit in HST group at 180°/sec, 300°/sec	Extension deficit in BPTB group at 60°/sec, 300°/sec Flexion deficit in HST group at 180°/sec

Table 5. Muscle strength outcomes of the included non-RCT, at the time between 4-24 months. (ND: no difference between groups (BPTB vs HST) for flexion/extension strength, - : No evaluated)

NRCT	Isokinetic-Flexion/Extension					
AUTHOR YEAR	4 months	6 months	8 months	11 months	12 months	24 months
Andersson 2002	—	ND between groups at 60°/sec	—	—	ND between groups at 60°/sec	—
Bizzini 2006	—	—	—	Flexion deficit in HST group at 180°/sec, 300°/sec	—	—
Gobbi 2007	—	—	—	—	Flexion deficit in HST group at 60°/sec, 180°/sec, 300°/sec	—
Two 2009	—	Trend towards HST flexion muscle weakness	—	—	—	Trend towards HST flexion muscle weakness
Webster 2005	—	—	9.3-11 Months ND between groups at 60°/sec, 240°/sec		—	—
Witvrow 2001	—	Flexion deficit in HST group at 60°/sec,	—	—	Flexion deficit in HST group at 60°/sec, 240°/sec	—

Figure Legents

Figure 1

Forest plots for isokinetic extensor muscle strength at 60°/sec at 12 months.

BPTB: Bone Patellar Tendon Bone, HST: Hamstring, SD: standard deviation, CI: confidence interval

Figure 2

Forest plots for isokinetic flexor muscle strength at 60°/sec at 12 months.

BPTB: Bone Patellar Tendon Bone, HST: Hamstring, SD: standard deviation, CI: confidence interval

Figure 3

Forest plots for isokinetic extensor muscle strength at 180°/sec at 12 months

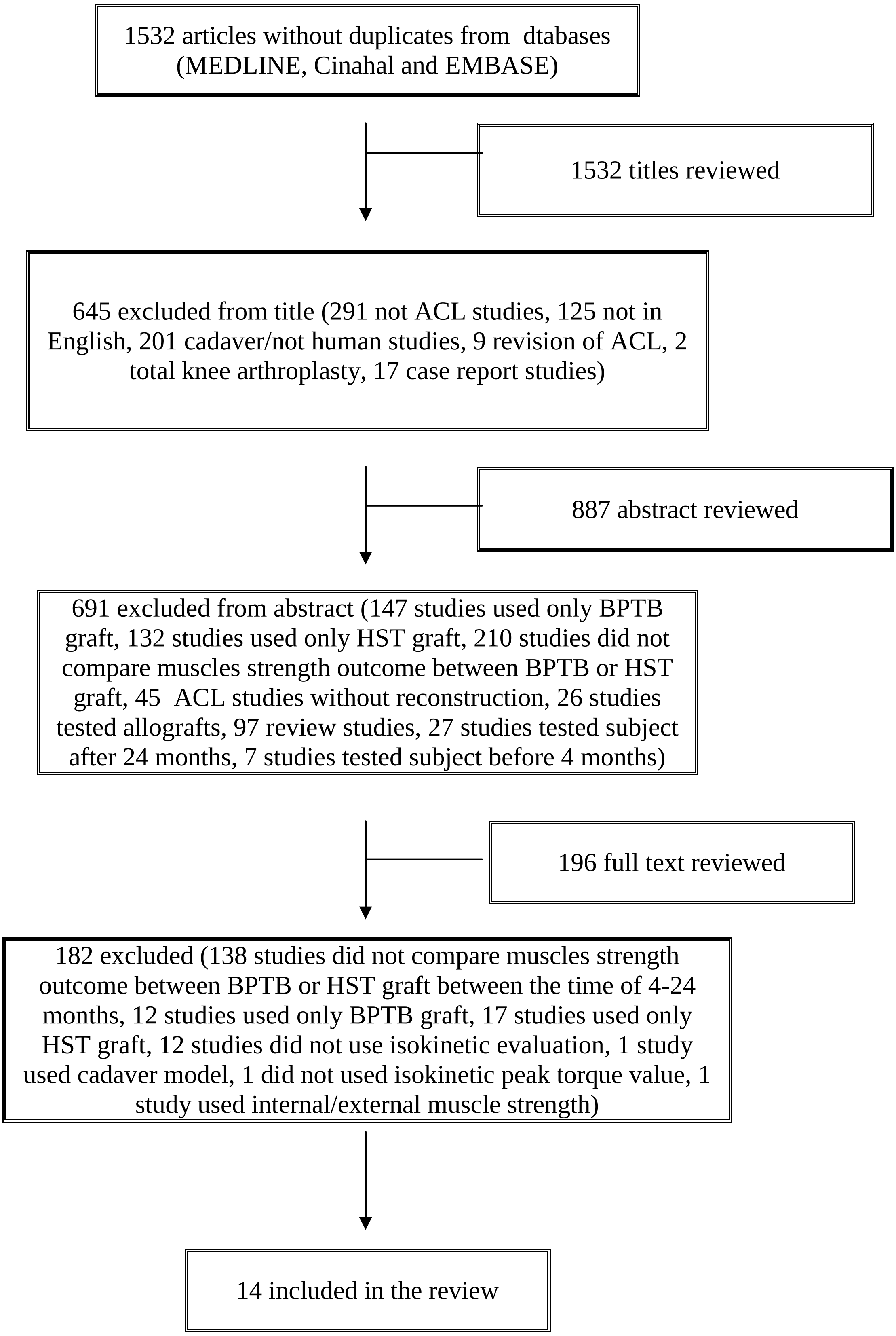
BPTB: Bone Patellar Tendon Bone, HST: Hamstring, SD: standard deviation, CI: confidence interval

Figure 4

Forest plots for isokinetic flexor muscle strength at 180°/sec at 12 months

BPTB: Bone Patellar Tendon Bone, HST: Hamstring, SD: standard deviation, CI: confidence interval

Appendix 1. Flow chart of the search and included and excluded studies.



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References

1. Ageberg E, Forssblad M, Herbertsson P, Roos E M (2010) Sex Differences in Patient-Reported Outcomes After Anterior Cruciate Ligament Reconstruction: Data From the Swedish Knee Ligament Register. Am J Sports Med 38:1334-1342

2. Ageberg E, Roos H P, Silbernagel K G, Thomee R, Roos E M (2009) Knee extension and flexion muscle power after anterior cruciate ligament reconstruction with patellar tendon graft or hamstring tendons graft: a cross-sectional comparison 3 years post surgery. Knee Surg Sports Traumatol Arthrosc 17: 162-169

3. Aglietti P, Buzzi R, Giron F, Simeone A J, Zaccherotti G (1997) Arthroscopic-assisted anterior cruciate ligament reconstruction with the central third patellar tendon. A 5-8-year follow-up. Knee Surg Sports Traumatol Arthrosc 5: 138-144

4. Aglietti P, Buzzi R, Zaccherotti G, De B P (1994) Patellar tendon versus doubled semitendinosus and gracilis tendons for anterior cruciate ligament reconstruction. Am J Sports Med 22: 211-217

5. Aglietti P, Giron F, Buzzi R, Biddau F, Sasso F (2004) Anterior cruciate ligament reconstruction: bone-patellar tendon-bone compared with double semitendinosus and gracilis tendon grafts. A prospective, randomized clinical trial. J Bone Joint Surg Am 86-A: 2143-2155

6. Anderson A F, Snyder R B, Lipscomb A B, Jr (2001) Anterior cruciate ligament reconstruction. A prospective randomized study of three surgical methods. Am J Sports Med 29: 272-279

7. Anderson J L, Lamb S E, Barker K L, Davies S, Dodd C A, Beard D J (2002) Changes in muscle torque following anterior cruciate ligament reconstruction: a comparison between hamstrings and patella tendon graft procedures on 45 patients. Acta Orthop Scand 73: 546-552

8. Andersson D, Samuelsson K, Karlsson J (2009) Treatment of anterior cruciate ligament injuries with special reference to surgical technique and rehabilitation: an assessment of randomized controlled trials. Arthroscopy 25: 653-685

9. Augustsson J, Thomeé R, Karlsson J (2004) Ability of a new hop test to determine functional deficits after anterior cruciate ligament reconstruction. Knee Surg Sports Traumatol Arthrosc 12:350-356.

10. Aune A K, Holm I, Risberg M A, Jensen H K, Steen H (2001) Four-strand hamstring tendon autograft compared with patellar tendon-bone autograft for anterior cruciate ligament reconstruction. A randomized study with two-year follow-up. Am J Sports Med 29: 722-728

11. Beard D J, Anderson J L, Davies S, Price A J, Dodd C A (2001) Hamstrings vs. patella tendon for anterior cruciate ligament reconstruction: a randomised controlled trial. Knee 8: 45-50

12. Beynnon B D, Johnson R J, Fleming B C, Kannus P, Kaplan M, Samani J, Renstrom P (2002) Anterior cruciate ligament replacement: comparison of bone-patellar tendon-bone grafts with two-strand hamstring grafts. A prospective, randomized study. J Bone Joint Surg Am 84-A: 1503-1513

13. Bizzini M, Gorelick M, Munzinger U, Drobny T (2006) Joint laxity and isokinetic thigh muscle strength characteristics after anterior cruciate ligament reconstruction: bone patellar tendon bone versus quadrupled hamstring autografts. Clin J Sport Med 16: 4-9

14. Bollen S R, Scott B W (1996) Rupture of the anterior cruciate ligament--a quiet epidemic? Injury 27: 407-409

15. Brand J, Jr., Weiler A, Caborn D N, Brown C H, Jr., Johnson D L (2000) Graft fixation in cruciate ligament reconstruction. Am J Sports Med 28: 761-774

16. Carter T R, Edinger S (1999) Isokinetic evaluation of anterior cruciate ligament reconstruction: hamstring versus patellar tendon. Arthroscopy 15: 169-172

17. Childs S G (2002) Pathogenesis of anterior cruciate ligament injury. Orthop Nurs 21: 35-40

18. Courtney C, Rine R M, Kroll P (2005) Central somatosensory changes and altered muscle synergies in subjects with anterior cruciate ligament deficiency. Gait Posture 22: 69-74

19. Dauty M, Tortellier L, Rochcongar P (2005) Isokinetic and anterior cruciate ligament reconstruction with hamstrings or patella tendon graft: analysis of literature. Int J Sports Med 26: 599-606

20. de Morton N A (2009) The PEDro scale is a valid measure of the methodological quality of clinical trials: a demographic study. Aust J Physiother 55: 129-133

21. Downs S H, Black N (1998) The feasibility of creating a checklist for the assessment of the methodological quality both of randomised and non-randomised studies of health care interventions. J Epidemiol Community Health 52: 377-384

22. Eitzen I, Holm I, Risberg M A (2009) Preoperative quadriceps strength is a significant predictor of knee function two years after anterior cruciate ligament reconstruction. Br J Sports Med 43: 371-376

23. Ejerhed L, Kartus J, Sernert N, Kohler K, Karlsson J (2003) Patellar tendon or semitendinosus tendon autografts for anterior cruciate ligament reconstruction? A prospective randomized study with a two-year follow-up. Am J Sports Med 31: 19-25

24. Eriksson K, Anderberg P, Hamberg P, Olerud P, Wredmark T (2001) There are differences in early morbidity after ACL reconstruction when comparing patellar tendon and semitendinosus tendon graft. A prospective randomized study of 107 patients. Scand J Med Sci Sports 11: 170-177

25. Eriksson K, Kindblom L G, Hamberg P, Larsson H, Wredmark T (2001) The semitendinosus tendon regenerates after resection: a morphologic and MRI analysis in 6 patients after resection for anterior cruciate ligament reconstruction. Acta Orthop Scand 72: 379-384

26. Feller J A, Webster K E (2003) A randomized comparison of patellar tendon and hamstring tendon anterior cruciate ligament reconstruction. Am J Sports Med 31: 564-573

27. Feller J A, Webster K E, Gavin B (2001) Early post-operative morbidity following anterior cruciate ligament reconstruction: patellar tendon versus hamstring graft. Knee Surg Sports Traumatol Arthrosc 9: 260-266

28. Ferretti A, Conteduca F, Morelli F, Masi V (2002) Regeneration of the semitendinosus tendon after its use in anterior cruciate ligament reconstruction: a histologic study of three cases. Am J Sports Med 30: 204-207

29. Finsterbush A, Frankl U, Matan Y, Mann G (1990) Secondary damage to the knee after isolated injury of the anterior cruciate ligament. Am J Sports Med 18: 475-479

30. Fischer-Rasmussen T, Jensen P E (2000) Proprioceptive sensitivity and performance in anterior cruciate ligament-deficient knee joints. Scand J Med Sci Sports 10: 85-89

31. Gobbi A, Mahajan S, Zanazzo M, Tuy B (2003) Patellar tendon versus quadrupled bone-semitendinosus anterior cruciate ligament reconstruction: a prospective clinical investigation in athletes. Arthroscopy 19: 592-601

32. Herzog W, Longino D, Clark A (2003) The role of muscles in joint adaptation and degeneration. Langenbecks Arch Surg 388: 305-315

33. Hiemstra L A, Webber S, MacDonald P B, Kriellaars D J (2000) Knee strength deficits after hamstring tendon and patellar tendon anterior cruciate ligament reconstruction. Med Sci Sports Exerc 32: 1472-1479

34. Hioki S, Fukubayashi T, Ikeda K, Niitsu M, Ochiai N (2003) Effect of harvesting the hamstrings tendon for anterior cruciate ligament reconstruction on the morphology and movement of the hamstrings muscle: a novel MRI technique. Knee Surg Sports Traumatol Arthrosc 11: 223-227

35. Jansson K A, Linko E, Sandelin J, Harilainen A (2003) A prospective randomized study of patellar versus hamstring tendon autografts for anterior cruciate ligament reconstruction. Am J Sports Med 31: 12-18

36. Johansson H, Sjolander P, Sojka P (1991) Receptors in the knee joint ligaments and their role in the biomechanics of the joint. Crit Rev Biomed Eng 18: 341-368

37. Kartus J, Movin T, Karlsson J (2001) Donor-site morbidity and anterior knee problems after anterior cruciate ligament reconstruction using autografts. Arthroscopy 17: 971-980

38. Konishi Y, Fukubayashi T, Takeshita D (2002) Mechanism of quadriceps femoris muscle weakness in patients with anterior cruciate ligament reconstruction. Scand J Med Sci Sports 12: 371-375

39. Kvist J (2004) Rehabilitation following anterior cruciate ligament injury: current recommendations for sports participation. Sports Med 34: 269-280

40. Lautamies R, Harilainen A, Kettunen J, Sandelin J, Kujala U M (2008) Isokinetic quadriceps and hamstring muscle strength and knee function 5 years after anterior cruciate ligament reconstruction: comparison between bone-patellar tendon-bone and hamstring tendon autografts. Knee Surg Sports Traumatol Arthrosc 16: 1009-1016

41. Lyman S, Koulouvaris P, Sherman S, Do H, Mandl L A, Marx R G (2009) Epidemiology of anterior cruciate ligament reconstruction: trends, readmissions, and subsequent knee surgery. J Bone Joint Surg Am 91: 2321-2328

42. Maletis G B, Cameron S L, Tengan J J, Burchette R J (2007) A prospective randomized study of anterior cruciate ligament reconstruction: a comparison of patellar tendon and quadruple-strand semitendinosus/gracilis tendons fixed with bioabsorbable interference screws. Am J Sports Med 35: 384-394

43. Marumoto J M, Mitsunaga M M, Richardson A B, Medoff R J, Mayfield G W (1996) Late patellar tendon ruptures after removal of the central third for anterior cruciate ligament reconstruction. A report of two cases. Am J Sports Med 24: 698-701

44. Mastrokalos D S, Springer J, Siebold R, Paessler H H (2005) Donor site morbidity and return to the preinjury activity level after anterior cruciate ligament reconstruction using ipsilateral and contralateral patellar tendon autograft: a retrospective, nonrandomized study. Am J Sports Med 33: 85-93

45. Matsumoto A, Yoshiya S, Muratsu H, Yagi M, Iwasaki Y, Kurosaka M, Kuroda R (2006) A comparison of bone-patellar tendon-bone and bone-hamstring tendon-bone autografts for anterior cruciate ligament reconstruction. Am J Sports Med 34: 213-219

46. McDaniel W J, Jr., Dameron T B, Jr (1983) The untreated anterior cruciate ligament rupture. Clin Orthop Relat Res 172: 158-163

47. Meunier A, Odensten M, Good L (2007) Long-term results after primary repair or non-surgical treatment of anterior cruciate ligament rupture: a

randomized study with a 15-year follow-up. Scand J Med Sci Sports 17: 230-237

48. Myer G D, Paterno M V, Ford K R, Quatman C E, Hewett T E (2006) Rehabilitation after anterior cruciate ligament reconstruction: criteria-based progression through the return-to-sport phase. J Orthop Sports Phys Ther 36: 385-402

49. Natri A, Jarvinen M, Latvala K, Kannus P (1996) Isokinetic muscle performance after anterior cruciate ligament surgery. Long-term results and outcome predicting factors after primary surgery and late-phase reconstruction. Int J Sports Med 17: 223-228

50. Nelson F, Billinghurst R C, Pidoux I, Reiner A, Langworthy M, McDermott M, Malogne T, Sitler D F, Kilambi N R, Lenczner E, Poole A R (2006) Early post-traumatic osteoarthritis-like changes in human articular cartilage following rupture of the anterior cruciate ligament. Osteoarthritis Cartilage 14: 114-119

51. Noyes F R, Matthews D S, Mooar P A, Grood E S (1983) The symptomatic anterior cruciate-deficient knee. Part II: the results of rehabilitation, activity modification, and counseling on functional disability. J Bone Joint Surg Am 65: 163-174

52. Noyes FR, Barber SD, Mangine RE (1991) Abnormal lower limb symmetry determined by function hop tests after anterior cruciate ligament rupture. Am J Sports Med. 19:513-8

53. Otero A L, Hutcheson L (1993) A comparison of the doubled semitendinosus/gracilis and central third of the patellar tendon autografts in arthroscopic anterior cruciate ligament reconstruction. Arthroscopy 9: 143-148

54. Papadonikolakis A, Cooper L, Stergiou N, Georgoulis A D, Soucacos P N (2003) Compensatory mechanisms in anterior cruciate ligament deficiency. Knee Surg Sports Traumatol Arthrosc 11: 235-243

55. Petersen W, Laprell H (1999) Combined injuries of the medial collateral ligament and the anterior cruciate ligament. Early ACL reconstruction versus late ACL reconstruction. Arch Orthop Trauma Surg 119: 258-262

56. Pua Y H, Bryant A L, Steele J R, Newton R U, Wrigley T V (2008) Isokinetic dynamometry in anterior cruciate ligament injury and reconstruction. Ann Acad Med Singapore 37: 330-340

57. Samuelsson K, Andersson D, Karlsson J (2009) Treatment of anterior cruciate ligament injuries with special reference to graft type and surgical technique: an assessment of randomized controlled trials. Arthroscopy 25: 1139-1174

58. Shelbourne K D, Foulk D A (1995) Timing of surgery in acute anterior cruciate ligament tears on the return of quadriceps muscle strength after reconstruction using an autogenous patellar tendon graft. Am J Sports Med 23: 686-689

59. Shelbourne K D, Gray T (1997) Anterior cruciate ligament reconstruction with autogenous patellar tendon graft followed by accelerated rehabilitation. A two- to nine-year followup. Am J Sports Med 25: 786-795

60. Smith B A, Livesay G A, Woo S L (1993) Biology and biomechanics of the anterior cruciate ligament. Clin Sports Med 12: 637-670.

61. Snyder-Mackler L, Fitzgerald G K, Bartolozzi A R, III, Ciccotti M G (1997) The relationship between passive joint laxity and functional outcome after anterior cruciate ligament injury. Am J Sports Med 25: 191-195

62. Sojka P, Sjolander P, Johansson H, Djupsjobacka M (1991) Influence from stretch-sensitive receptors in the collateral ligaments of the knee joint on the gamma-muscle-spindle systems of flexor and extensor muscles. Neurosci Res 11: 55-62

63. Stijak L, Radonjic V, Nikolic V, Blagojevic Z, Aksic M, Filipovic B (2009) Correlation between the morphometric parameters of the anterior cruciate ligament and the intercondylar width: gender and age differences. Knee Surg Sports Traumatol Arthrosc 17: 812-817

64. Torry M R, Decker M J, Viola R W, O'Connor D D, Steadman J R (2000) Intra-articular knee joint effusion induces quadriceps avoidance gait patterns. Clin Biomech (Bristol , Avon) 15: 147-159

65. Tow B P, Chang P C, Mitra A K, Tay B K, Wong M C (2005) Comparing 2-year outcomes of anterior cruciate ligament reconstruction using either patella-tendon or semitendinosus-tendon autografts: a non-randomised prospective study. J Orthop Surg (Hong Kong) 13: 139-146

66. Tsepis E, Giakas G, Vagenas G, Georgoulis A (2004) Frequency content asymmetry of the isokinetic curve between ACL deficient and healthy knee. J Biomech 37: 857-864

67. Van d, V, Gill T J, DeFrate L E, Papannagari R, Li G (2008) The effect of anterior cruciate ligament deficiency and reconstruction on the patellofemoral joint. Am J Sports Med 36: 1150-1159

68. Webster K E, Wittwer J E, O'Brien J, Feller J A (2005) Gait patterns after anterior cruciate ligament reconstruction are related to graft type. Am J Sports Med 33: 247-254

69. West R V, Harner C D (2005) Graft selection in anterior cruciate ligament reconstruction. J Am Acad Orthop Surg 13: 197-207

70. Witvrouw E, Bellemans J, Verdonk R, Cambier D, Coorevits P, Almqvist F (2001) Patellar tendon vs. doubled semitendinosus and gracilis tendon for anterior cruciate ligament reconstruction. Int Orthop 25: 308-311

71. Yunes M, Richmond J C, Engels E A, Pinczewski L A (2001) Patellar versus hamstring tendons in anterior cruciate ligament reconstruction: A meta-analysis. Arthroscopy 17: 248-257

72. Zatterstrom R, Friden T, Lindstrand A, Moritz U (1994) The effect of physiotherapy on standing balance in chronic anterior cruciate ligament insufficiency. Am J Sports Med 22: 531-536

Figure 1
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Study or Subgroup	BPTB Mean	BPTB SD	BPTB Total	HST Mean	HST SD	HST Total	Weight	Mean Difference IV, Random, 95% CI
1.1.1 Extensor muscle strength as percentage of the involved limb compared to the uninvolved limb								
Beard 2001	107	32	22	105	30	23	13.1%	2.00 [-16.14, 20.14]
Maletis 2007	70	18	43	83	23	50	46.8%	-13.00 [-21.34, -4.66]
Witvrouw 2001	76.8	15.3	17	83.5	16.7	32	40.1%	-6.70 [-15.99, 2.59]
Subtotal (95% CI)			**82**			**105**	**100.0%**	**-8.51 [-15.38, -1.64]**
Heterogeneity: $Tau^2 = 8.15$; $Chi^2 = 2.53$, df = 2 (P = 0.28); $I^2 = 21\%$								
Test for overall effect: Z = 2.43 (P = 0.02)								
1.1.2 Extensor muscle strength as percentage deficit of the involved limb compared to the uninvolved limb								
Feller 2003	-22.7	29.9	21	-11.1	16.5	18	43.6%	-11.60 [-26.49, 3.29]
Webster 2005	-9.73	13.59	17	-12.96	17.75	17	56.4%	3.23 [-7.40, 13.86]
Subtotal (95% CI)			**38**			**35**	**100.0%**	**-3.23 [-17.64, 11.18]**
Heterogeneity: $Tau^2 = 66.42$; $Chi^2 = 2.53$, df = 1 (P = 0.11); $I^2 = 60\%$								
Test for overall effect: Z = 0.44 (P = 0.66)								

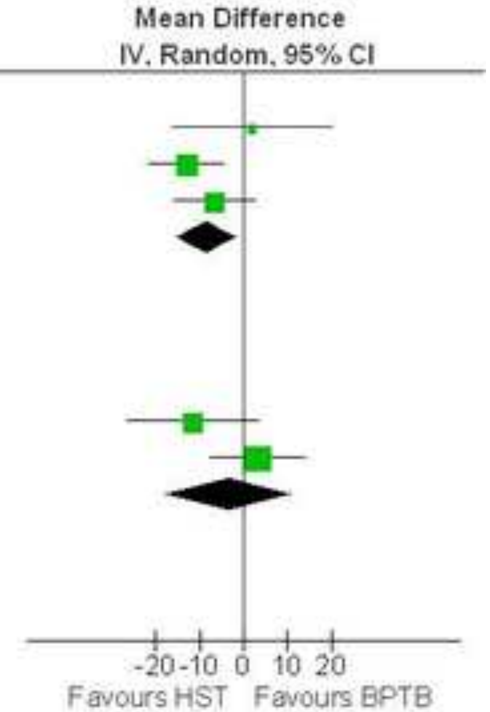

Figure 2
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Study or Subgroup	BPTB Mean	BPTB SD	BPTB Total	HST Mean	HST SD	HST Total	Weight	Mean Difference IV, Random, 95% CI
1.2.1 Flexor muscle strength as percentage of the involved limb compared to the uninvolved limb								
Beard 2001	100	32	22	92	33	23	7.6%	8.00 [-10.99, 26.99]
Maletis 2007	95	19	43	89	21	50	41.5%	6.00 [-2.13, 14.13]
Witvrouw 2001	98.2	11.2	17	88.7	14.6	32	50.9%	9.50 [2.16, 16.84]
Subtotal (95% CI)			**82**			**105**	**100.0%**	**7.93 [2.69, 13.17]**
Heterogeneity: Tau² = 0.00; Chi² = 0.39, df = 2 (P = 0.82); I² = 0%								
Test for overall effect: Z = 2.97 (P = 0.003)								
1.2.2 Flexor muscle strength as percentage deficit of the involved limb compared to the uninvolved limb								
Feller 2003	-1.7	28.4	21	-8.7	17.1	18	63.4%	7.00 [-7.49, 21.49]
Webster 2005	5.93	22.1	17	-7.85	33.5	17	36.6%	13.78 [-5.30, 32.86]
Subtotal (95% CI)			**38**			**35**	**100.0%**	**9.48 [-2.06, 21.02]**
Heterogeneity: Tau² = 0.00; Chi² = 0.31, df = 1 (P = 0.58); I² = 0%								
Test for overall effect: Z = 1.61 (P = 0.11)								

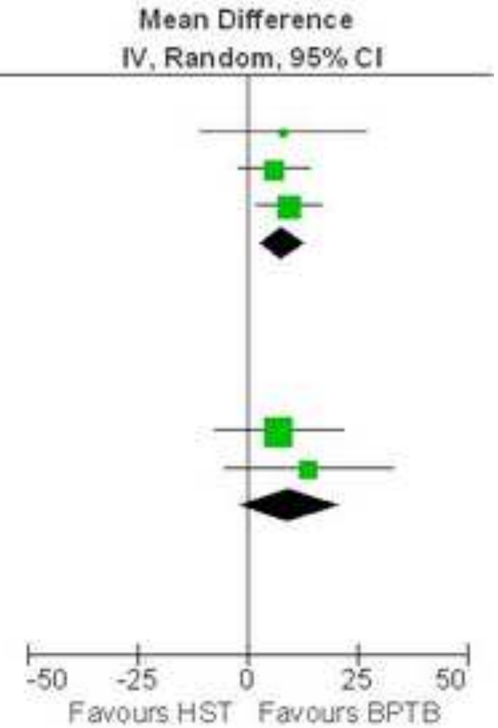

Figure 3

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	BPTB			HST				Mean Difference
Study or Subgroup	Mean	SD	Total	Mean	SD	Total	Weight	IV, Random, 95% CI
1.3.1 Extensor muscle strength as percentage of the involved limb compared to the uninvolved limb								
Carter 1999	68.3	20.2	38	78.1	15.2	35	37.4%	-9.80 [-17.96, -1.64]
Maletis 2007	80	15	43	85	16	50	62.6%	-5.00 [-11.31, 1.31]
Subtotal (95% CI)			**81**			**85**	**100.0%**	**-6.79 [-11.78, -1.80]**
Heterogeneity: Tau² = 0.00; Chi² = 0.83, df = 1 (P = 0.36); I² = 0%								
Test for overall effect: Z = 2.67 (P = 0.008)								
1.3.2 Extensor muscle strength as percentage deficit of the involved limb compared to the uninvolved limb								
Bizzini 2006	-14.9	9.3	87	-11.8	6.4	66	73.3%	-3.10 [-5.59, -0.61]
Webster 2005	5.54	17.67	17	-0.5	19.4	17	26.7%	6.04 [-6.43, 18.51]
Subtotal (95% CI)			**104**			**83**	**100.0%**	**-0.66 [-8.58, 7.27]**
Heterogeneity: Tau² = 20.71; Chi² = 1.98, df = 1 (P = 0.16); I² = 50%								
Test for overall effect: Z = 0.16 (P = 0.87)								

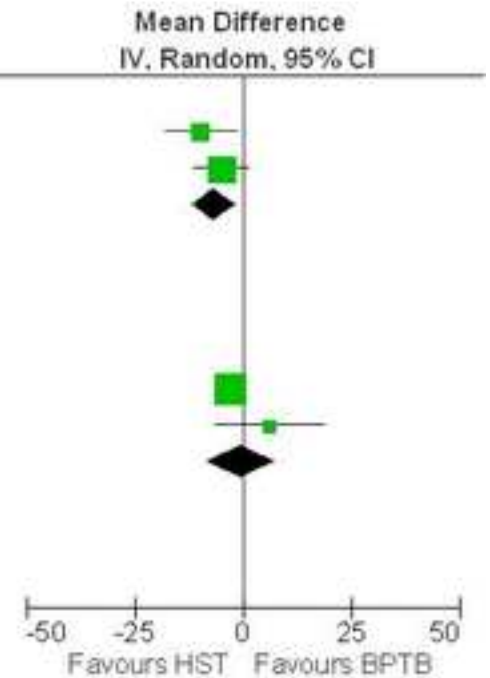

Figure 4

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	BPTB			HST				Mean Difference
Study or Subgroup	**Mean**	**SD**	**Total**	**Mean**	**SD**	**Total**	**Weight**	**IV, Random, 95% CI**
1.4.1 Flexor muscle strength as percentage of the involved limb compared to the uninvolved limb								
Carter 1999	86.1	21.9	38	81.7	18.5	35	41.4%	4.40 [-4.88, 13.68]
Maletis 2007	101	15	43	88	15	50	58.6%	13.00 [6.89, 19.11]
Subtotal (95% CI)			**81**			**85**	**100.0%**	**9.44 [1.13, 17.74]**
Heterogeneity: Tau² = 20.91; Chi² = 2.30, df = 1 (P = 0.13); I² = 57%								
Test for overall effect: Z = 2.23 (P = 0.03)								
1.4.2 Flexor muscle strength as percentage deficit of the involved limb compared to the uninvolved limb								
Bizzini 2006	12.2	7.8	87	-10.4	3.6	66	77.1%	22.60 [20.75, 24.45]
Webster 2005	11.04	22.1	17	-1.75	20.34	17	22.9%	12.79 [-1.49, 27.07]
Subtotal (95% CI)			**104**			**83**	**100.0%**	**20.35 [12.28, 28.43]**
Heterogeneity: Tau² = 21.14; Chi² = 1.78, df = 1 (P = 0.18); I² = 44%								
Test for overall effect: Z = 4.94 (P < 0.00001)