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Muscle strength changes following different surgical approaches used in primary total hip arthroplasty: A Systematic Review and Meta-analysis

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Abstract

Background: Persistent functional abnormalities and strength deficits are commonly reported despite the advances in surgical approaches for primary total hip arthroplasty (THA). Understanding the influence of different approaches on hip muscle strength changes following THA may play a crucial role in optimizing post-operative recovery. Aim: Systematic review and meta-analysis of between-approach comparison of directly measured hip muscle strength following primary-THA. **Method:** A comprehensive online database search was performed, identifying studies that compare muscle strength between at least two different THA approaches. Based on Cochrane guidelines, a qualitative and quantitative analysis was completed along with a meta-analysis of the eligible studies. ROBINS-i and ROB-2 were used to analyse the risk of bias, and the Pedro tool was used for quality appraisal. **Results:** 881 publications were appraised, yielding 23 eligible publications. Sufficient data for analysis was found only between posterior and lateral approaches for hip abduction strength in all categories. No statistically significant difference was found between the two approaches at 12 months and over time-period following THA (Z=1.51, P=0.13, Std Mean diff = 0.24, 95% CI [-.07,.56]). However, the results slightly favoured posterior approach. Additionally, no statistically significant difference found in the strength ratio of the operated side to the unoperated side (U = 15, z = -0.52, p = 0.69) or in the percentage change in muscle strength at 3 months (U=10, z=-.577, p=0.686) and 12 months (U = 10, z=-.577, p = 0.686) from pre-operative baseline. **Conclusion:** This systematic review and meta-analysis found no statistically significant difference between posterior and lateral approaches for directly measured hip muscle strength measured. Despite the increasing popularity of AA, ALA, and other minimally invasive or modified approaches, and the relationship between muscle strength and function, a sparsity was identified in published studies that performed a comparison between approaches of hip muscle strength.

Keywords: Hip, Replacement, Arthroplasty, Surgical approach, Muscle, Strength, Systematic review, Meta-analysis.

INTRODUCTION

Total hip arthroplasty (THA) is the "gold-standard" intervention for cost-effective management of severe hip pain in individuals with poor responsiveness to non-surgical treatments [1-3]. Although regional estimates vary widely, the utilization trend of THA has consistently increased across the globe in the last two decades [4-7]. This is attributed to a multitude of factors, including an aging population, increasing rates of osteoarthritis, obesity, and rising expectations for improved quality of life [8-11]. Many modeling studies predict a continuing worldwide demand for THA in the coming decades [4-14]. Singh *et al* [13]. predicted a 284% increase in THA rates by 2040 in the United States, while Ackerman *et al* [4]. predicted a 208% increase in THA for managing osteoarthritis in Australia by 2030. The increased demand in primary THA, along with a projected increase in revision hip arthroplasties, may increase the health and economic burden, thereby highlighting the importance of optimizing all outcomes following primary total hip arthroplasties [10-15].

Anterior (AA), posterior (PA), lateral (LA), and anterolateral (ALA) approaches for performing total hip arthroplasties are generally considered as "traditional or standard" THA approaches" [16-19]. Over time, many modifications of these approaches, including different "minimally invasive" and "muscle-sparing" techniques, have been developed to minimize post-operative complications like pain and muscle dysfunction and to facilitate better post-operative functional recovery [16-23]. However, despite the increased

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utilization trends and advances in surgical techniques, the most effective surgical approach to optimize clinical and functional outcomes particularly remains contentious [18-33]. Furthermore, many studies report no significant differences between different approaches, particularly in terms of long-term functional outcomes, despite the variations in surgical technique and muscles implicated for each approach [26-30, 32, 33]. Many of these studies, use a variety of Patient-Reported Outcome Measures (PROMs) as the basis to assess functional outcomes [26,27,30]. Although various PROMs have been widely used due to cost-effectiveness and ease of administration, it can be argued that the reported results may be constrained by the subjective nature, ceiling effect, and inadequate sensitivity of various PROMs to determine the true extent of the patient's functional ability [26-30, 34-40]. Additionally, regardless of the type of approach used, several studies report persistent pain, muscle strength deficits, and abnormal movement patterns post-operatively though the patients are considered "rehabilitated" [32, 41-47].

The compromise of hip abductor mechanism and the resultant has been documented as one of the most common musculoskeletal dysfunctions following THA, with many techniques evolving as an attempt to overcome this issue [48]. However, as seen in Table-1, each surgical approach uses different muscular and inter-nervous interval, which may result in approach-specific direct trauma (via incision, detachment, or retraction) or indirect trauma by injury to the nerve supply or damage to other surrounding structures, potentially leading to musculoskeletal dysfunction [16-23, 49-51]. Thus, based on the approach, other muscles like Gluteus Maximus (GMax), Rectus Femoris, Obturators which are well documented to have multiple functions as movement stabilizers or movement facilitators at the hip, knee, pelvis, and trunk, during activities such as standing, walking, stairs, squats, may also potentially be affected [52-58]. This presents the possibility of other hip movements like extension, flexion, and rotation being compromised during THA. In pre-and post-operative periods, other factors like discrepancies in limb-length, asymmetrical limb loading, prolonged inactivity, and pain inhibition may also contribute to strength deficits in the different muscle groups surrounding the hip [59-62]. Thus, it can be argued that monitoring and understanding muscle strength changes in all hip muscle groups following THA may be an important tool in optimizing patient management.

Muscle strength has long been a core component of the rehabilitation following THA and can be measured and monitored easily by clinicians to optimize functional recovery [63-70]. However, variations in measurement tools, methodology, and test positions used in THA research make the extrapolation of results and comparison of muscle strength outcomes complex. A variety of methods, including the Medical Research Council scale rating, manual muscle testing, handheld or isokinetic dynamometry, or other customized devices, has been used to quantify muscle strength in literature [21-50,51-69,71-85]. Substantial variability is also seen in the reporting of strength outcomes with the results expressed as raw numbers, values normalized to limb-length or the contralateral side, and strength or torque ratios to the non-operated side [21-50,51-69,71-85]. These factors contribute to the challenge of obtaining clinically meaningful information from the conducted research. The purpose of this review was to assimilate, analyze, and summarize the existing literature on changes in muscle strength measures between different approaches of primary total hip arthroplasty at at various pre- and -post- operative time point.

Table 1: Description of approaches with the salient features used for defining each approach for the purpose of this systematic review

Approach	Alternative names	History	Description of approach	Reported implications
Posterior	*Moores (1950s) *Southern *Exeter **Variations seen** ^Standard posterior ^Minimally invasive ^Gibson	This approach was first described by Langenbeck (1874), and Kocher (1902), And later modified by Moore (1950) and by Gibson (1950) [17, 18, 51].	Surgically this is defined by the split of gluteus maximus, division of tendons of piriformis / superior and inferior gemellus, and obturator internus.	- This is a muscle splitting approach - It may negatively impact the rotatory kinetics[112]. - Higher known dislocation rates [17]. - Higher risk of sciatic nerve injury compared to other approaches[116].
Lateral	**Alternative names** *Hardinge approach *Direct lateral **Variations seen** ^Modified Lateral ^Bauer-Hardinge	This approach is a muscle splitting approach initially described by McFarland and Osborne (1954) and popularised by Hardinge and involves surgical release and repair of the abductor musculature [17, 18, 119].	Surgically this involves splitting the line of fibres of gluteus medius and vastus lateralis, along with elevation of gluteus medius and minimus from the greater trochanter.	- It is a muscle splitting approach - It may negatively impact the gait and other functional mechanics, including a Trendelenburg gait or a compensatory contralateral pelvic tilt due to abductor dysfunction [17,120]. - Risk of greater trochanteric fractures[121] - Risk of superior gluteal palsy (2.2-42.5%) leading to abductor insufficiency or femoral nerve palsy mostly due to retractor placement over acetabular rim [17,117].
Anterior	**Alternative names** *Smith-Peterson (the 1940s) *Heuter approach **Variations seen** ^Direct anterior ^Minimally invasive ^mod Smith-Peterson	This approach was initially described by Heuter (1881) and popularised by Smith-Peterson (1917), and Judet brothers (1950s) [17, 51-122].	This approach is defined by the use of an inter-nervous plane between sartorius and tensor fascia latae. It involves the elevation of tensor fascia latae from its iliac origin and retraction of rectus femoris from its origin, along with elevation of fibres of illiocapsularis.	- Issues relating to hip flexion / illiopsoas - Risk of fracture (trochanteric and femur) which is reported to be worse when surgeons are less experienced[123, 124]. - Increased wound complications and periprosthetic joint infection[16]. - Risk of lateral cutaneous nerve palsy /neuropraxia (15-80%)[125, 126].
Anterolateral	**Alternative names**			

	Watson-jones **Variations seen** ^ Modified Watson-jones ^ Muscle sparing – MSS variations ^Rottinger	This approach was first described by Sayer (1874), and popularised by Watson-jones (1936)[98, 127, 128].	This approach is defined by the use of an intermuscular plane between tensor fascia latae (TFL), and Gluteus medius, along with elevation or reflection of the rectus femoris and psoas tendon from the capsule. Classically it can utilize a trochanteric osteotomy or elevation of the gluteal tendon. ***For the purpose of this review, trochanteric osteotomies (extensile approaches) have been classified under a separate heading.**	- Avoids some of the drawbacks of posterior and lateral approaches. - It is associated with abductor or hip flexion related weakness/issue.
Others	**Includes** *Trochantric ostrotomies *Extensile approaches		It is characterized by the posterior capsule, piriformis tendon, external rotators, and posterior capsule being incised and uses no true interval.	Higher dislocation rate than anterior exposure unless anterior capsule and short external rotators are repaired. It is easily converted to more extensile exposures like trochanteric osteotomies.
Note: - These descriptions have been used for the purpose of this systematic review. - Each technique that involves minimally invasive and modified approaches have been included under each of the basic direction of the approach. - For the purpose of this review, trochanteric osteotomies (extensile approaches) have been included as a separate heading.				

METHOD

This systematic review is reported in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement guidelines and Cochrane guidelines [86-87]. The protocol for this review was registered with the International Prospective Register for Systematic Reviews PROSPERO: registration number CRD42020178873.

Search strategy

A comprehensive database search was conducted online on Cochrane, EBSCOhost, Pubmed, Web of Science, and SCOPUS (Embase, Medline, Science Direct) with an initial search done in November 2019 to identify studies that compared muscle strength changes pre-and post-operatively between at least two different surgical approaches of primary THA. The keywords were matched with exploded MeSH combinations with terms to generate themes around muscle parameters, hip arthroplasty, and approach-specific terms with the language limited to English. This included title and abstract search of Hip AND (arthroplast* OR prosthe* OR replacement* OR "THR" OR "THA" OR implant OR reconstruct* OR operat* OR technique* OR approach*) AND full text search of (muscle* OR glute* OR abduct* OR extensor* OR extension OR rotator* OR rotation OR quadricep* OR "EMG" OR electromyography OR strength OR power OR activity OR sonography OR ultrasound OR function OR echogenicity OR morphology OR anatomy OR "CSA" OR "Cross-sectional area"). Search alerts were created on each database to identify articles published after the initial search. The search was repeated in Oct 2021. The reference list of all studies that measured muscle strength following THA was checked for additional papers not identified in the initial search.

Study selection – inclusion and exclusion criteria

Studies were selected based on the specific eligibility criteria following the PICO Principle (Table-2). Citations were uploaded to Endnote (version X9, Thomson Reuters Corporation) and transferred to Rayyan QCRI web application for review following removal of duplicates (Figure-1) [88]. Using Rayyan two authors, independently screened the study titles and abstracts to identify those that met the eligibility criteria. Discrepancies were resolved by a consensus discussion between the two authors. A third reviewer was sought where consensus could not be reached. Further full test screening was done by all three authors independently to ensure that the studies met the eligibility criteria and could be categorised based on the classification of each surgical approach as outlined in table-1.

Study Quality Assessment

The risk of bias and methodological quality of the included studies were independently assessed by two authors based on the recommendations from the Cochrane Collaboration [86]. The risk of bias was assessed using ROB-2 for randomized control trials (RCTs) and ROBINS-i for non-randomized studies (Table-3 and 4) [86]. The methodological quality of the included studies was assessed using the PEDro Scale. PEDro Scale is a list of 11 items based on "The Delphi List" developed by Verhagen and colleagues (1998) for quality assessment of clinical trials [89-91]. Total PEDro score was derived for each study by awarding a point for each of the ten scored PEDro criteria relating to internal validity that is fully satisfied with the final unscored criteria relating to external validity [9-92]. The higher the total PEDro score better the internal validity and methodological quality of the study. Based on the total score, the studies were stratified as very high (>8), high (8 ≤ 7), moderate (6 ≤ 4), and low quality (≤ 3) (table-5). Any discrepancies identified in the risk of bias and PEDro assessment, was discussed with a consensus decision was made.

Data Extraction

Data extraction from the included studies was completed using Microsoft Excel®™ 2009 (Microsoft 365, Microsoft, Washington U.S.A) with information including but not patient characteristics, type of surgery, time-points in measurements, muscle strength outcome measured, and results recorded. The surgical approaches were grouped based on the soft tissue intervals and the plane of dissection in relation to the hip joint regardless of whether it was standard, minimally invasive, or modified. Studies were classified based on surgical approach as outlined in table-1, muscle strength measurement time points, and muscle groups assessed. The pre-operative time point included any strength outcome measure reported up to one month prior to THA. Post-operative time-points were identified as <6 weeks, 3-months, 6-months, and 12-months and over. Where studies reported a different time-point, data were merged to the closest common time-point within a 4-week period. If a study reported strength measurement at 12 months and at a later time-point, the last reported strength value was used in the analysis. No eligible study was excluded during this process. Attempts were made to contact the authors of the included studies that were deemed to have missing data.

Outcomes

The primary outcome is directly measured muscle strength at different time points. This included outcomes in accordance with the three possible methods of reporting muscle strength deficit, typically expressed as 1) directly measured value, 2) strength ratio between the affected and unaffected side, 3) percentage change from pre-operative baseline.

Statistical Analysis

The data was extracted and prepared using the reported mean values with or without standard deviations (SDs) or by using transformed mean and SD values by computing maximum likelihood estimates based on the information given. The extracted hip muscle strength data was attempted to be grouped and analyzed in accordance with the plan outlined.

The strength ratio was calculated as the ratio between the mean values of the affected and unaffected sides if it was not reported directly. Similarly, the change from baseline was either the directly reported value or calculated as a percentage change from the reported pre-operative value.

A random-effects model was used for the meta-analysis with pooled estimates and 95%CI for standardized mean differences. The heterogeneity was assessed using the I^2 test and Q statistic. I^2 values range from 0% (homogeneous) to 100% (maximal heterogeneity) [86-93]. The p-value for heterogeneity was set at <0.1 due to the low number of studies at each time point [86-93].

Table 2: Eligibility Criteria

Inclusion Criteria: studies included (PICO)	**Population and Intervention:** Participants 18 years and over in age and over who underwent a primary total hip replacement. **Comparison**: Studies which compare outcome between at least two primary total hip arthroplasty approaches following any condition. **Outcome:** Directly measured muscle strength using methods like manual muscle testing, Medical Research Council testing scale, handheld or fixed dynamometry, or testing devices like isokinetic dynamometers.
Exclusion Criteria	• Samples that included children and adolescents (under the age of 18). • Samples that included participants with conditions like neuromuscular or cognitive disorders, e.g., muscular dystrophies, Parkinson's. • Studies that did not compare at least two or more different types of arthroplasties. • Studies wherein included participants. - were treated with partial hip replacement - had previous hip replacement - had traumatic multiple complex fractures of pelvis or/and spine - had morphological disorders of knee and spine • Studies that evaluated muscle strength where surgical complications have occurred (e.g., nerve palsies following THA). • Studies that evaluated participants with knee arthroplasty (if data were not provided separately for hip arthroplasty). • Abstracts with no Full texts available, reviews, case reports, case series, protocols, personal opinions, letters, posters, thesis, and laboratory results. • Full text is not available in English despite all efforts to find it.

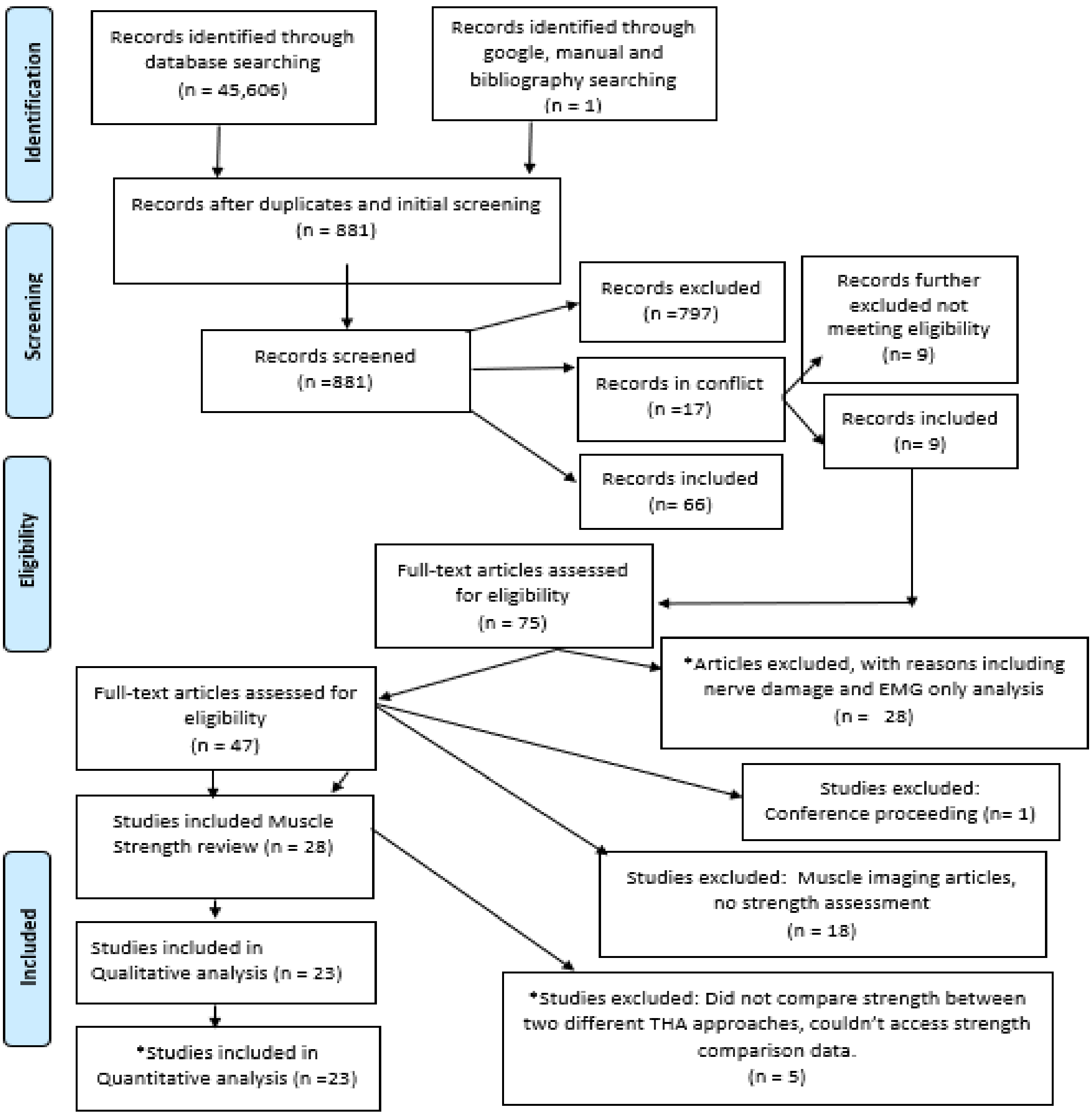

Figure 1: PRISMA Flow Diagram

Table 3: Risk of bias assessment - Non-randomized controlled studies - ROBINS - i

Study names	Domains in ROBINS - i							Overall
	1	2	3	4	5	6	7	
Araujo et al., 2017	S	C	L	L	L	S	L	Critical
Ayasama et al 2005	S	M	L	L	L	M	L	Serious
Barber et al., 1996	S	M	L	L	S	S	S	Critical
Catma et al., 2017	S	L	L	L	M	S	M	Serious
Downing et al., 2001	M	L	L	L	S	L	M	Serious
Gore et al., 1982	S	M	L	L	NI	M	M	Serious
Jelsma et al., 2017	S	S	L	L	L	L	M	Serious
Kiyama et al., 2010	M	M	L	L	L	M	L	Moderate
Klausmeier., et al 2010	S	M	L	L	L	M	L	Serious
Minns et al., 1993	S	S	L	L	L	M	L	Serious
Murray et al., 1979	S	L	L	L	L	S	S	Serious
Obrant et al., 1989	S	S	L	L	L	L	L	Serious
Winther et al., 2019	M	L	L	L	M	L	L	Moderate

Winther et al., 2016	M	L	L	L	M	L	L	Moderate
Zeni., et al 2016	S	M	L	L	L	M	L	Serious

Legend for Table – 3

No:	Domains in Robins-i	No:	Domains in Robins-i
1	Bias due to confounding	5	Bias due to missing outcome data
2	Bias in the selection of participants into the study	6	Bias in measurement of the outcome
3	Bias in Classification of Intervention	7	Bias in selection of the reported result
4	Bias due to deviations from intended interventions		
Grade : C = Cri tical, S = Serious, M = Moderate , L = Low , NI – No information			

Table 4: Risk of bias assessment - ROB-2

Study Name	Domains in ROB-2					Overall
	1	2	3	4	5	
Cheng et al., 2017	L	L	L	SC	L	Some concerns
Kyrch et al., 2010	L	L	L	SC	L	Some concerns
Kyrch et al., 2011	L	L	L	SC	L	Some concerns
Muller et al., 2011	L	L	L	SC	L	Some concerns
Muller et al., 2010	L	L	L	SC	L	Some concerns
Rosenlund et al., 2016	L	L	L	SC	L	Some concerns
Tudor et al., 2015	SC	L	L	SC	L	Some concerns
Wang et al., 2018	L	L	L	SC	L	Some concerns

Legend for Table – 4

No:	Domain	No:	Domain
1	Bias arising from the randomization process	4	Bias in measurement of the outcome
2	Bias due to deviations from intended intervention	5	Bias in selection of the reported result
3	Bias due to missing outcome data		
Grade: L = Low, SC = Some Concerns			

Table 5: PEDro Scale Analysis

	STUDY	RATING		STUDY	RATING
1	Araujo et al., 2017	Low	13	Minns et al 1993	Moderate
2	Ayasama et al., 2005	Low	14	Muller et al., 2011	High
3	Barber et al., 1996	Moderate	15	Muller et al., 2010	High
4	Catma et al., 2017	Moderate	16	Murray et al., 1979	Moderate
5	Cheng et al., 2017	High	17	Obrant et al 1989	Moderate
6	Downing et al., 2001	Low	18	Rosenlund et al., 2016	High
7	Gore et al., 1982	Moderate	19	Tudor et al., 2015	Moderate
8	Jelsma et al., 2017	Moderate	20	Wang et al., 2018	Moderate
9	Kiyama et al., 2010	Moderate	21	Winther et al., 2019	Moderate
10	Klausmeier et al., 2010	Moderate	22	Winther et al., 2016	Moderate
11	Krych et al., et al 2010	High	23	Zeni et al., 2016	Moderate
12	Krych et al., et al 2011	High			

Legend for Table – 5

Score	Rating	Score	Rating	Score	Rating	Score	Rating
> 8	Very high	8 ≤ 7	High	6 ≤ 4	Moderate	≤ 3	Low

Table 6: THA approaches and number of subjects

THA approach	Number of Subjects
Total	1321
Posterior – PA	422
Lateral – LA	440
Anterior – AA	164
Anterolateral – ALA	159
Other *	136
The definitions used in each approach is as per table 1 Note: * 21 subjects were classified as "Anterolateral or direct lateral" in the study by Zeni et al., 2016 and are not included as ALA or LA.	

RESULTS

Study selection and patient characteristics

A total of 881 studies were appraised from the 45606 studies identified, with 23 studies meeting the full eligibility criteria. It was then summarized according to the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) statement in Figure-1. The studies were categorised by design and included eight randomised controlled studies [23-80,81-95], five retrospective studies [71-97] and ten non-randomised controlled studies [50, 51-82,83-85]. Where data was duplicated, only one data set was used in the meta-analysis [28-51, 80, 81]. The data for 1321 primary THA patients using different surgical approaches were available, of which approximately 45% were males, and 55% were females (table-6).

Risk of Bias and Quality Assessment

Results of the risk of bias assessment using ROBINS-i and ROB-2 are presented in tables 3 and 4. Ten of the fifteen studies assessed using ROBINS-i recorded a 'serious' overall score, while all eight studies assessed using ROB-2 had an overall grading of "some concerns." The quality assessment results using the PEDRO scale are provided in table-5, with 14 of 23 studies recording a rating of only 'moderate' quality based on our grading.

Muscle strength comparison between different THA approaches

The baseline characteristics and lay summary of included studies are shown in table 7. It is evident from tables 7 and 8 that methods used in study protocols, including testing position, equipment, strength outcome measures used, and reporting, are not consistent in the included studies. To reduce the variance in the analysis, results were grouped according to the surgical approach as defined in table-2 and the time-point of data collection. Three studies (Araujo et al., 2017, Catma et al., 2017, Gore et al., 1982) [76,-82] were reclassified from anterolateral approach to lateral approach due to the classic Watson-Jones approach or abductor tenotomy or violation of gluteus medius [98].

On pooling the available data, the minimum number of studies required for performing meta-analysis was found only for studies comparing posterior and lateral approaches at over 12 months post-operatively and only for hip abduction strength measurement. Regression analysis was not performed due to the low number of studies reporting specific muscle outcomes at different time points of our grouping.

The mean difference between the PA and LA was not statistically significant for hip abduction strength at 12 months and over following THA ($Z=1.51$, $P=0.13$, Std Mean diff = 0.24, 95% CI [-0.07,0.56]) with substantial heterogeneity identified (Figure -2). However, the results tend to slightly favour the posterior approach (PA). It is recognized that heterogeneity statistics are limited as only a small number of studies were involved in each comparison.

In studies comparing posterior and lateral approaches, although hip abduction strength was higher in the posterior approach in most studies, the percentage change in muscle strength from pre-operative baseline was not statistically significant at three months ($U = 10$, $z=-0.577$, $p = 0.686$) or 12 months ($U = 10$, $z=-0.577$, $p = 0.686$) using an independent samples Mann-Whitney U test.

Additionally, no statistically significant difference was found in the strength ratio of the operated side to the unoperated side on comparing lateral and posterior approach using an independent samples Mann-Whitney U test ($U = 15$, $z = -0.52$, $p = 0.69$).

Study or Subgroup	Posterior Approach Mean	SD	Total	Lateral Approach Mean	SD	Total	Weight	Std. Mean Difference IV, Random, 95% CI
Araujo et al 2017	7.4	2.95	13	4.58	2.29	15	9.5%	1.05 [0.25, 1.85]
Barber et al 1996	4.5	0.6	28	4.3	0.88	21	13.7%	0.27 [-0.30, 0.84]
Downing et al 2001	86	28.89	40	92	35.56	33	16.1%	-0.19 [-0.65, 0.28]
Gore 1982	785.5	243.5	52	684.5	173.5	33	16.6%	0.46 [0.01, 0.90]
Kiyama et al 2010	87.3	38.52	40	86.1	28.9	38	16.5%	0.03 [-0.41, 0.48]
Roselund et al 2016	1.89	0.34	23	1.65	0.32	24	13.2%	0.72 [0.12, 1.31]
Wang et al 2019	237.73	149.8	26	275.03	116.34	28	14.4%	-0.28 [-0.81, 0.26]
Total (95% CI)			**222**			**192**	**100.0%**	**0.24 [-0.07, 0.56]**

Heterogeneity: Tau² = 0.11; Chi² = 14.79, df = 6 (P = 0.02); I² = 59%
Test for overall effect: Z = 1.51 (P = 0.13)

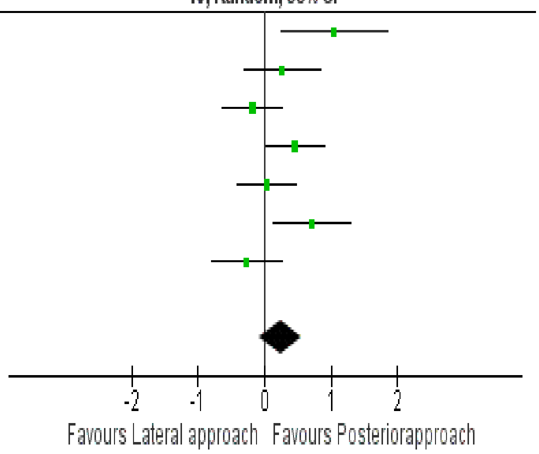

Figure 2: Results of meta-analysis of strength measurement at 12 months (and over) postoperatively

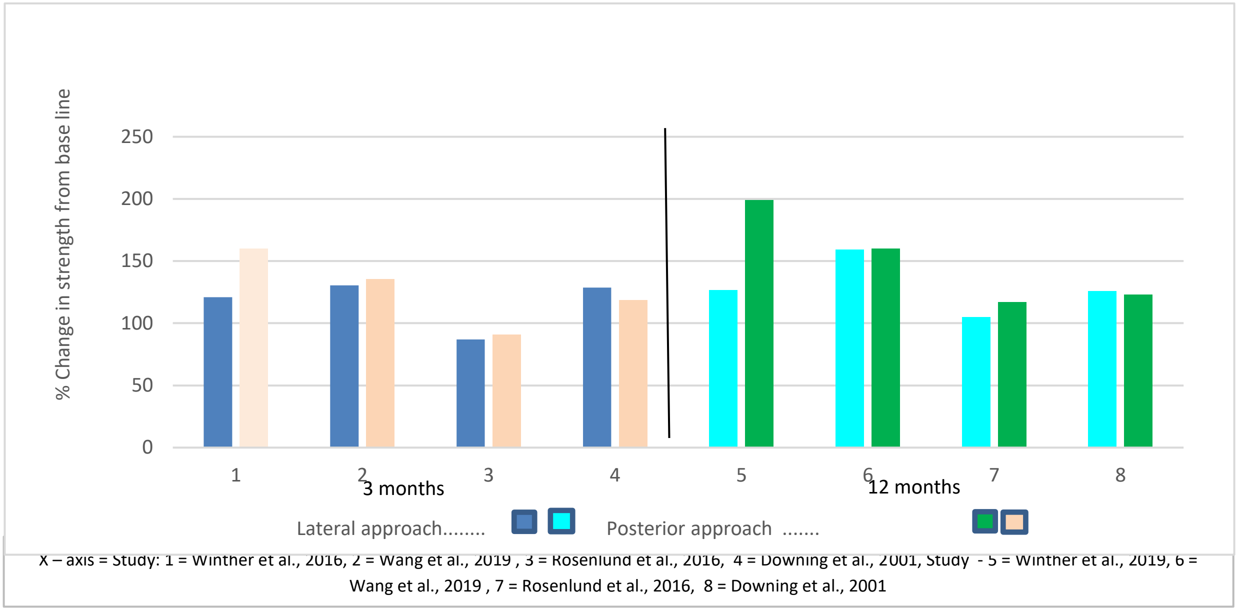

Figure 3: Percentage change in muscle strength from baseline at 3 & 12 months following total hip arthroplasty between LA and PA

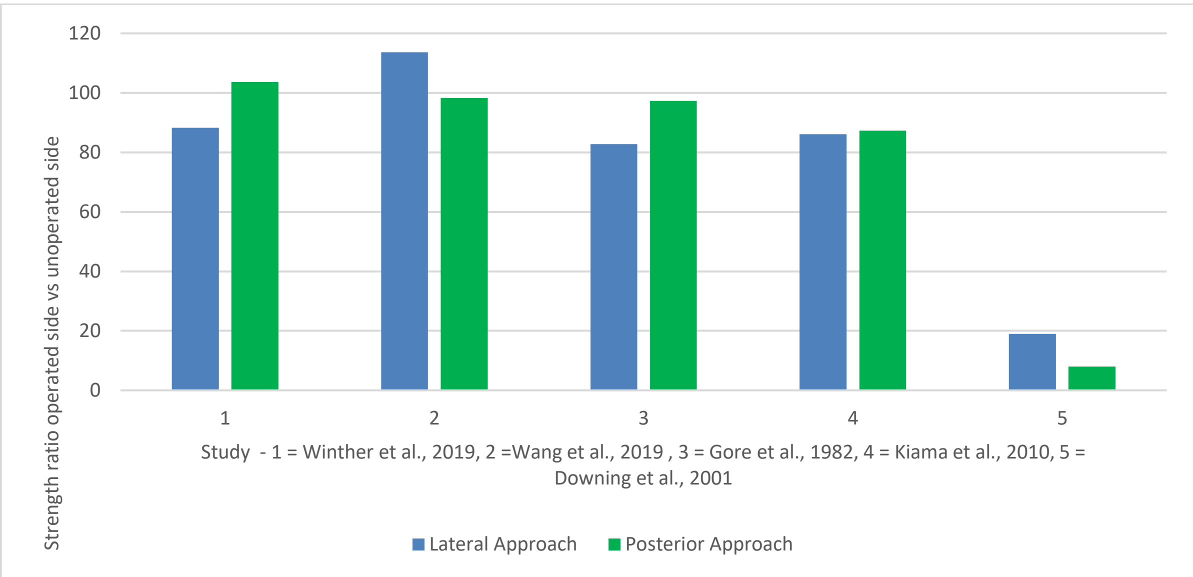

Figure 4: Percentage change in strength ratio of operated side compared to unaffected side at 12 months + PA and LA

Table 7: Baseline Characteristics and details of the study

	Study	Study type	no of THA subjects	THA approaches	Timepoints (w=weeks, m=months)	Outcome tool	Muscle assessed	Strength Results	Approach favoured for muscle strength
1	Araujo et al., 2013	R	94	PA vs. LA*	6m,12m,18m,24+m	HHD	Hip Abduction	LA strength lower at 6 , 12 and 24 months	PA
2	Ayasama et al.,	R	30	PA and ALA	18m+	IKD	Hip Abduction	No between study comparison - Femoral offset study	NA
3	Barber et al., 1996	PNRCT	49	PA vs. LA	24m	NRS	Hip Abduction	No Significnat difference at 12 and 24 months	Same
4	Catma et al., 2017	PNRCT	68	PA vs. LA*	0,6m	NRS	Hip Abduction	PA higher score at 6 months	PA
5	Cheng et al., 2017	RCT	73	PA vs. AA	0,<6w,3m	NRS	Hip Abduction Hip Flexion #	No difference PA favoured at 6 weeks, no difference at 3 months	Same
6	Downing et al., 2001	PNRCT	100	PA vs. LA	0,3m,6m	IKD	Hip Abduction	Same 3 and 12 months	Same
7	Gore et al., 1982	PNRCT	85	PA vs. LA*	24+m	HHD	Hip Abduction Hip Adduction	Men ALA less abductor strength over 24 months	PA
8	Jelsma et al., 2017	R	119	AA vs (LA* + PA)	0,3m	Unclear	Leg Press Power test ©	Only Eccentric power better in non-DAA	DAA - initial post op
9	Kiyama et al., 2010	R	78	PA * vs. LA	24+m	HHD	Hip Abduction	No Difference at 24 months +	Same
10	Klausmeier et al ., 2010	PNRCT	23	AA vs. ALA	6 w and 4M	IKD	Hip Abduction	6 weeks or 16 weeks no difference in hip abductor strength , Neither approach provided faster recovery	Same
11	Krych et al., 2010	RCT	24	AA vs. PA (AA - 2 incision approach, PA - Mini posterior approach)	6 weeks	IKD	Hip Abductor Hip Adduction Hip Flexion / extension Hip Int rot / ext rot	6 weeks - No significant difference . But trend with PA haviing better hip extension , IR and Flex strength recovery	PA
12	Krych et al., 2011	RCT	21	AA vs. PA (AA - 2 incision approach, PA - Mini posterior approach)	12 months	IKD	Hip Abductor Hip Addduction Hip Flexion / extension Hip Int rot / ext rot	12 month PA had gerater improvements in hip flexor and Int rotation strength and better function	PA
13	Minns et al., 1993	R	81	LA vs. TO	24+m	HHD	Hip Abductor Hip Addduction Hip Flexion Hip Extension	flexion strength and internal rotation strength,	Same
14	Muller et al., 2011	RCT	44	LA vs. ALA	0,3m,12m	HHD	Hip Abduction	No Significant difference in strength 3 and 12 months	ALA
15	Muller et al., 2010	RCT	44	LA vs. ALA	0,3m,12m	HHD	Hip Abduction	No Significant difference in strength 3 and 12 months	ALA
16	Murray et al., 1979	PNRCT	89	Charnley and Muller	0,6m,24+m	OTH	Hip Abduction	PA significantly better only in women at 24 months	Same
17	Obrant et al., 1989	PNRCT	27	ALA Vs. TO LA	0, 20+m		Hip Abductor Hip Flexion Hip Extension	The abduction strength was normal after trochanteric osteotomy and weaker than normal in the nonosteotomized hips (At avg 20 months +)	ALA

18	Rosenlund et al., 2016	RCT	47	PA vs. LA	0,3m,12m	HHD	Hip Abductor Hip Flexion Hip Extension	PA had comparatively less hip extension strength from pre-op values at 3 months PA had more improvement in hip abduction & flexion at 12 months	PA
19	Tudor et al., 2015/16	RCT	130	LA vs. ALA (Modified LA no muscle sparing vs Modified Muscle sparing ALA)	3m,12m,24+m	HHD	Hip Abduction	Immediate post OP no significant difference, ALA better at 3 12 and 24+ months	ALA
20	Wang et al., 2019	RCT	54	PA* vs. LA* (Mini posterior approach vs Modified lateral approach)	0,<6w,3m,12m	HHD	Hip Abduction	No Difference	Same
21	Winter et al., 2019	PNRCT	60	PA vs. LA vs AA	0,6m,12m	OTH	Leg Press Hip abduction	6 and 12 months -1 RM hip abduction strength on operated side was significantly weaker with LA compared to AA and PA– no difference PA and AA 6 months or 12 months – Leg press - no statistical difference between groups 6 to 12 months : No significnat change in leg press strength in the operated leg in any group. 6 to 12 months: AA and PA groups showed a significant increase in 1 RM abduction strength in the operated leg, whereas the DLA group showed a non-significant decrease. Inter-limb difference found in all groups at 6 months, LA persisted at 12 months. No differences were found in PA or AA	Mixed
22	Winter et al., 2016	PNRCT	60	PA vs. LA vs AA	0, 6w, 3m	OTH	Leg Press Hip abduction	6 weeks – Leg press PA better percentage muscle strength change than LA , but similar to AA 3 months - Leg press– no statistical difference between groups 6 weeks – 1RM Hip abduction PA better percentage muscle strength change than LA and AA , No difference AA and LA 3 months – 1RM Hip abduction– no statistical difference between groups 3 months – all groups operated leg weaker than other limb.	at 3 months Same
23	Zeni et al., 2016	PNRCT	63	PA Vs. (ALA + LA) 42 Vs. 21	0, 3m, 12m	HHD - (hip abd) / MECH (Kneeext	Hip Abductor Knee Extension	12 months - LA resulted in weaker hip abduction ; However, signifi cant and clinically meaningful improvements in functional ability were seen for most subjects, regardless of surgical approach	at 12 months PA

Legend for Table 7: Baseline characteristics

Surgical approach	General	Study type	Outcome tool
PA - Posterior approach LA – Lateral approach	*: reclassified based on our definition	R – retrospective	HHD – handheld dynamometer
AA – Anterior approach	# - Straight Leg Raise	PNRCT – Prospective non-randomized control trial	NRS – numeric rating scale
ALA - Anterolateral approach	© - Concentric / eccentric power test	RCT _ randomized control trial	IKD -isokinetic dynamometers (like - KINCOM, Biodex, HUMAC)
TO- transverse osteotomy	NA – not applicable		OTH - exact device not defined

Table 8 : Muscle strength outcome measurement tools, groups tested and position in which the strength tests are conducted

		TOOL				MUSCLE GROUP TESTED								POSITION OF TESTING FOR HIP ABDUCTION				
		HHD	NRS 0 - 5	IKD	OTH	H Abd	H Add	H Flx	H Ext	H IR	H ER	Knee ext	Other tests	Lateral decubitus	Supine	Standing	Side lying	Mixed/not defined
1	Araujo et al., 2013	1	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0
2	Ayasama et al., 2005	0	0	1	0	1								0	1	0	0	0
3	Barber et al., 1996	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1
4	Catma et al., 2017	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0
5	Cheng et al., 2017	0	1	0	0	1	0	1	0	0	0	0	0	0	0	0	1	0
6	Downing et al., 2001	0	0	1	0	1	0	0	0	0	0	0	0	0	0	1	0	0
7	Gore et al., 1982	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	1
8	Jelsma et al., 2017	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	1
9	Kiyama et al., 2010	1	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0
10	Klausmeier et al., 2010	0	0	1	0	1	0	0	0	0	0	0	0	0	0	1	0	0
11	Krych et al., et al 2010	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	1	0
12	Krych et al., et al 2011	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	1	0
13	Minns et al., 1993	0	0	0	1	1	1	1	1	0	0	0	0	0	0	1	0	0
14	Muller et al., 2011	1	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0
15	Muller et al., 2010	1	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0
16	Murray et al., 1979	0	0	0	1	1	0	0	0	0	0	0	0	0	0	1	0	0
17	Obrant et al 1989	0	0	1	0	1	0	1	1	0	0	0	0	0	0	0	1	0
18	Rosenlund et al., 2016	0	0	0	1	1	0	1	1	0	0	0	0	0	0	1	0	0
19	Tudor et al., 2016	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	1
20	Wang et al., 2019	1	0		0	1	0	0	0	0	0	0	0	1	0	0	0	0
21	Winter et al., 2019	0	0	M*	M*	1	0	0	0	0	0	0	1	0	1	0	0	1
22	Winter et al., 2016	0	0	M*	M*	1	0	0	0	0	0	0	1	0	1	0	0	1
23	Zeni et al., 2016	0	0	M*	M*	1	0	0	0	0	0	1	0	0	0	0	1	1

Legend for Table – 8
TOOLS : OTH =Other device including non-defined devises , non IKD devices and other mechanical devices. HHD - hand held dynamometers, NRS = Numeric rating scale of 0-5, IKD = isokinetic dynamometers - Cybex, Biodex, KinCom and other machines etc
Muscle group: H Abd - hip Abduction, H Add - hip adduction, H Flx - Hip flexion, H Ext - hip extension , H IR - hip internal rotation , H ER - Hip external rotation
* M = the study has used IKD for one test and HHD or other devices for another test

DISCUSSION

Muscle strength alone does not reflect overall post-surgical functional outcome with its relative importance debated [37,99-102]. However, muscle strength is an important post-surgical outcome that forms the basis of musculoskeletal rehabilitation and may inform the direction of the exercise program aimed at optimizing functional recovery following THA [64-69]. Understanding the strength changes across multiple pre-and post-operative time points may improve the evaluation of patient outcomes and facilitate optimizing functional recovery following THA.

This systematic review and meta-analysis investigated the changes in the directly measured muscle strength outcomes between different THA approaches. We found that posterior (PA) and lateral approaches (LA) were the two approaches that were compared the most, with sufficient data found only for hip abduction strength between these two approaches to enable a between-approach analysis. The paucity in data of studies comparing muscle strength was found despite the surgical approaches being classified based on only the direction of the approach and not separated based on it being a traditional or minimally invasive (MIS) or modified (MOD) approach for the purpose of this study. Our study showed that while results marginally favored PA, no statistically significant difference was found between PA and LA in 1) meta-analysis of directly measured hip abduction strength measured 12 months after THA, 2) in the percentage change from baseline at 12 months, 3) strength ratio between operated and unoperated side at 3 and 12 months.

This contrasts with the expectation that the lateral approach in which the hip abductors are reflected from the greater trochanter (GT) should have a greater negative impact on hip abduction strength when compared to other THA approaches, such as the detachment of short external rotators or Piriformis (Pi) during a posterior approach. However, partially or poorly controlled factors in each study, such as pre-existing abductor complex tears, modification of surgical techniques by limiting incision length or partial release of muscle-tendon complex, additional procedures such as repair of the posterior capsule and/or short external rotators, changing prosthesis characteristics and quality of the technique employed to optimize post-surgical outcome may have influenced the overall outcomes and results of our study [21-33,80,81,103-106]. For example, the study by Wang et al., 2019 [23]. compares MOD lateral approach to MIS posterior approach, in which the LA incision was limited to a maximum of 3 centimeters along the Gluteus Medius (GMed) fibers, with the aim to minimize the potential damage to the inferior branch of the superior gluteal nerve and the abductor mechanism and may have resulted in both approaches having comparable results [23].

Our results also show that despite advancements in surgeries and the development of many modified and minimally invasive techniques, not enough muscle strength data was found to compare different approaches and establish the superiority of one approach. Even though the ALA approach (without compromise of the GMed) and more recently anterior approach (AA) or direct anterior approach, gained increasing popularity over the last two decades, insufficient data was found to perform meaningful analysis due to a low number of studies comparing these approaches to each other or to PA and LA. The study by Winther et al., 2016 and 2019 was the only study found that compared and reported the data comparing the traditionally popular approaches – AA, PA, and LA[50, 51]. However, they measure only leg press strength and hip abduction strength between all three approaches. Jelsma et al., 2017 also compared AA, PA, and LA; however, they presented the data as AA and non-AA groups, failing to separate the data for LA and PA. Studies that used approaches with trochanteric osteotomies and other extensile approaches were separately grouped and not included in the AA, PA, ALA, and LA analyses.

The heterogeneity in surgical techniques, study methodology, reported results, along with small sample sizes, and lack of studies comparing all approaches and all hip muscle groups does limit the meaningfulness of this study [21-50,51-63,71-74,76-85, 96,103-109]. However, this study is in agreement with other systematic reviews and meta-analyses that show no differences between THA approaches in function, PROMs, and strength [23-32,110-113]. It also supports the argument that damage to muscles around the hip joint occurs regardless of the THA approach [23-80,81,114].

As evident in table-1, various surgical approaches utilize different muscular and inter-nervous intervals that may result in differing patterns of muscle damage and dysfunction following THA [49-51]. While abductor mechanism dysfunction has most commonly been attributed to the direct incision or detachment of muscles in the lateral approach, other reasons like blunt trauma, retraction, denervation injury, and less common factors like thermal injury from polymethyl methacrylate can lead to damage to other muscles around the hip, including during modified or minimally invasive approaches [16-49,109, 115-117]. Despite this, our systematic review found a poor representation of muscle groups other than hip abductors in the comparative studies assessing strength changes following THA approaches [21-51,69,71-85,96-109]. It shows that despite persisting strength and functional abnormalities being reported following THA, not enough muscle strength data was found to compare different approaches or establish the superiority of one approach. The heterogeneity in surgical techniques, study methodology, reported results, along with small sample sizes and study population, does limit the meaningfulness of this study [78]. The study by Zeni et al., 2016 compares hip abduction and knee extension between groups of subjects who underwent PA, LA, and ALA. However, they presented the data of both LA and ALA as "lateral group."

Based on our finding it can be put forward that this study supports the other systematic reviews and meta-analyses that show no significant differences between THA approaches in function and PROMs [23-32,110-113]. Thus, favouring the argument that damage to muscles around the hip may occur regardless of the THA approach [23-81,114].

Recommendations

This systematic review emphasizes the need for comprehensive, methodologically rigorous studies that evaluate muscle strength changes and their relationship to routinely assessed outcome measures and functional changes following THA. While a multi-tiered, blinded, randomized controlled study is the gold standard, it is acknowledged that blinding of surgeons and assessors in a long-term prospective study with multiple follow-up time-points is not pragmatic [118].. Further research employing standardized study protocols including pre-defined reporting of critical confounding factors like pre-operative indications, rehabilitation protocols, physical activity undertaken, standardized outcome measures including PROMs, muscle strength, and key functional tasks in the pre- and post-operative time-points is warranted to assess the effects of different surgical approaches on muscle strength following THA. Furthermore, validation of best-practice clinical outcome measures inclusive of muscle strength against the gold standard measurement techniques may inform post-operative protocols inclusive of tracking patient recovery, exercise and rehabilitation programs in the THA population to help optimize longer-term patient outcomes.

CONCLUSION

This systematic review and meta-analysis found no statistically significant difference between posterior and lateral approaches for directly measured hip muscle strength measured. A sparsity was identified in published studies that performed a comparison between other approaches of directly measured hip muscle strength despite the increasing popularity of anterior, anterolateral, and other minimally invasive or modified approaches in the last two decades. This, along with the heterogeneity identified, warrants further research employing standardized study protocols to assess the effects of different surgical approaches on muscle strength following primary THA. The exact impact of the different approaches used in primary total hip arthroplasty on muscle strength changes, their clinical relevance, and their influence on functional performance continues to remain largely unknown.

Highlights

The exact impact of the different approaches used in primary THA on hip muscle strength remains largely unknown. A paucity in information comparing muscle strength changes occurring at various post-operative time points between THA approaches was identified. This, along with the heterogeneity identified, warrants further research employing standardized study protocols to assess the effects of different surgical approaches on muscle strength following primary THA.

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Conflict of Interest

The authors have no conflicts of interest to declare.

Ethics Statement

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Abbreviations

AA – Anterior approach

ALA – Anterolateral approach

LA – Lateral approach

MIS – Minimally invasive surgery

MOD - Modified surgical approach

PA – Posterior approach

PEDro – Physiotherapy evidence database

PROM – Patient reported outcome measures

RCT- randomised controlled trials

TO – Transverse Osteotomy

THA – Total hip arthroplasty

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