Original Article

The Effect of Intensive Abductor Strengthening on Postoperative Muscle Efficiency and Functional Ability of Hip-Fractured Patients: A Randomized Controlled Trial

Abstract

Background: Hip fractures are common in the elderly and many patients fail to regain prefracture hip abductor strength or functional status. The purpose of this clinical trial was to compare the effects of an intensive abductor muscle exercise program versus a standard physiotherapy intervention in hip-fractured patients. **Materials and Methods:** Ninety six femoral neck-fractured patients were randomized into equal-sized groups. A 12-week standard physiotherapy program was implemented in the control group(S-PT) whereas an intensive exercise program, emphasizing on abductors' strengthening, was implemented in the research group(I-PT). Abductors' isometric strength of the fractured hip, abductor ratio% in the fractured compared to contralateral hip, and functional level were assessed at the 3rd (postintervention) and 6th (followup) months. **Results:** Postintervention, abductors' isometric strength was 35.7% greater ($P < 0.0005$) and abductor ratio% was 2.5% higher ($P < 0.0005$) in I-PT group, compared to S-PT group. With regard to functional assessments, I-PT group was 29.1% faster during Timed Up and Go (TUG) test and achieved a 26.7% higher Lower Extremity Functional Scale Greek version's (LEFS-Greek) total score, compared to S-PT group ($P < 0.0005$). At followup, abductors' isometric strength was 37.0% greater ($P < 0.0005$) and abductor ratio% was 7.1% higher ($P < 0.0005$) in I-PT group, compared to S-PT group. In addition, I-PT group was 45.9% faster during TUG test ($P < 0.0005$) and achieved an 11.2% higher LEFS-Greek total score, compared to S-PT group ($P = 0.013$). **Conclusions:** Compared to the standard physiotherapy intervention, the intensive abductor-strengthening program significantly increased both abductors' isometric strength of the fractured hip and abductor ratio% and resulted in patients' enhanced functional level. **Clinical Trial Identifier:** ISRCTN30713542.

Keywords: *Functional recovery, hip fractures, muscle strength, outcome assessment, physiotherapy*

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Introduction

Femoral neck fractures usually occur in elderly people as a result of low-impact falls and in most cases require surgical intervention.[1] Postoperatively, those fractures are associated with mobility deficits, varied degrees of inability and pain, and have other deleterious health and economic consequences for patients, their families, and the health-care system.[2] Studies have shown a substantial decline in function following hip fracture,[3-5] even 1 year postfracture.[6] The challenge that clinicians are facing today is to deliver rehabilitation that can minimize these significant impairments and maximize recovery after a hip fracture.[7] In light of this challenge, several studies have examined the benefits of intensive strengthening exercise programs in addition to[8,9] or following[10-15] usual rehabilitation care. These studies have provided evidence that intensive exercise training can improve functionality, compared to standard physiotherapy interventions.[8-15] However, there are no studies, to our knowledge, that have examined the specific effects of intensive strengthening of the fractured limb's hip abductor (HA) muscles on the functionality of hip-fractured patients. It has been suggested that the strength and efficiency of HA are vital for the normal functioning of the hip joint and the patient's overall functional capacity.[16,17] In hip-fractured patients, insufficient HA strength, which may be a normal consequence of aging but is worsened by the trauma of surgery,[18] usually results in serious mobile and functional limitations,

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including joint stiffness, limping, reduced endurance in ambulation, and difficulties overcoming obstacles and ascending stairs.[19] In addition, HA weakness is a major risk factor for falls in community-dwelling individuals[20] and predisposes for a second hip fracture.[21]

The main purpose of the present clinical trial was to study the effects of an intensive abductor-strengthening exercise program in hip-fractured patients compared to the standard physiotherapy intervention.

Materials and Methods

The present study was a prospective, stratified, randomized controlled trial (Clinical Trial Identifier: ISRCTN30713542) conducted in accordance with the ethical principles stated in the Declaration of Helsinki and its later amendments.[22] The Faculty of Medicine of the National and Kapodistrian University of Athens, Greece, and the Scientific Research Council of the "KAT" General Hospital of Attica, Athens, Greece, approved the protocol of the study.

It was estimated that a sample size of 48 patients per group was required to yield an 80% probability of detecting any statistically significant difference between the control and research groups. Sex and age were used as stratification factors in the randomization process. The sex ratio was 3/1 (3 females to 1 male), given that three quarters of the total number of hip fractures occur in women.[23,24] The age ratio was 1/1/1 (three age sub-groups), equally spaced using block size 4. The study's randomization list was formed on the basis of these principles.

To be eligible for randomization, patients had to meet the following inclusion criteria: a diagnosis of displaced femoral neck fracture (Garden's classification III or IV),[25] age between 70 and 84 years, with community-dwelling status before hip fracture, not having undergone previous orthopedic surgery on the fractured or the contralateral hip, and with a body mass index between 19 and 35 kg/m^2. Before hip fracture, the patients should have been able to walk outdoors for two neighborhood blocks.

All patients' admissions were controlled following the orthopedic department's duty roster. Every community-dweller with a Garden's III or IV femoral neck fracture who matched the stratification factors and fulfilled the inclusion criteria was invited to participate in the study. Upon acceptance, and before surgery, participants gave their written informed consent and their demographic and clinical characteristics were recorded. Randomization to either control or research group was performed by an independent clinician according to the randomization list.

All participants underwent hip hemiarthroplasty through Hardinge's direct lateral approach,[26] performed by the same team of orthopedic surgeons. For both study groups, the physiotherapy intervention was initiated on the 2nd postoperative day and lasted 12 weeks, on an in-patient basis for 1 week and home-based for the remaining 11 weeks. Certain precautions were observed during the first postoperative 5 weeks (maximum protection phase) with respect to the aforementioned surgical procedure. Specifically, extension of the operated hip beyond 0° was avoided, while neither adduction nor external rotation passed the body's midline. The combination of extension and external rotation was also avoided,[27] as was a straight leg raise (SLR), since this exercise applies excessive loads to the hip joint that may reach three times the body weight and generates torque that potentially rotates the femoral stem around its axis and can lead to femoral loosening.[28] A physiotherapist member of the research team provided individual daily sessions to all participants during hospitalization [Appendix 1a-c].[29-31] Following discharge, the rehabilitation program continued at home, under the supervision of the same physiotherapist, 3 times per week until the 12th postoperative week (end of the 3rd month). On the days between sessions, all patients were encouraged to continue the program according to the detailed instructions they had been given for the correct and safe performance of the exercises.

A standard physiotherapy program (S-PT), moderate in intensity, was implemented in the control group, based on the rehabilitation protocol of Papathanasiou *et al*. [Appendix 1a-c].[29-31] The latter is in accordance with the American College of Sports Medicine Position Stand for exercise and activity in older adults.[32] Initially, and up to the 3rd postoperative week, the physiotherapy intervention was the same for both study groups. However, at the beginning of the 4th postoperative week, an intensive abductor-strengthening exercise program (I-PT) was implemented in the experimental group, in conjunction with the standard program, as follows:

1. The abductor-strengthening program was applied as described in Table 1, which also shows the progression mode of the exercises and performance tips. This set of exercises was not performed in the contralateral limb
2. The active isotonic exercises for HA in the upright position were started at the beginning of the 4th week, whereas in the S-PT group, they were started at the beginning of the 6th week
3. Starting in the 7th week, HA resistive exercises were performed using both loop elastic bands and cuff weights. In the S-PT group, resistive exercises were started in the 9th week, using only loop elastic bands
4. The duration of the S-PT program home sessions was initially 30 min, increasing to a maximum of 45 min. The I-PT program added approximately 10 min.

Precautions that applied to both groups are given in the Appendix; supplementary precautions for the I-PT group are reported in Table 1.[33,34] Upon completion of the physiotherapy intervention (end of the 3rd month), patients of both groups were encouraged to continue their late-stage individualized program 3 times per week for

Table 1: Intensive exercise program group: The intensive abductor-strengthening exercise program

Exercise description	Levels of difficulty
Abduction from upright position (0°-30°)	Support with two hands
	2 sets of 10 repetitions (4^{th} week-1^{st} session)
	3 sets of 10 repetitions (4^{th} week-2^{nd} session)
	2 sets of 15 repetitions (4^{th} week-3^{rd} session)
	3 sets of 15 repetitions (5^{th} week-1^{st} session)
	Support with one hand
	2 sets of 10 repetitions (5^{th} week-2^{nd} session)
	3 sets of 10 repetitions (5^{th} week-3^{rd} session)
	2 sets of 15 repetitions (6^{th} week-1^{st} session)
	3 sets of 15 repetitions (6^{th} week-2^{nd} session)
	Support with two fingers
	2 sets of 10 repetitions (6^{th} week-3^{rd} session)
	3 sets of 10 repetitions (7^{th} week-1^{st} session)
	2 sets of 15 repetitions (7^{th} week-2^{nd} session)
	3 sets of 15 repetitions (7^{th} week-3^{rd} session)
Abduction from upright position (0°-30°) with cuff weights (0.5-2.5 kg)	Support with two hands
	2 sets of 10 repetitions (8^{th} week-1^{st} session)
	3 sets of 10 repetitions (8^{th} week-2^{nd} session)
	2 sets of 15 repetitions (8^{th} week-3^{rd} session)
	3 sets of 15 repetitions (9^{th} week-1^{st} session)
	Support with one hand
	2 sets of 10 repetitions (9^{th} week-2^{nd} session)
	3 sets of 10 repetitions (9^{th} week-3^{rd} session)
	2 sets of 15 repetitions (10^{th} week-1^{st} session)
	3 sets of 15 repetitions (10^{th} week-2^{nd} session)
	Support with two fingers
	2 sets of 10 repetitions (10^{th} week-3^{rd} session)
	3 sets of 10 repetitions (10^{th} week-2^{nd} session)
	2 sets of 15 repetitions (10^{th} week-3^{rd} session)
	3 sets of 15 repetitions (11^{th} week-1^{st} session)
Abduction from contralateral side - lying position	Outer range of motion
	2 sets of 10 repetitions (9^{th} week-1^{st} session)
	3 sets of 10 repetitions (9^{th} week-2^{nd} session)
	2 sets of 15 repetitions (9^{th} week-3^{rd} session)
	3 sets of 15 repetitions (10^{th} week-1^{st} session)
	Mid and outer range of motion
	2 sets of 10 repetitions (10^{th} week-2^{nd} session)
	3 sets of 10 repetitions (10^{th} week-3^{rd} session)
	2 sets of 15 repetitions (11^{th} week-1^{st} session)
	3 sets of 15 repetitions (11^{th} week-2^{nd} session)

Contd...

Table 1: Contd...

Performance's tips: (1) Progressive mode of exercise loading: During each session, the physiotherapist evaluates the patient's capability and decides what level of difficulty could be performed without supervision until the next session. If a patient performs the sets of a prior level of difficulty without pain or fatigue, he/she rests for 5 min in a chair and then performs the sets of the next level of difficulty. (2) The rest period between sets was 30-60 s, as individually tolerated. (3) The cuff-weight resistance training gradually progressed in difficulty, with increments of 0.5 kg up to the maximum of 2.5 kg, as individually tolerated. (4) At the 9^{th} week, the patients perform two abductor-strengthening exercises: (a) abduction from upright position with cuff-weights and (b) abduction while lying on the contralateral side.(5) Precautions concerning the surgical procedure for the I-PT group*: The inner range of abduction while lying on the contralateral side might be avoided because greater abductor force is required to compensate for the weight of the lower limb, leading to increased hip loading.* I-PT group=The group in which the intensive abductor-strengthening exercise program was implemented

another 3 months. All patients received verbal and written instructions and were asked to record the exercises in a page calendar. The participants' optimal compliance was ensured by personal meetings with the physiotherapist once per fortnight until the end of the 6^{th} month.

Outcome measures were obtained at three different time points: before surgery (baseline), at the end of the 3^{rd} month (postintervention), and at followup at the end of the 6^{th} month. At baseline, the patient's prefracture functional level was assessed using the Lower Extremity Functional Scale (LEFS),[35] a functional evaluation tool that aims to measure the degree of difficulty that an individual with lower extremity disorders of musculoskeletal origin experiences while performing everyday tasks.[31] In the present study, the reliable[36] and validated[37] Greek version of the LEFS questionnaire (LEFS-Greek) was used. At the end of the 3^{rd} and 6^{th} months, the HA isometric strength was measured and recorded. Measurements of the HA's isometric strength were performed in both the fractured and the contralateral limb with a reliable digital handheld dynamometer [Dial Push-Pull Gauge, USA. (intraclass correlation coefficient: 0.899; 95% confidence interval: 0.764–0.959)].[38] The ratio between abductor strengths in the fractured hip and the contralateral hip (the abductor ratio%) was also calculated and its inverse (the abductor deficit%) was derived. Patients' functional capacity was assessed using the LEFS-Greek questionnaire and the "Timed Up and Go" (TUG) test,[39] a widespread clinical tool.[40] The measurement procedures are shown in Table 2 and Figure 1. The use of a walking aid and the incidence of new falls were also recorded. All assessments were carried out by the same examiner, who was not involved in any way with the rehabilitation program and was blinded with respect to the group assignment.

Figure 1: The procedure for measuring the isometric strength of abductor muscles. The examined limb should be in a neutral position with the knee extended and the ankle in dorsiflexion position

Statistical methods

Data were expressed as mean ± standard deviation for quantitative variables and as percentages for qualitative variables. The Kolmogorov–Smirnov test was utilized for normality analysis of the quantitative variables. The homogeneity between compared groups was examined using Student's *t*-test, the Chi-squared test, and Fisher's exact test for the quantitative and qualitative demographic and clinical variables, respectively.

Two-way mixed model ANOVA was used to compare TUG performance time, abductor isometric strength, abductor ratio%, and LEFS-Greek total score between groups at each measurement point. Pair-wise multiple comparisons were performed using the Bonferroni test. To indicate the trend from baseline to 6 months, the median percentage changes in LEFS-Greek total score were calculated for each time point. The percentage changes in LEFS-Greek from baseline to the 6th month were compared between the two groups using the Mann–Whitney test.

All tests were two sided and $P < 0.05$ was used to denote statistical significance. All analyses were carried out using Statistical Package for the Social Sciences, software version 17.00 (SPSS Inc., Chicago, IL, USA).

Results

Patient recruitment lasted from April 2012 to November 2015, by which time the required number of participants had been reached. The recruitment procedure is depicted in the flow diagram in Figure 2. Demographic and clinical characteristics at baseline are shown in Table 3. Nonsignificant differences were found between the I-PT group and S-PT group regarding the participants' personal and clinical characteristics, such as the initial fall position, the direction of fall, the type of Garden's fracture, or the prefracture functional status.

Table 2: Evaluation procedures of the outcome measures

Outcome measure	Procedures
Measurement of HA's isometric strength	The contralateral limb was examined first, and the fractured limb 5 min later
	With the patient supine and the examined limb in a neutral position with the knee extended and the ankle in dorsiflexion position, the dynamometer was mounted 2 cm above the lateral femoral condyle, with the device stabilized against a wall [Figure 1]
	The participants performed two voluntary isometric contractions, each for 2-3 s, with a resting interval of 1 min
	The higher of the two values measured was recorded in Newtons
TUG test	The participants were instructed to perform the test with a self-selected "quick but safe" gait speed and were allowed to use the walking aid on which they depended at the time of measurements
	The TUG test was performed so that the contralateral limb was closer to the cone at the turn
	The participants performed the test twice, with a 5 min resting interval in between
	The quicker of the two times was recorded in seconds
LEFS-Greek	The Lower Extremity Functional Scale's questionnaire consists of 20 items, each of which is scored on a 5-point scale (0-4) with minimum value of 0 and maximum of 80
	The patients reported their prefracture functional capacity (baseline) and the degree of difficulty experiences in performing everyday tasks due to their hip-fracture (at the end of the 3rd and 6th postoperative months)

HA=Hip abductor , TUG=Timed Up and Go, LEFS-Greek=The Greek version of Lower Extremity Functional Scale

The explicit values for abductor isometric strength of both lower limbs, postintervention and during followup, are shown in Table 4. Postintervention, abductors of the fractured hip in the I-PT group had 35.7% greater isometric strength compared to the S-PT group ($P < 0.0005$) [Figure 3a]. In addition, abductor ratio% was 2.5% higher in the I-PT group than in the S-PT group ($P < 0.0005$) [Figure 3b]. In followup measurements, abductors of the fractured hip in patients of the I-PT group had 37.0% greater isometric strength compared to controls ($P < 0.0005$) [Figure 3a] and their abductor ratio% was 7.1% higher ($P < 0.0005$) [Figure 3b].

Postintervention, the I-PT group were 29.1% faster during the TUG test compared to the S-PT group ($P < 0.0005$) [Figure 4a]. In the LEFS-Greek questionnaire, I-PT patients achieved a 26.7% higher total score compared to the S-PT

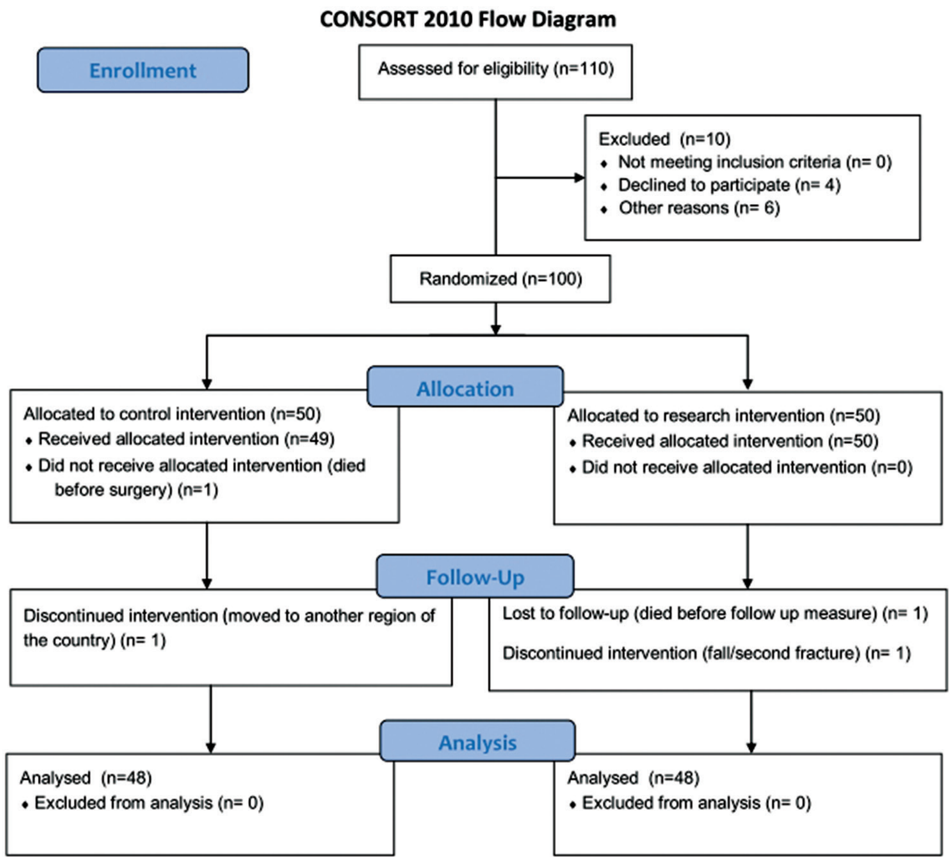

Figure 2: Flow diagram of the study

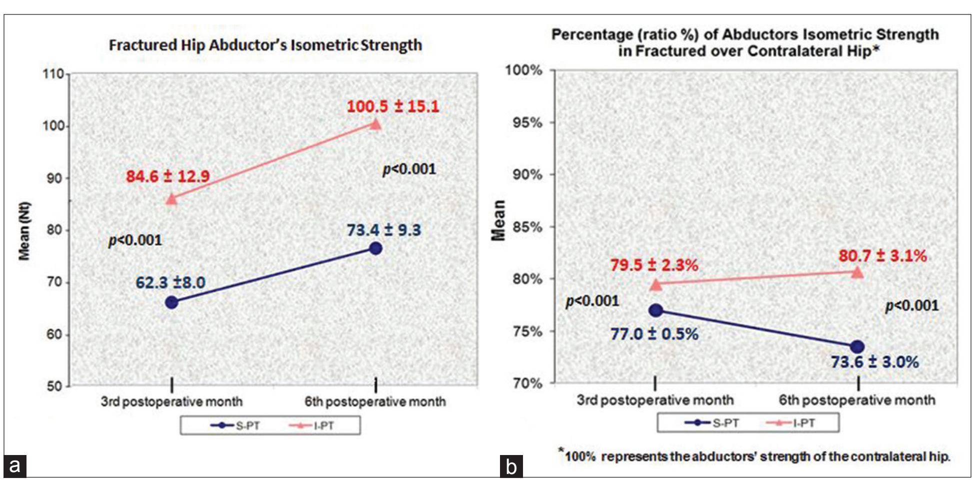

Figure 3: Effects of the two physiotherapy interventions (S-PT vs. I-PT) on measurements of hip abductor muscle strength over time: (a) diagram of the fractured hip abductor's isometric strength of both groups, (b) diagram of the percentage (ratio %) abductor's isometric strength in fractured over the contralateral hip of both groups

Table 3: Personal and clinical characteristics of the study population

Characteristics	Total sample (*n*=96)	I-PT group* (*n*=48)	S-PT group† (*n*=48)	P‡
Age (years)§,‖	77.5±4.2	77.5±4.0	77.5±4.5	0.981 (NS)
Height (cm)§,‖	166.8±7.1	167.75±7.89	165.9±6.1	0.202 (NS)
Weight (kg)§,‖	74.5±9.2	75.3±7.3	73.8±9.0	0.435 (NS)
BMI (kg/m2)§,‖	26.7±2.3	28.7±3.6	26.7±2.2	0.920 (NS)
LEFS-Greek total score§,‖,††	55.9±11.1	57.8±10.5	54.0±11.5	0.098 (NS)
Sex (%)**				
Male	25	25	25	1.000 (NS)
Female	75	75	75	
Dominant lower limb (%)**				
Right	88.5	87.5	89.6	1.000 (NS)
Left	11.5	10.4	12.5	
Fractured hip (%)**				
Right	56.3	50.0	62.5	0.304 (NS)
Left	43.8	50.0	37.5	
Initial fall position (%)**				
Upright	83.3	75.0	91.7	0.053 (NS)
Seated	16.7	25.0	8.3	
Fall direction (%)**				
Posterior	12.5	16.7	8.3	0.450 (NS)
Lateral	49.0	47.9	50.0	
Posterolateral	38.5	35.4	41.7	
Fracture type(%)**				
Garden's III	55.2	64.6	45.8	0.066 (NS)
Garden's IV	44.8	35.4	54.2	
Use of a walking aid at baseline (%)**				
No	81.3	85.4	77.1	0.433 (NS)
Yes	18.8	14.6	22.9	
Use of a walking aid at 3rd postoperative month (%)**,‡‡				
No	44.8	81.3	8.3	0.0005
Yes	55.2	18.8	91.7	
Use of a walking aid at the 6th postoperative month (%)**,‡‡				
No	79.2	85.4	72.9	0.208 (NS)
Yes	20.8	14.6	27.1	

*I-PT group=The group in which the intensive abductor-strengthening exercise program was implemented, †S-PT group=The group in which the standard physiotherapy program was implemented, ‡P value between S-PT and I-PT, §Independent samples *t*-test was used, ‖Values are expressed as mean±SD, **Fisher's exact test was used, ††The Greek version of the LEFS's total score at baseline, ‡‡Use of walking aid (cane) outdoors, and/or over long distances. SD=Standard deviation, BMI=Body mass index, LEFS=Lower Extremity Functional Scale, NS=Not significant

group ($P < 0.0005$) [Figure 4b]. It is worth noting that, during the first 3 postoperative months, 81.3% of the I-PT group reported that they did not need a walking aid (cane) outdoors and/or over long distances, in contrast to 8.3% in the S-PT group ($P < 0.0005$) [Table 3]. In followup, I-PT patients were 45.9% faster than S-PT patients during the TUG test ($P < 0.0005$) [Figure 4a] and achieved an 11.2% higher LEFS-Greek total score ($P = 0.013$) [Figure 4b]. During the followup measurements, 85.4% of the I-PT group reported that they did not need a walking aid (cane) outdoors, in contrast to 72.9% of the S-PT group; however, this difference did not reach statistical significance ($P = 0.208$) [Table 3].

No patient experienced severe pain or fatigue during the physiotherapy sessions and no patient experienced a new fall before the date of the followup measurements.

Discussion

In the present study, intensive abductor-strengthening, in addition to the standard physiotherapy intervention, was found to increase the isometric strength of HA and enhance the functional capacity of hip-fractured patients significantly more than a moderate standard exercise program.

To our knowledge, this is the first study to investigate the effect of an intensive HA-strengthening program on postoperative abductor strength and ratio% in hip-fractured patients. The main factor appears to have been the addition of strengthening exercises that target the HA specifically. Significant gains in strength after high-intensity strengthening exercise programs have also been reported in studies involving hip-fractured patients.[14,41-43] However,

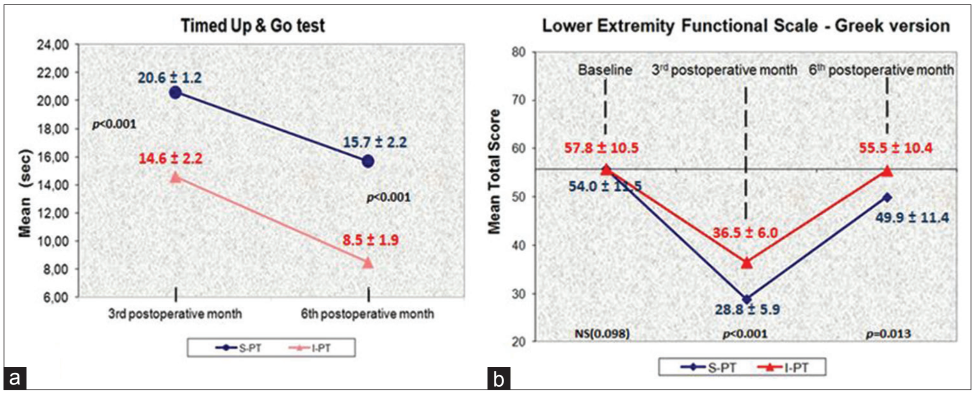

Figure 4: Effects of the two physiotherapy interventions (S-PT vs. I-PT) on functional outcomes (Timed Up and Go test and Lower Extremity Functional Scale-Greek version) over time (a) diagram of theTimed Up and Go test's performance time of both groups, (b) diagram of the Lower Extremity Functional Scale-Greek version's total score of both groups

Table 4: Explicit values of abductor isometric strength of both lower limbs (*N*)

Postoperative measurement time points	I-PT group*			S-PT group†		
	Fractured hip	Contralateral hip	*P*‡	Fractured hip	Contralateral hip	*P*‡
3rd postoperative month	19.04±1.80§	23.99±3.94§	<0.005	13.99±2.91§	18.15±2.34§	<0.005
6th postoperative month	22.55±3.41§	27.89±3.54§	<0.005	16.53±2.12§	22.40±2.22§	<0.005

*I-PT group=The group in which the intensive abductor-strengthening exercise program was implemented, †S-PT group=The group in which the standard physiotherapy program was implemented, ‡*P* value between abductor isometric strength of the fractured versus contralateral hip, §Values are expressed as mean±SD. SD=Standard deviation

very few studies have compared physiotherapy programs with different intensities (high-intensity vs. moderate) during the acute postoperative period,[8,10] and these focused not on HA, but on quadriceps muscle strengthening. According to these results, a high-dose strengthening program, implemented on the lower limb,[10] did not lead to a significant improvement in isometric strength, in contrast to a targeted quadriceps-strengthening program.[8] A possible reason may be that the high-dose program[10] was not targeted at a specific muscle group. It seems that targeted training (specificity of exercise), as in our study, is a key factor for increasing muscle strength.

We also found that intensive HA strengthening in the fractured limb resulted in a significantly greater increase in abductor strength ratio% (decreased deficit%), compared to the standard physiotherapy program. This is the first report of targeted exercise having a beneficial effect on abductor deficit%, though a few studies reported an improvement in quadriceps deficit% during acute postoperative period[8,9] or after the first 6 months.[11] A decrease in the quadriceps deficit% of the fractured limb was recorded only in studies where the intensive strengthening program was either targeted at a muscle group[8] or involved intensive exercise of the fractured limb[11] for an extended period (6–12 weeks).[8,11] Once again, it seems that intensive and targeted exercise, for a prolonged period of time, as applied in our study, is the key to reducing the strength deficit% of the fractured compared to the contralateral limb. However, further research is needed to study the benefits of additional intensive strengthening during the acute postoperative period in hip-fractured patients and to determine the optimum amount and duration of exercise for maintaining or enhancing muscle strength.

This is also the first study to examine the specific effects of intensive versus moderate strengthening of the fractured limb's HA on hip-fractured patients' functional capacity. Randomized controlled trials carried out during[8] or after[12] the acute postoperative period in hip-fractured patients examined the effect of an intensive strengthening program on their functional status. However, these studies did not focus on abductor-strengthening, but on quadriceps strengthening in the fractured limb,[8] or on the kinetic chain of both lower limbs (bilateral), with greater loads on the fractured limb.[12] Nevertheless, intensive muscle strengthening enabled hip-fractured patients to significantly improve their performance in functional tests, such as the Functional Reach Test[8] or Chair-rise Time.[12]

Comparing our TUG findings with the results of previous studies, it appears that intensive and targeted HA-strengthening improves the test performance time, whereas this was not the case with intensive quadriceps strengthening[8] or intensive strengthening of the kinetic chain of the lower limb.[12] One reason for this discrepancy may be the position in which exercises were carried out. Previous investigators observed a decrease in TUG test performance time when most of the program's exercises were performed in the upright position,[13] whereas in other studies,[8,12] the intensive strengthening exercises were mainly implemented in a sitting position and so did not challenge the dynamic balance. In our study, patients in the I-PT group performed most abductor exercises in the upright position, to help the development of better HA strength and increased balance control. This improved the patients' ability to perform functional activities,[17] as our TUG test results showed.

The TUG test is also a valid method for identifying older adults who are prone to fall.[44] The determination of the risk of falls, using TUG cut-off scores for different population or patient groups, is a very important prerequisite for planning effective preventive interventions. For community-dwelling older frail adults, such as our patients, there is a TUG cutoff score of 14 s, indicating that people who have a TUG test performance time >14 s have an 83% probability of sustaining a fall.[44] At the postintervention time point, patients in our I-PT group had a mean TUG test performance time of 14.6 s, whereas at followup, they achieved an impressive 8.5 s, indicating normal mobility[39] [Figure 4]. It appears that the risk of a future fall and a second hip fracture is significantly reduced in patients who have undergone an intensive abductor-strengthening exercise program.

Our assessment of hip-fractured patients' functional capacity based on the LEFS-Greek total score showed that intensive abductor strengthening resulted in an improved ability to carry out daily-life activities, compared to moderate standard physiotherapy. As one might expect, the increase in HA isometric strength of the fractured limb in the I-PT group and the improvement in abductor ratio% led to a greater ease in carrying out daily-life activities. The change in the functional capacity of the I-PT group was so striking that, at postintervention, 81.3% of these patients reported that they did not need a walking aid outdoors, in contrast to only 8.3% of the patients in S-PT group [Table 3]. In line with our results, a recent Cochrane review provides evidence that progressive resistance training can effectively improve physical functioning in elderly people, enhancing muscle power and the performance of basic activities of daily living.[45] Moreover, it has been reported that a home-based progressive resistance exercise program increased the force production of lower extremity muscles, achieved moderate-to-large effects on physical performance and improved quality of life.[46]

Strengths and limitations

The present study was a prospective, stratified, randomized, controlled exercise intervention trial with a very low dropout rate. All participants underwent hip hemiarthroplasty through Hardinge's direct lateral approach,[26] performed by the same team of orthopedic surgeons, and the same physiotherapist was responsible for the physiotherapy intervention in both groups. Supervision and guidance from the physiotherapist during sessions helped ensure the patient's adherence. Furthermore, all measurements were made by the same examiner, who was not involved in any part of the rehabilitation program and was blinded with respect to the group assignment. These factors added strength and statistical power to the results of this study.

On the other hand, there are important limitations that must be mentioned. Patients were invited to participate in the study after their admission to the hospital; hence, there was no opportunity to obtain baseline measurements of HA strength and TUG performance time. In addition, because of limited equipment availability, the measurement of HA isometric strength was used as the main indicator of muscle capacity, whereas it was not possible to record other assessments of HA strength, such as maximum torque, endurance, or total work. However, it has been reported that isometric strength measured with handheld dynamometers is an objective indicator of muscle capacity commonly used in clinical practice,[47-49] and may be preferred over other forms of dynamic muscle testing, such as isokinetic assessments or variable-resistance weight-lifting.[50] It should be mentioned that we did not record postsurgical pain levels; however, no patient discontinued the physiotherapy sessions because of severe pain. Finally, the study's sample population consisted of community-dwelling individuals, who were capable of performing exercises safely in an upright position. Therefore, it must be underlined that our findings cannot be generalized to all hip-fractured patients, since the prefracture functional level is among the factors affecting postoperative hip fracture recovery.[51]

Conclusions

The results shown here indicate that the implementation of an intensive abductor-strengthening exercise program, in addition to the standard physiotherapy intervention, may significantly increase both the HA isometric strength of the fractured hip and the abductor ratio%, while enhancing patients' functional capacity. Further research is needed in order to understand the effects of this targeted strengthening exercise program on the abductor muscle capacity and functional ability of hip-fractured patients.

Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent forms. In the form, the patient (s) has/have given his/her/their consent for his/her/their images and other clinical information to be reported in the journal. The patients understand that their names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

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Conflicts of interest

There are no conflicts of interest.

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Appendix

Appendix 1: (a-c) Standard physiotherapy program for hip-fractured patients who have undergone hemiarthroplasty

Appendix 1a

Standard physiotherapy for hip-fractured patients who have undergone hemiarthroplasty (S-PT)

Timeframe	Exercises	Performance Guidelines
Timeframe: 1^{st} – 2^{nd} week	Respiratory Physiotherapy (If needed)	Diaphragmatic breathing. Exhale and cough instructions must be given for secretion drainage. Upper limb combined with respiratory manoeuvres can be performed.
	Trunk Exercises	Supine position. Trunk extensors and individually modified abdominal exercises.
	Isotonic or resistive training of the contralateral limb	
	Ankle pumps	Supine position. Two sets of 10 repetitions each for both limbs, alternately.
	Ankle dorsiflexion – plantar flexion with manual resistance	
	Isometric contractions of knee extensors	Supine position. Isometric contraction for 5 s, with a resting interval of 8s.
	Isometric contractions of knee flexors	Semi-seated position. Isometric contraction for 5 s, with a resting interval of 8 s.
	Isotonic knee extension and flexion exercises (short arc)	Supine position. A towel roll is placed under the patient's knee. The patient is asked to straighten the lower leg, lift the foot and extend the knee. The patient must hold and count to 5, then lower the foot slowly with the ankle joint in dorsal flexion position.
	Heel slides	Supine position. Initially the exercise is performed with assistance, later as active isotonic. During execution, hip flexion should not exceed 30°.
	Isometric contractions of hip extensors muscles	Supine position. Isometric contraction for 5 s, with a resting interval of 8 s.
	Hip abduction – adduction slides	Supine position. Neutral leg position (concerning hip rotation), with knee joint in extension and ankle joint in dorsal flexion. During the first postoperative days, the exercise is performed with assistance, later as active isotonic. Initially, abduction should not exceed 20°, and adduction is performed until the anatomical position (0°).
	Modified bridges	Supine position. The patients are asked to bend the knee of the contralateral limb and to try to lift their pelvis off the bed surface. The fractured limb remains extended on the bed.
	Balance exercises from short-sitting position on the bed	Sitting on the lateral side of the bed, with the hips in abduction and the feet supported on a footstool. The patient performs trunk and upper-limb exercises. (***Note***: The trunk-to-hip-joint angle should not be <100°)

Appendix 1b (continued S-PT)

Timeframe: 3rd - 5th week	Modified Thomas Exercise	Supine position. The patient bends the contralateral limb and uses his/her hands to pull the knee towards the torso, while the fractured limb is actively extended against the bed surface.
	Stretching exercises	Emphasizing soft-tissue stretching and joint flexibility.
	Bridging	Supine position. The patients are asked to bend the knees of both limbs and to lift their pelvis just off the bed surface.
	Isotonic knee extension and flexion exercises (long arc)	Sitting on a chair with armrests and seat-height 45-50 cm. The patient extends the knee joint (90°→0°). The patient must hold and count to 5, then lower the foot slowly with the ankle in dorsal flexion position.
	Balance exercises from short-sitting position on the bed	Sitting on the lateral side of bed with the hips in abduction and the feet resting on the floor. The patient performs trunk and upper-limb exercises.
	Standing toe raises	Upright position. When the patient acquires sufficient balance and ease in changing direction during walking with assistance and is able to turn safely while walking with the assistive device, then he/she may start to train with exercises in the upright position. The hands hold on to a firm surface to provide the patient with support.
	Knee flexion with ankle joint in dorsal flexion position	
	Hip flexion (0°→90°) with knee flexed	
	Mini wall squats (hip flexion 0°→ 50°)	
Timeframe: 6th-8th week	Lower limb stretching exercises	Emphasizing soft-tissue stretching and joint flexibility.
	Standing toe raises	Upright position. The degree of difficulty depends on how the patient is supported while performing the exercises. Initially, the patient uses both hands, then just the hand on the fractured side, and ultimately is supported using only two fingers on the fractured side.
	Hip flexion (0°→60°-70°) combined with knee flexion	
	Hip abduction (0°→30°)	
	Hip extension over 0° (hyperextension 0°→10°-20°)	
	Mini squats (hip flexion 0°→ 60°-70°)	
	Sit-to-stand	Chair with armrests and seat-height 45-50 cm. The patients are seated with the knee joint at 90°. They push off each armrest with both arms to lift themselves from the chair and then slowly lower themselves on to the chair.
	Lateral steps	Upright position. The patient is facing forward and performs lateral steps, starting with the fractured side (initially 5 steps are performed for each side).
	Balance and proprioceptive training	Standing with eyes opened and then closed. Standing with one foot directly in front of the other. Stepping forwards-backwards, etc., as individually tolerated.

Appendix 1c (continued S-PT)

Timeframe: 9th - 12th week	Lower limb stretching exercises	Emphasizing soft-tissue stretching and joint flexibility.
	Knee extension resistive exercises	Sitting position. Use loop elastic bands, starting with the lowest resistance [10 lbs (4.5 kg)]
	Knee flexion resistive exercises	
	Hip flexion (0°→60°-70°) resistive exercises combined with knee flexion	Upright position. Use loop elastic bands, starting with the lowest resistance. [10 lbs (4.5 kg) for hip flexion and hip extension, 5 lbs (2.3 kg) for hip abduction]
	Hip abduction resistive exercises (0°→30°)	
	Hip extension resistive exercises over 0° (hyperextension 0°→10°-20°)	
	Lateral steps	
	Jumping over obstacle	Increase height and/or width of obstacle as individually tolerated.
	Balance and proprioceptive training	Walking on uneven or soft surfaces, with eyes opened/closed, walking backwards. Sitting on Swiss Ball, standing on BOSU, etc., as individually tolerated.

Recommendation Notes:

1. This is an outline of the standard physiotherapy programme. The gait training with/without assistive devises, according to the guided incremental progression of full weight-bearing, and the training of ascent/descent stairs are not described here, because of space limitations.
2. During the Maximum Protection Phase (first 3-5 weeks), all precautions and considerations concerning the surgical approach and the gradually loading of the hip joint, must be taken into account.
3. If the patient has any difficulty with a particular exercise, the programme can be modified accordingly.
4. All patients are trained to breathe with a normal inhalation/exhalation rhythm while performing the isometric exercises, in order to avoid a Valsalva manoeuvre.
5. Each exercise starts with 1 set (5 to 10 repetitions), reaching a maximum of 2 sets of 10 repetitions, as individually tolerated.
6. It is strongly recommended that exercises involving a risk of falling should be performed only under the physiotherapist's supervision.
7. Precautions to be taken concerning the surgical procedure for both study groups: Abduction from the upright position should not pass the 30°, because when the angle of abduction in upright standing is increased, the centre of gravity of the lower limb moves laterally and the gravitational moment is increased. Hence, the counteracting muscle activity of hip abductor, as well as the hip-joint load, are increased.