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Research

Incorporating hip abductor strengthening exercises into a rehabilitation program did not improve outcomes in people following total knee arthroplasty: a randomised trial

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KEY WORDS

Randomised controlled trial
Arthroplasty
Knee replacement
Muscle strength
Exercise therapy
Treatment outcome

ABSTRACT

Question: In adults following primary total knee arthroplasty, does the incorporation of hip abductor strengthening exercises into a 6-week rehabilitation program improve muscle strength, functional performance and patient-reported outcomes at the end of rehabilitation and at 26 weeks? **Design**: Randomised controlled trial with concealed allocation, blinded assessors and intention-to-treat analysis. **Participants**: One hundred and five adults admitted to an inpatient rehabilitation facility immediately following total knee arthroplasty. **Intervention**: Participants in both groups attended 12 days of inpatient physiotherapy followed by 6 weeks of outpatient physiotherapy, which aimed to improve knee range of movement, strength and mobility. The experimental group completed a standard rehabilitation protocol with the addition of hip abductor strengthening. The control group completed the same standard rehabilitation protocol, with the addition of 15 minutes of general functional exercises. **Outcome measures**: Primary outcomes were the Knee Injury and Osteoarthritis Outcome Score (KOOS) and isometric hip abductor muscle strength normalised to body mass index. Secondary outcome measures included the stair climb test, 6-minute walk test, Timed Up and Go test, 40-m fast-paced walk test, 30-second chair stand test, step test, isometric quadriceps muscle strength, Lower Extremity Functional Scale, and Short Form-12. **Results**: The experimental intervention did not result in significantly greater improvements in hip strength, KOOS or any of the secondary outcome measures than the control intervention at 6 weeks or 26 weeks. **Conclusion**: Similar improvements in muscle strength, functional performance and patient-reported outcomes were observed whether specific hip-strengthening exercises were incorporated or general functional exercises were continued instead as part of a postoperative rehabilitation program for participants after total knee arthroplasty. **Registration**: ANZCTR 12615000863538. **[Schache MB, McClelland JA, Webster KE (2019) Incorporating hip abductor strengthening exercises into a rehabilitation program did not improve outcomes in people following total knee arthroplasty: a randomised trial. *Journal of Physiotherapy* 65:136–143]**

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Introduction

Total knee arthroplasty remains the most effective treatment for end-stage knee osteoarthritis.[1] The number of procedures performed per year has increased, with approximately 62 000 primary total knee arthroplasties performed on Australian adults in 2017, which is an increase of 4.3% compared with 2016.[2] Total knee arthroplasty is successful in relieving the symptoms of osteoarthritis and restoring walking speed and stair climbing ability to preoperative levels by 6 months after surgery;[3,4] however, it is important to seek improvement beyond preoperative levels towards normal function.

Despite symptomatic improvement following total knee arthroplasty, some patients experience persistent muscle weakness, ongoing functional difficulties, and pain when compared with healthy age-matched controls.[1,5–7] Muscle weakness affecting the quadriceps and hip abductor muscles can persist well beyond 3 years after total knee arthroplasty.[6] Patients report greater difficulty in completing daily tasks and perform worse than normal on a range of functional outcomes.[5–7] It is therefore justified that postoperative rehabilitation programs address the persistent muscle weakness and functional deficits for this growing population.

Restoring quadriceps strength is a common goal of most postoperative rehabilitation programs; however, functional deficits remain even after completion of these programs. Increasing hip strength may improve outcomes after total knee arthroplasty, and there is some evidence that hip abductor strength influences physical function following total knee arthroplasty.[8–10] Hip abductor strength has also been shown to be more strongly associated with functional performance than quadriceps strength.[10] Furthermore, in a small pilot study, the addition of hip abductor strength exercises to rehabilitation

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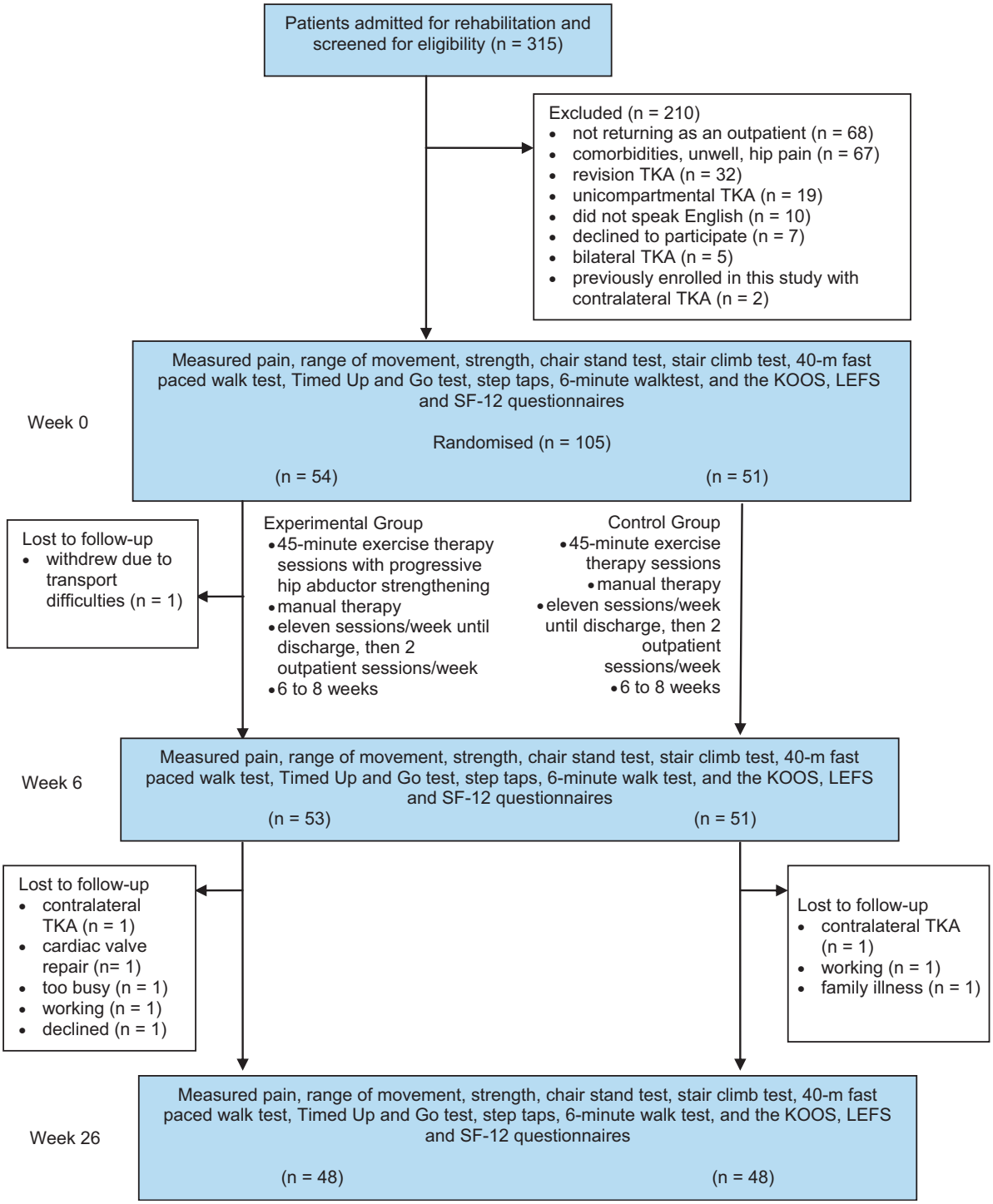

Figure 1. Design and flow of participants through the trial. TKA = total knee arthroplasty, KOOS = Knee Injury and Osteoarthritis Outcome Score, LEFS = Lower Extremity Functional Scale, SF-12 = Short Form-12 version 1.

after total knee arthroplasty achieved significant improvement in functional outcomes after total knee arthroplasty.[11]

The addition of targeted hip abductor strengthening in other populations with knee pain, such as those with knee osteoarthritis and patellofemoral pain, has been shown to reduce pain and improve physical function and quality of life.[12–16] These effects are greater when compared with quadriceps strengthening alone.[13–15] It is therefore reasonable to hypothesise that the addition of hip strengthening exercises to total knee arthroplasty rehabilitation programs would also result in greater improvements in patient-reported and functional outcomes. Larger randomised controlled trials are required to determine the benefit of incorporating targeted hip abductor strengthening exercises into postoperative total knee arthroplasty rehabilitation, which is the primary aim of the current trial.

Therefore, the research question for this randomised controlled trial was:

> In adults following primary total knee arthroplasty, does the incorporation of hip abductor strengthening exercises into a 6-week rehabilitation program improve muscle strength, functional performance and patient-reported outcomes at the end of rehabilitation and at 26 weeks?

Method

Design

A randomised controlled trial was conducted with concealed allocation, blinded assessors, and intention-to-treat analysis.

Table 1
Characteristics of participants at baseline.

Characteristic	Exp (n = 54)	Con (n = 51)
Age *(yrs)*, mean (SD)	70 (7)	69 (7)
Gender, n female (%)	39 (72)	30 (58)
Height *(cm)*, mean (SD)	166 (9)	167 (10)
Mass *(kg)*, mean (SD)	84 (18)	87 (17)
Body mass index *(kg/m^2)*, mean (SD)	30 (6)	31 (6)
Time since surgery *(d)*, mean (SD)	8 (2)	7 (2)
Side of surgery, L:R	27:27	33:18
Prosthesis and patella resurfacing, n (%)		
cruciate retaining + patella resurfaced	17 (31)	13 (25)
cruciate retaining – patella resurfaced	18 (33)	19 (37)
posterior stabilised + patella resurfaced	16 (30)	19 (37)
posterior stabilised – patella resurfaced	3 (6)	0 (0)
Previous joint replacements, n TKA:THA	11:3	23:6

Con = control group, exp = experimental group, THA = total hip arthroplasty, TKA = total knee arthroplasty.

Participants in the experimental group were allocated standard rehabilitation plus 15 minutes of additional hip strengthening exercises, whereas participants in the control group were allocated standard rehabilitation plus 15 minutes of additional general functional exercise; these interventions are described further below and in the published protocol of this study.[17] Although participants were aware of their allocated intervention, they were not informed of what the other group had been allocated.

Participants were randomised by a computer-generated list of random numbers concealed in sealed, opaque envelopes that were prepared by a person not involved in delivering the treatment or testing. The intervention commenced on admission to inpatient rehabilitation. A blinded assessor measured all outcomes immediately before the intervention (Week 0), at the end of the intervention period (Week 6) and at follow-up 20 weeks later (Week 26).

Participants, therapists, centres

The trial was conducted in a private rehabilitation hospital. All patients admitted to inpatient rehabilitation were screened for eligibility to participate in the trial. Participants were recruited by their treating physiotherapist. The experience of the physiotherapists who provided the intervention ranged from 2 to 26 years.

Participants were eligible for inclusion if they were at least 50 years of age and had undergone a primary unilateral total knee arthroplasty for end-stage knee osteoarthritis in the previous 2 weeks. Participants were excluded if they had: unstable medical conditions, such as uncontrolled cardiovascular disease or uncontrolled diabetes; a history of ipsilateral hip replacement, ipsilateral hip osteoarthritis or lateral hip pain; or neurological or any other conditions affecting strength or function of the lower limbs.

Intervention

Standard rehabilitation

Participants attended either two 45-minute sessions of physiotherapy or one 45-minute session of physiotherapy and one 45-minute session of hydrotherapy each week day. All participants also attended one 45-minute session of either physiotherapy or hydrotherapy on the weekend. All participants were given an exercise program to complete whilst admitted to the rehabilitation hospital. These exercises included exercises targeted at improving quadriceps, hamstring and calf strength, increasing knee range of movement, and improving walking and stair-climbing ability. These exercises have been described in detail previously.[17] Manual therapy, including joint mobilisation and massage, was also used. Participants were discharged from the inpatient rehabilitation hospital facility after approximately 12 days when they could mobilise independently and negotiate stairs safely.

Once discharged from the inpatient facility, participants returned for weekly outpatient physiotherapy rehabilitation for 6 to 8 weeks for one 45-minute session of physiotherapy and either one 45-minute session of hydrotherapy (if indicated) or land-based exercise (if hydrotherapy not indicated). After 6 to 8 weeks of outpatient physiotherapy, participants were discharged and encouraged to continue their home exercise program.

Experimental group

Participants in the experimental group received standard rehabilitation plus additional exercises designed specifically to target strengthening of the hip abductor muscles.[12,16,18–21] The

Table 2
Intention-to-treat analysis of mean (SD) of groups, mean (SD) within-group difference, and mean (95% CI) between-group difference for pain and objectively measured outcomes.

Outcome	Groups						Within-group difference				Between-group difference	
	Week 0		Week 6		Week 26		Week 6 minus Week 0		Week 26 minus Week 0		Week 6 minus Week 0	Week 26 minus Week 0
	Exp (n = 54)	Con (n = 51)	Exp (n = 52)	Con (n = 50)	Exp (n = 48)	Con (n = 48)	Exp	Con	Exp	Con	Exp minus Con	Exp minus Con
Pain	3	4	1	2	0	1	−2	−2	−3	−3	0	0
(0 to 10)	(2)	(2)	(2)	(2)	(1)	(1)	(2)	(2)	(2)	(2)	(−1 to 1)	(−1 to 1)
Flexion ROM	83	81	109	107	121	118	27	26	38	37	1	1
(deg)	(10)	(12)	(8)	(10)	(6)	(9)	(12)	(10)	(12)	(12)	(−4 to 5)	(−4 to 6)
Extension ROM	−5	−5	−2	−2	0	0	3	3	4	5	0	−1
(deg)	(6)	(5)	(3)	(3)	(1)	(2)	(5)	(4)	(5)	(5)	(−2 to 2)	(−3 to 2)
Hip strength	1.9	2.1	3.5	3.6	4.0	4.1	1.6	1.5	2.0	2.0	0.0	0.0
(N/kg/m^2)	(0.9)	(1.1)	(1.4)	(1.8)	(1.6)	(1.7)	(1.1)	(1.2)	(1.1)	(1.1)	(−0.4 to 0.5)	(−0.5 to 0.5)
Quadriceps strength	1.5	1.4	4.9	5.3	6.6	6.9	3.4	3.9	5.1	5.5	−0.5	−0.4
(N/kg/m^2)	(0.9)	(1.0)	(2.3)	(2.9)	(3.0)	(3.4)	(1.9)	(2.6)	(2.7)	(3.2)	(−1.4 to 0.4)	(−1.6 to 0.8)
Chair stand test	7	8	13	14	15	15	6	6	7	8	0	0
(n in 30 s)	(3)	(3)	(4)	(5)	(4)	(5)	(2)	(3)	(3)	(4)	(−1 to 1)	(−2 to 1)
Stair climb test	25	22	8	8	7	7	−16	−14	−17	−15	−2	−2
(s)	(10)	(8)	(3)	(3)	(2)	(2)	(9)	(6)	(8)	(7)	(−5 to 1)	(−5 to 1)
40-m fast-paced walk	95	85	34	35	29	29	−61	−52	−55	−55	−9	0
(s)	(60)	(41)	(10)	(12)	(9)	(10)	(57)	(37)	(39)	(36)	(−28 to 10)	(−15 to 16)
Timed Up and Go	29	25	9	10	8	8	−20	−16	−19	−17	−4	−2
(s)	(14)	(11)	(3)	(4)	(2)	(3)	(12)	(9)	(11)	(9)	(−8 to 0)	(−6 to 2)
Step taps	5	5	16	17	17	18	11	12	12	13	−1	−1
(n)	(5)	(6)	(4)	(5)	(4)	(5)	(4)	(6)	(5)	(6)	(−3 to 1)	(−3 to 1)
6-minute walk test	178	194	411	420	474	477	233	226	285	281	7	4
(m)	(75)	(101)	(97)	(126)	(106)	(128)	(78)	(88)	(87)	(95)	(−26 to 40)	(−33 to 41)

Con = control group, Exp = experimental group, ROM = range of movement.

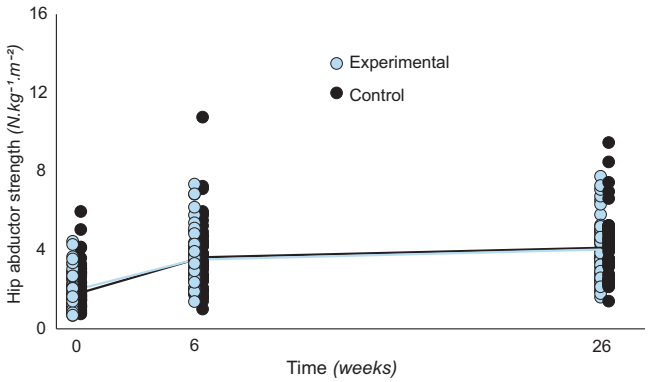

Figure 2. Hip abductor strength by time. Symbols show individual participants' outcomes. Lines join group means at baseline and at Weeks 6 and 26. Experimental and control group data have been offset slightly for clarity.

participants initially performed non-weight-bearing, antigravity, hip-strengthening exercises (side lying hip abduction, prone hip extension and standing hip abduction). The exercises were progressed to weight-bearing, gravity-resisted and TheraBand-resisted exercises (sideways walking, hip hitching and hip abduction whilst standing on the operated leg) based on pre-defined criteria. These exercises have previously been described in detail.[17]

Control group

Participants in the control group received standard rehabilitation plus an additional 15 minutes of general functional exercises at each physiotherapy session to serve as a time control for the additional hip strengthening exercises prescribed for the experimental group. These exercises were chosen to replicate functional activities and included sit-to-stand, marching and walking around a pre-measured circuit. If the participant received hydrotherapy, the same additional exercises were performed in the water.

Outcome measures

Demographic information recorded at baseline included name, age, gender, height, weight and body mass index. The type of prosthesis used (including patellar resurfacing), left or right total knee arthroplasty, previous joint replacements and co-interventions (eg, hydrotherapy) were recorded. Length of hospital stay, number of treatment sessions, and adverse effects were also recorded.

Primary outcomes: The primary outcomes were the Knee Injury and Osteoarthritis Outcome Score (KOOS)[22] and isometric hip abductor muscle strength.[23] The KOOS is a self-reported questionnaire with 42 items in five separately analysed subscales of pain, other symptoms, function in daily living, function in sport and recreation, and knee-related quality of life.[22] (The sport and recreation subscale was not considered in this study.) Isometric hip abductor muscle strength was measured in supine with a handheld dynamometer, recorded in Newtons and normalised to body mass index.[23] The measurement of isometric hip abductor strength has previously been described in detail.[17]

Secondary outcomes: Secondary outcome measures included the stair climb test (ie, time taken to climb four steps in seconds),[24,25] the 6-minute walk test (measured in metres),[24,26] Timed Up and Go (measured in seconds),[27] the 40-m fast-paced walk test (measured in seconds),[24,28] 30-second chair stand test (measured as number of stands),[24,29] step taps (measured as number of taps),[30] isometric quadriceps muscle strength (measured in Newtons and normalised to body mass index),[17,31,32] passive knee range of movement (measured in degrees),[17,31] the Lower Extremity Functional Scale,[33] and Short Form-12 version 1.[34]

Data analysis

The sample size calculation was based around the primary outcome measure: KOOS.[22] We nominated a between-group difference of 10 as the smallest worthwhile effect,[35] and 17 as the anticipated standard deviation.[36] To ensure statistical power of 0.8 at a significance level of $\alpha = 0.05$, a minimum sample of 94 participants (47 per group) would be needed. To allow for 10% loss to follow-up at 6 months,[37–39] the aim was to recruit a sample of 105 participants.

For all primary and secondary outcomes, between-group comparisons at 6 weeks and at 26 weeks were reported as mean difference with 95% confidence intervals. Statistical analyses were conducted according to the intention-to-treat principle, with all available data analysed according to group allocation.

In addition, a per-protocol analysis was conducted, in which participants were considered to have adhered to the program if they received the allocated intervention, attended one exercise session per day as an inpatient, and attended six consecutive weeks as an outpatient. Apart from analysing only the adherent participants, the per-protocol analysis used the same statistical methods as the intention-to-treat analysis.

Results

Compliance with the study protocol

There were no important deviations from the study protocol. The interventions were delivered as allocated, with hydrotherapy sessions

Table 3
Intention-to-treat analysis of mean (SD) of groups, mean (SD) within-group difference, and mean (95% CI) between-group difference for questionnaires.

Outcome	Groups						Within-group difference				Between-group difference	
	Week 0		Week 6		Week 26		Week 6 minus Week 0		Week 26 minus Week 0		Week 6 minus Week 0	Week 26 minus Week 0
	Exp (n = 54)	Con (n = 51)	Exp (n = 52)	Con (n = 49)	Exp (n = 47)	Con (n = 48)	Exp	Con	Exp	Con	Exp minus Con	Exp minus Con
KOOS *(0 to 100)*												
symptoms	45	46	66	63	82	79	21	18	36	34	3	2
	(13)	(16)	(16)	(17)	(13)	(14)	(15)	(19)	(14)	(18)	(−4 to 10)	(−4 to 9)
pain	46	47	73	71	87	71	27	23	40	39	4	1
	(14)	(19)	(16)	(15)	(11)	(15)	(18)	(17)	(13)	(18)	(−3 to 10)	(−5 to 8)
ADL	54	55	82	78	90	88	27	23	35	33	5	3
	(18)	(22)	(15)	(15)	(11)	(13)	(20)	(19)	(15)	(22)	(−3 to 12)	(−5 to 11)
quality of life	29	28	59	55	73	70	30	27	45	41	3	3
	(17)	(21)	(18)	(22)	(19)	(21)	(23)	(23)	(22)	(24)	(−6 to 12)	(−6 to 13)
LEFS	22	21	42	43	53	54	20	22	30	32	−2	−2
(0 to 80)	(12)	(13)	(11)	(13)	(12)	(12)	(14)	(13)	(13)	(13)	(−7 to 4)	(−7 to 3)
SF-12 physical	30	29	40	38	47	46	11	9	17	16	2	1
(0 to 100)	(7)	(6)	(10)	(9)	(8)	(9)	(10)	(9)	(10)	(9)	(−2 to 6)	(−3 to 5)
SF-12 mental	51	49	55	52	57	55	3	2	6	5	1	1
(0 to 100)	(11)	(11)	(8)	(10)	(6)	(8)	(9)	(12)	(11)	(10)	(−3 to 5)	(−4 to 5)

ADL = activities of daily living, Con = control group, Exp = experimental group, LEFS = Lower Extremity Functional Scale, ROM = range of movement, SF-12 = Short Form 12 quality of life questionnaire component summary scores.

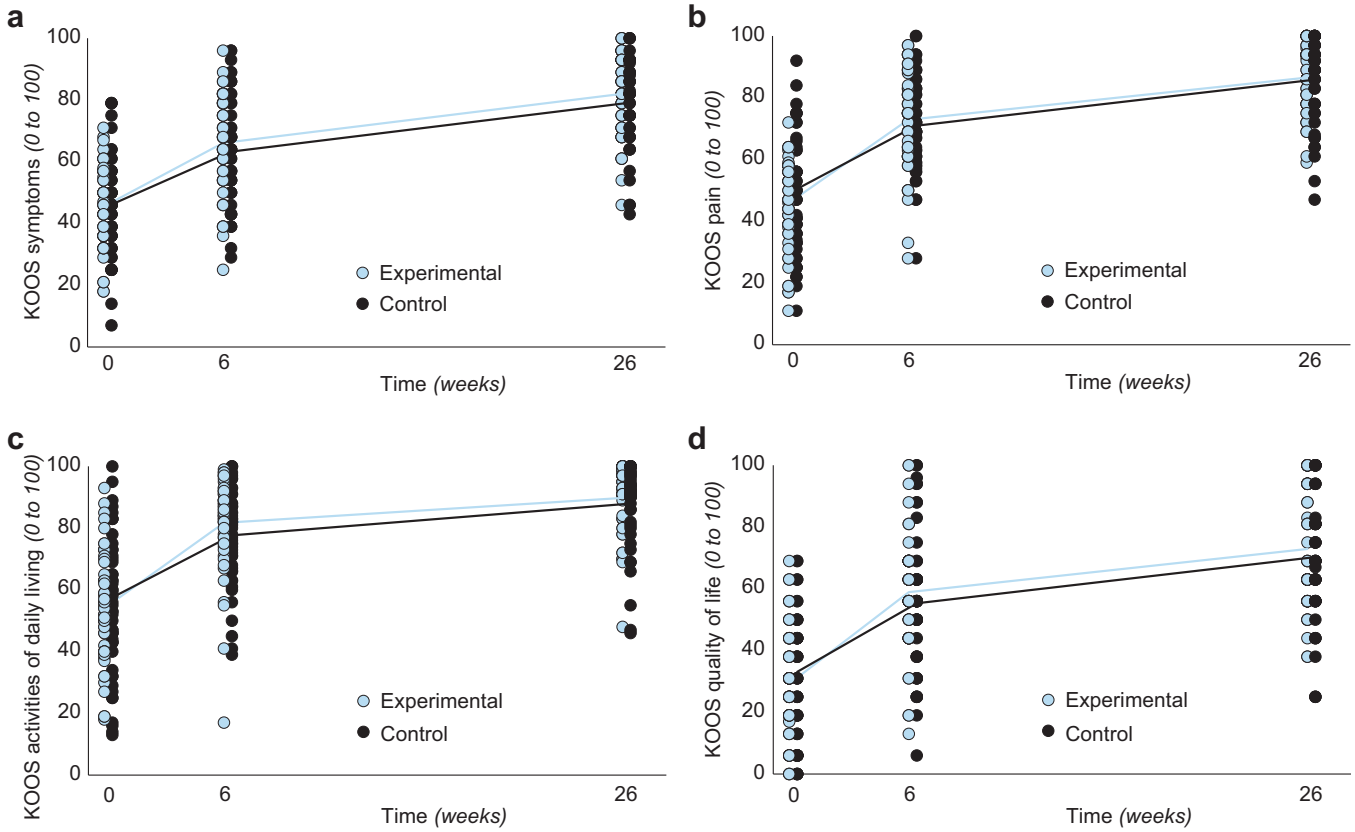

Figure 3. Knee Injury and Osteoarthritis Outcome Score (KOOS) by time, for the subscales (a) symptoms, (b) pain, (c) activities of daily living, and (d) quality of life. Symbols show individual participants' outcomes. Lines join group means at baseline and at Weeks 6 and 26. Experimental and control group data have been offset slightly for clarity.

during the rehabilitation period being completed by 74% of the experimental group and 71% of the control group. All prospectively registered primary and secondary outcomes were reported. The planned assessment at 3 weeks was not undertaken, but the registered assessments at Weeks 0, 6 and 26 are reported here.

Flow of participants through the study

Between October 2015 and August 2016, 315 patients were screened for eligibility. One hundred and twelve patients were eligible and 105 patients (69 females, 36 males) agreed to participate. These participants were randomly allocated to experimental and control groups (Figure 1).

Characteristics of the participants

At baseline, the demographic characteristics of the two groups were similar, as shown in Table 1. The control group had a higher proportion of participants with a previous arthroplasty of the other knee and other hip, but the key baseline clinical characteristics of the groups were similar (as shown in Table 1 and the first two columns of data in Table 2 and Table 3).

Primary outcomes

Hip abductor strength improved in both the experimental and control groups over the 26-week study period, with most improvement occurring during the initial 6-week supervised exercise period (Figure 2). However, the average amount of improvement in hip strength did not differ between the experimental and control groups (Table 2), with mean between-group differences of 0 N/kg/m^2 both at Week 6 and Week 26. The confidence intervals around these between-group differences extended no further than 0.5 N/kg/m^2 in either direction (Table 2).

The KOOS subscales all showed improvement over the 26-week study period (Figure 3). Again, however, there were no significant differences for any of the KOOS subscales between the experimental and control groups at either Week 6 or Week 26 (Table 3). The mean estimates of the between-group differences ranged between 1 and 5 on the 100-point subscales, and were therefore all well below the smallest worthwhile effect of 10. In some subscales, the confidence intervals around these between-group differences did include the smallest worthwhile effect of 10 (Table 3).

Secondary outcomes

Although both groups experienced improvements in function and patient-reported outcomes, the incorporation of targeted hip strengthening did not result in significantly greater improvements than the control intervention at either Week 6 or Week 26 (Tables 2 and 3).

Per-protocol analysis

Thirty-six participants from the experimental group and 43 participants from the control group were deemed to be adherent and were analysed in the per-protocol analysis. There were no significant between-group differences in most of the primary and all of the secondary outcomes at Week 6 and Week 26 (Tables 4 and 5). Two KOOS domains (symptoms and activities of daily living) had a significant between-group difference in favour of the experimental group at Week 6. The mean differences and lower limits of the confidence intervals were below the smallest worthwhile effect, indicating uncertainty about whether the effect may be clinically worthwhile. Neither effect remained statistically significant at Week 26 (Table 5).

Individual participant data are presented in Table 6, which is available on the eAddenda.

Table 4
Per-protocol analysis of mean (SD) of groups, mean (SD) within-group difference, and mean (95% CI) between-group difference for pain and objectively measured outcomes.

Outcome	Groups						Within-group difference				Between-group difference	
	Week 0		Week 6		Week 26		Week 6 minus Week 0		Week 26 minus Week 0		Week 6 minus Week 0	Week 26 minus Week 0
	Exp (n = 36)	Con (n = 43)	Exp (n = 36)	Con (n = 42)	Exp (n = 33)	Con (n = 40)	Exp	Con	Exp	Con	Exp minus Con	Exp minus Con
Pain	3	4	1	2	0	0	−2	−2	−3	−3	0	0
(0 to 10)	(2)	(2)	(2)	(2)	(1)	(1)	(2)	(2)	(2)	(3)	(−1 to 1)	(−1 to 2)
Flexion ROM	81	81	109	106	120	117	28	25	39	36	3	3
(deg)	(8)	(12)	(8)	(10)	(6)	(9)	(10)	(10)	(11)	(12)	(−1 to 8)	(−2 to 8)
Extension ROM	−5	−6	−2	−2	0	−1	3	4	5	5	−1	−1
(deg)	(6)	(5)	(3)	(3)	(2)	(2)	(5)	(5)	(6)	(5)	(−3 to 2)	(−3 to 2)
Hip strength	1.8	2.2	3.5	3.8	4.2	4.2	1.7	1.6	2.3	1.9	0.1	0.3
($N/kg/m^2$)	(0.9)	(1.1)	(1.5)	(1.8)	(1.6)	(1.7)	(1.0)	(1.2)	(1.2)	(1.3)	(−0.4 to 0.6)	(−0.2 to 0.9)
Quadriceps strength	1.6	1.5	5.0	5.6	6.8	7.3	3.4	4.0	5.2	5.7	−0.6	−0
($N/kg/m^2$)	(0.9)	(1.1)	(2.3)	(3.0)	(2.8)	(3.5)	(1.9)	(2.7)	(2.5)	(3.2)	(−1.7 to 0.5)	(−1.9 to 0.8)
Chair stand test	7	8	13	14	15	15	6	6	8	8	0	0
(n in 30 s)	(3)	(2)	(3)	(5)	(4)	(5)	(2)	(4)	(3)	(4)	(−1 to 2)	(−2 to 2)
Stair climb test	25	22	8	8	7	7	−16	−14	−18	−16	−2	−2
(s)	(10)	(9)	(3)	(3)	(2)	(2)	(10)	(7)	(9)	(7)	(−6 to 2)	(−6 to 2)
40-m fast-paced walk	91	85	34	35	28	30	−57	−51	−52	−54	−6	2
(s)	(55)	(44)	(11)	(13)	(7)	(11)	(52)	(39)	(28)	(38)	(−27 to 14)	(−13 to 18)
Timed Up and Go	29	25	10	10	8	8	−20	−15	−19	−16	−5	−3
(s)	(13)	(11)	(3)	(4)	(2)	(3)	(12)	(9)	(10)	(9)	(−9 to 0)	(−7 to 2)
Step taps	5	5	16	17	17	18	10	12	11	13	−2	−2
(n)	(5)	(6)	(4)	(6)	(4)	(5)	(4)	(7)	(5)	(6)	(−4 to 1)	(−4 to 1)
6-minute walk test	178	198	415	420	479	476	237	222	292	276	15	17
(m)	(74)	(109)	(91)	(133)	(101)	(138)	(73)	(93)	(77)	(100)	(−23 to 53)	(−26 to 59)

Con = control group, Exp = experimental group, ROM = range of movement.

Discussion

This is the first large, longitudinal, randomised controlled trial to investigate the effects of incorporating hip abductor strengthening exercises in rehabilitation after total knee arthroplasty. In each group, within-group improvements were observed in muscle strength, function and patient-reported outcomes following total knee arthroplasty. However, incorporating targeted hip strengthening did not result in a substantially greater improvement of the primary outcomes when compared with the control intervention at either the end of the 6-week supervised rehabilitation period or 20 weeks later.

The first primary outcome was hip abductor strength. The equivalence of the effects of the experimental and control interventions on hip abductor strength was demonstrated fairly clearly by the absence of any mean between-group difference accompanied by confidence intervals that excluded effects > 0.5 N/kg/m^2 in either direction.

The other primary outcome (KOOS) indicated a mean estimate of the between-group difference between 1 and 5 on the 100-point subscales. While these mean differences would not be considered worthwhile and these results were statistically non-significant, some of the confidence intervals did extend to or slightly beyond the smallest worthwhile effect of 10, indicating that the possibility of a worthwhile effect was not completely excluded by the data in this study. These were also the only effects to identify a statistically significant benefit on the per-protocol analysis, suggesting that if adherence could be improved, an effect might be more evident. However, with 18 outcomes being assessed at two time points for both intention-to-treat and per-protocol analyses, the possibility that these statistically significant findings were Type-I errors must be acknowledged. Therefore, overall, there is no robust evidence of an effect on the KOOS.

Across the secondary outcomes, the mean estimates of effect were generally very small, with more than half the secondary outcomes having a mean between-group difference with a magnitude of ≤ 1 unit on whatever scale was used. Although a formal smallest worthwhile effect was not nominated for each secondary outcome measure, the upper (ie, most favourable) limits of the confidence intervals was $\leq 10\%$ of the available scale for most of the secondary outcome measures.

There is limited research against which to compare these results. In a small pilot study by Harikesavan et al,[11] the experimental group achieved significantly greater improvements in hip abductor and quadriceps strength, and some of the physical performance measures compared with the control group 12 months after total knee arthroplasty, which did not occur in the current study. One notable difference between the Harikesavan study and this trial is the content of the control group, where the inclusion of simple step-ups and stair climbing differed to the usual care program included in this trial where participants performed higher intensity single leg exercises. These differences in the content of the control group exercise program likely explain why there were between-group differences in the Harikesavan study. The pilot study had higher frequency of outpatient physiotherapy sessions with four to five sessions per week for 4 weeks, followed by two to three sessions per week for 12 weeks. This could have contributed to the significantly greater improvements in muscle strength and physical performance. A higher volume of therapy has been shown to better improve pain and functional outcomes among patients following unilateral total knee arthroplasty.[40] The frequency of physiotherapy sessions in our study is consistent with current practice. A higher frequency of visits similar to the pilot study would significantly increase the cost of the rehabilitation and limit accessibility to rehabilitation due to the high cost. The results of this study are similar to the results in other trials where the addition of specific exercises to usual care have not resulted in greater improvement in outcomes following total knee arthroplasty.[39,41]

The current study showed that both the experimental and control groups experienced improvements in hip abduction strength. The rationale for including the targeted hip strengthening exercises was based on maximal activation of gluteal muscles. The weight-bearing nature of the functional exercises, which recruited the hip abductors to stabilise the pelvis, also resulted in significant increases in hip abductor strength after total knee arthroplasty. Functional exercises may increase hip abductor muscle strength as effectively as targeted hip abductor exercises, and the strength gains of the hip abductors during the non-specific functional exercises may have been underestimated. Both programs in the current study were progressive in dosage. The loads imposed on the hip abductors by the program that the control group experienced were similar to the loads experienced by the experimental group. This presumably resulted in

Table 5
Per-protocol analysis of mean (SD) of groups, mean (SD) within-group difference, and mean (95% CI) between-group difference for questionnaires.

Outcome	Groups						Within-group difference				Between-group difference	
	Week 0		Week 6		Week 26		Week 6 minus Week 0		Week 26 minus Week 0		Week 6 minus Week 0	Week 26 minus Week 0
	Exp (n = 36)	Con (n = 43)	Exp (n = 36)	Con (n = 41)	Exp (n = 33)	Con (n = 40)	Exp	Con	Exp	Con	Exp minus Con	Exp minus Con
KOOS *(0 to 100)*												
symptoms	44	47	68	62	81	79	24	15	36	32	9	4
	(13)	(16)	(14)	(17)	(13)	(15)	(15)	(18)	(14)	(17)	(1 to 16)	(−2 to 11)
pain	45	49	73	71	87	85	28	22	40	37	6	3
	(14)	(19)	(15)	(15)	(10)	(14)	(19)	(16)	(13)	(18)	(−2 to 14)	(−4 to 11)
ADL	52	56	83	77	91	88	31	21	38	31	10	7
	(17)	(22)	(15)	(15)	(9)	(15)	(20)	(19)	(14)	(22)	(1 to 19)	(−2 to 16)
quality of life	26	27	59	55	73	69	33	28	47	41	5	5
	(15)	(21)	(18)	(23)	(17)	(22)	(21)	(22)	(21)	(24)	(−5 to 15)	(−5 to 16)
LEFS	22	22	43	42	56	53	21	19	33	30	2	3
(0 to 80)	(12)	(14)	(11)	(13)	(11)	(13)	(15)	(13)	(12)	(13)	(−4 to 8)	(−3 to 9)
SF-12 physical	29	29	40	38	49	45	12	9	20	16	3	4
(0 to 100)	(7)	(7)	(10)	(9)	(7)	(9)	(10)	(9)	(9)	(9)	(−1 to 7)	(−1 to 8)
SF-12 mental	52	49	54	52	58	54	3	2	6	5	0	1
(0 to 100)	(11)	(12)	(8)	(10)	(5)	(8)	(9)	(12)	(11)	(10)	(−5 to 5)	(−4 to 6)

ADL = activities of daily living, Con = control group, Exp = experimental group, LEFS = Lower Extremity Functional Scale, ROM = range of movement, SF-12 = Short Form 12 quality of life questionnaire component summary scores.

improvements in hip strength in both the control group and the targeted hip strengthening group, and therefore no difference in hip strength in the per-protocol analysis was observed.

This study has implications for clinical practice. Hip abductor strengthening occurred during general functional exercise as well as targeted hip strengthening exercises. Specific hip abductor strengthening exercises may therefore not be necessary to improve hip strength and other outcomes following total knee arthroplasty. An equally successful outcome can be achieved from performing functional exercises in this population. This has been demonstrated in people following total hip arthroplasty who have had a similar diagnosis of osteoarthritis and subsequent joint replacement.[42] This is particularly useful in the early postoperative period when pain and swelling can be a barrier to exercise progression and emphasis is on regaining functional movements such as getting out of a chair and walking.

A possible research implication from the study is suggested by the more positive findings on the per-protocol analysis. That is, the hip abductor strengthening exercises might be worthy of further research if a way could be found to improve either their intensity or the patients' adherence to them.

There were a number of limitations in this study. Participants in the experimental group were not isolated from those in the control group, as both groups used the same gym. However, the gym was large and included many patients with other conditions. A number of different therapists with varying years of experience delivered the treatments. The therapists were instructed in the rehabilitation protocols prior to commencement of the trial, with opportunities for clarification throughout the trial as well as regular verbal encouragement for the duration of the trial. The compliance level of the participants was high, although not perfect because the trial was conducted over a 6-month period and some of the patients had holidays during this period. This trial was conducted at one centre with privately insured patients only. Therefore, the generalisability of the results to the public sector or other centres may be limited. Note that the demographics of the cohort in this study match those reported in previous investigations.[10,39]

Overall, this well-designed and appropriately powered study showed that the incorporation of targeted hip strengthening into standard rehabilitation after total knee arthroplasty did not clearly demonstrate superior muscle strength, functional outcomes or patient-reported outcomes when compared with a control group at the end of a 6-week period of supervised rehabilitation or 20 weeks later. The relevance of specific hip strengthening could be questioned, as very similar improvements in hip abductor strength, functional outcomes and patient-reported outcomes were observed in both the experimental and control groups.

What was already known on this topic: Muscle weakness persists following total knee arthroplasty. Hip abductor strength is associated with functional performance following total knee arthroplasty.
What this study adds: Similar improvements in muscle strength, functional performance and patient-reported outcomes are observed when targeted hip strengthening exercises are incorporated into rehabilitation in adults following total knee arthroplasty in place of general functional exercises.

eAddenda: Table 6 can be found online at: https://doi.org/10.1016/j.jphys.2019.05.008.

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