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Comparative analysis of normalized hip muscle strength according to surgical approach in total hip arthroplasty

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Patients who require total hip arthroplasty (THA) experience atrophy and weakness of the thigh muscles, which affects the ability to maintain balance while standing and walking. THA corrects a certain imbalance in muscle function, but the surgical approach used may also affect the recovery of individual groups of thigh muscles. Methods. The results of treatment of 41 patients who underwent unilateral THA with a modified lateral (group I) or direct anterior surgical approach (group II) were analysed. Group I included 23 patients aged 34 to 74 years, 17 (73.9 %) men and 6 (26.1 %) women, and group II included 18 people aged 27 to 75 years, 11 (61.1 %) men and 7 (38.9 %) women. The strength of the muscles of the contralateral and healthy limbs was measured using a device based on the SBA-100L strain gauge before THA, 1 and 3 months after the surgery. To assess muscle strength, the normalized coefficient (NC) was used, as the ratio of muscle strength to body weight. Results. Before THA, according to the NC assessment, no intergroup differences in muscle strength were established in patients ($p > 0.05$). One month after THA, the strength of the adductor group of the operated limb in group II was greater ($p = 0.014$) compared to group I, and the strength of the flexors and extensors were significantly greater ($p = 0.026$) in group I compared to group II. No statistical difference was found for the abductor group of muscles. After 3 months, the abductor muscle strength ($p = 0.003$) was greater in group II than in group I, and the flexor muscle strength ($p = 0.009$) was greater in group I than in group II. The adductor and extensor muscle groups did not differ. NC of all muscle groups were significantly lower than the contralateral limb for all patients after 3 months, except for the extensor muscles in group I, where no difference was found. Conclusions. The restoration of thigh muscle strength in patients after total hip arthroplasty had a positive linear dynamics regardless of the surgical approach used during 3 months of observation; however, there is asymmetry in the restoration of the studied muscle groups.

У пацієнтів, які потребують проведення тотального ендопротезування кульшового суглоба (ТЕКС), спостерігається атрофія та слабкість м'язів стегна, що впливає на здатність підтримки рівноваги під час стояння і ходьби. ТЕКС усуває певний дисбаланс роботи м'язів, проте застосований хірургічний доступ також може впливати на особливості відновлення окремих груп м'язів стегна. Методи. Проаналізовано результати лікування 41 пацієнта, яким виконали одностороннє ТЕКС модифікованим латеральним (I група) або прямим переднім хірургічним доступом (II група). До I групи увійшли 23 особи віком від 34 до 74 років, 17 (73,9 %) чоловіків та 6 (26,1 %) жінок, а II — 18 віком від 27 до 75 років, 11 (61,1 %) чоловіків і 7 (38,9 %) жінок. Вимірювали силу м'язів стегна контрлатеральної та здорової кінцівки за допомогою пристрою на основі силовимірювального тензорезисторного датчика SBA-100L до ТЕКС, через 1 і 3 міс. після втручання. Для оцінювання сили м'язів використовували нормалізований коефіцієнт (НК), як відношення сили м'язів до маси тіла. Результати. До проведення ТЕКС у пацієнтів за даними оцінки НК сили м'язів міжгрупових відмінностей не встановлено ($p > 0,05$). Через місяць після втручання НК сили привідної групи м'язів оперованої кінцівки в групі II більші ($p = 0,014$) як порівняти з I, а показники сили згиначів і розгиначів були значущо більшими ($p = 0,026$) у групі I порівняно з II. Для відвідної групи м'язів статистичної різниці не виявлено. Через 3 міс. після ТЕКС НК сили відвідних м'язів ($p = 0,003$) більші в групі II, ніж в I, а сили згинальних ($p = 0,009$) мали більші значення в групі I, ніж у II. Групи привідних м'язів і розгиначів не відрізнялися. НК сили всіх груп були значуще нижчими за контрлатеральну кінцівку для всіх пацієнтів через 3 міс., крім м'язів-розгиначів у групі I, де різниці не виявлено. Висновки. Відновлення сили м'язів стегна в пацієнтів після ендопротезування кульшового суглоба мало позитивну лінійну динаміку незалежно від застосованого хірургічного доступу впродовж 3 міс. спостереження, проте є асиметрія у відновленні досліджуваних м'язових груп. Ключові слова. Сила м'язів, м'язи стегна, ендопротезування кульшового суглоба, реабілітація, модифікований латеральний доступ, прямий передній доступ.

Keywords. Muscle strength, hip muscles, total hip arthroplasty, rehabilitation, modified lateral approach, direct anterior approach

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Introduction

Hip osteoarthritis and aseptic necrosis of the femoral head are associated with pain and significant functional limitations. In the advanced stages of these diseases, marked atrophy and weakness of the thigh muscles develop, particularly of the abductor muscle group, affecting patients' ability to maintain balance while standing and walking [1–3]. Muscle weakness, rather than pain, is a factor that leads to impaired gait biomechanics, manifested as limping, and over time results in pelvic obliquity and functional limb shortening [4].

The main feature of degenerative and post-traumatic hip pathology is restricted joint mobility [5, 6], which progresses with disease severity and causes substantial loss of strength not only in the abductors but also in all lower limb muscles [7]. Avoidance of loading the affected limb leads to overloading of the contralateral limb, which may cause asymmetry and, consequently, increased asymmetry in muscle strength. At the same time, reliable evidence regarding differences in thigh muscle size between the affected and unaffected limbs in such patients remains insufficient [8], although there is evidence that muscle strength decreases together with reduced muscle size [9].

Total hip arthroplasty (THA) is an effective surgical treatment method for the aforementioned conditions and contributes to restoration of proper thigh muscle function [10, 11]. Elimination of pain and improvement of mobility have a positive effect on functional recovery; however, prolonged disease progression often causes irreversible muscle changes, particularly in elderly patients. Such conditions require rehabilitation, often with an individualized approach, aimed at restoring lower limb muscle strength and endurance [7]. At the same time, recovery of thigh muscles may differ depending on the surgical approach used [12], requiring further detailed investigation.

Purpose: to identify the characteristics of normalized thigh muscle strength recovery depending on the surgical approach used (direct anterior or modified lateral) during total hip arthroplasty.

Materials and Methods

The study was conducted in accordance with the principles of the Declaration of Helsinki. All patients provided informed consent for participation in the study, which was approved by the Bioethics Committee Protocol No. 263 dated 04.05.2026, of the Professor M.I. Sytenko Institute of Spine and Joint Pathology of the National Academy of Medical Sciences of Ukraine.

Patients

The treatment outcomes of 41 patients requiring total hip arthroplasty at the Professor M.I. Sytenko Institute of Spine and Joint Pathology of the National Academy of Medical Sciences of Ukraine were analyzed.

The patients were divided into two groups:

– Group I (HA) consisted of 23 patients aged 55.3 ± 11.9 years (range, 34–74 years), including 17 men (73.9 %) and 6 women (26.1 %). Surgery was performed using the modified lateral approach (Hardinge approach — HA);

– Group II (DAA) comprised 18 patients aged 58.3 ± 10.5 years (range, 27–75 years), including 11 men (61.1 %) and 7 women (38.9 %). Surgery was performed using the direct anterior approach (DAA).

No statistically significant differences were found between the groups in terms of age ($t(39) = -0.861$; $p = 0.395$) or sex ($\chi^2 = 0.764$; $p = 0.382$).

The mean length of hospital stay after THA was 13.6 ± 3.0 bed-days in the HA group and 6.5 ± 1.4 bed-days in the DAA group; the difference was statistically significant ($t(32.6) = 9.794$; $p < 0.001$).

Dynamometry

Muscle strength was measured using a device based on an SBA-100L strain gauge force sensor. The study used the positioning scheme described by V. Marks [13].

To assess muscle strength, the normalized muscle strength coefficient (NC) was used, which was calculated according to the formula:

$$K = \frac{F}{m} \times g,$$

where F is muscle strength (kg); m is patient body weight (kg); g = 9.81 is the gravitational constant.

The standard examination protocol for patients with hip pathology included measurement of the strength of the adductor (medial), abductor (lateral), flexor (anterior), and extensor (posterior) muscle groups. Patients were examined before surgical treatment and at 1 and 3 months after surgery.

Considering that the patients differed in age (27–75 years) and sex, muscle strength was assessed using normalized strength coefficients adjusted for demographic characteristics. Muscle strength coefficients eliminate variability related to body weight, sex, and age, making their assessment more objective. Although NC values differ between men and women and decrease with age, the critical minimum

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functional norm (MFN) is considered to be a value of 2. This represents the minimum level at which pelvic balance can be maintained. Loss of balance is manifested by a positive Trendelenburg test [14, 15]. A decrease in MFN below 2 leads to significant impairment of balance, increased risk of falls, difficulty walking, and other functional limitations.

Statistical methods

The Shapiro–Wilk test for data distribution demonstrated a normal distribution in all samples. Therefore, quantitative variables are presented as mean values and standard deviations (M ± SD), as well as minimum and maximum values.

Comparisons between groups were performed using Student's t-test for independent samples, with calculation of the t-statistic, statistical significance level (p), and Cohen's d effect size coefficient with a 95 % confidence interval (95 % CI). Comparisons between two time points were performed using Student's t-test for paired samples, with calculation of the t-statistic, statistical significance level (p), and the repeated-measures effect size coefficient (d_rm) with a 95 % CI. In cases of high paired correlation values ($r \approx 0.999$), the effect size was assessed using Cohen's d_z coefficient for paired comparisons. Comparisons between the operated and contralateral limbs were performed using Student's t-test for paired samples.

Considering the presence of three observation time points during muscle strength assessment by dynamometry, a mixed analysis of variance (Mixed ANOVA; group × time × side) was used to analyze changes in strength parameters over time. Graphs illustrating the dynamics of changes in muscle strength parameters at different follow-up periods were generated for visualization of the results.

Differences were considered statistically significant at $p < 0.05$. Statistical analysis was performed using the R environment (R Foundation for Statistical Computing).

Results

Before THA, no between-group differences were identified in normalized muscle strength coefficient values ($p > 0.05$) (Table 1). For the abductor muscle

Table 1

Assessment of the normalized thigh muscle strength coefficient before THA

Muscle group	Normalized muscle strength coefficient	HA (M ± SD) / (min ÷ max)	DAA (M ± SD) / (min ÷ max)	Student's t-test (t, p) Cohen`s d; [95 % CI]
Adduction	NC in coxarthrosis	1.75 ± 0.44 0.96 ÷ 2.41	1.63 ± 0.38 1 ÷ 2.6	t = 0.888; p = 0.380 d = 0.27; [–0.35; 0.89]
	NC of the contralateral limb	2.12 ± 0.5 1.26 ÷ 2.9	1.97 ± 0.44 1.31 ÷ 3.12	t = 0,977; p = 0,335 d = 0,3; [–0,32; 0,92]
	ΔM; [95% CI] t, p drm; [95 % CI]	ΔM = –0.37; [–0.39; –0.34] t = –28.745; p < 0.001 drm = –0.299; [–0.32; –0.278]	ΔM = –0.34; [–0.37; –0.31] t = –22.415; p < 0.001 drm = –0.363; [–0.396; –0.33]	—
Abduction	NC in coxarthrosis	1.67 ± 0.37 1 ÷ 2.25	1.61 ± 0.32 0.98 ÷ 2.43	t = 0.56; p = 0.579 d = 0.17; [–0.45; 0.79]
	NC of the contralateral limb	2.03 ± 0.41 1.33 ÷ 2.7	1.95 ± 0.35 1.3 ÷ 2.92	t = 0.688; p = 0.495 d = 0.21; [–0.41; 0.83]
	ΔM; [95% CI] t, p drm; [95 % CI]	ΔM = –0.36; [–0.38; –0.34] t = –37.439; p < 0.001 drm = –0.6; [–0.635; –0.566]	ΔM = –0.34; [–0.36; –0.31] t = –31.635; p < 0.001 drm = –0.634; [–0.677; –0.59]	—
Flexion	NC in coxarthrosis	2.68 ± 0.54 1.75 ÷ 3.57	2.58 ± 0.46 1.72 ÷ 3.85	t = 0.688; p = 0.495 d = 0.21; [–0.41; 0.83]
	NC of the contralateral limb	2.81 ± 0.6 1.75 ÷ 3.77	2.71 ± 0.51 1.72 ÷ 4.07	t = 0,618; p = 0,54 d = 0,19; [–0,43; 0,81]
	ΔM; [95% CI] t, p drm; [95 % CI]	ΔM = –0.13; [–0.16; –0.1] t = –9.726; p < 0.001 drm = –0.086; [–0.103; –0.069]	ΔM = –0.13; [–0.16; –0.11] t = –10.778; p < 0.001 drm = –0.118; [–0.139; –0.096]	—
Extension	NC in coxarthrosis	2.53 ± 0.48 1.73 ÷ 3.35	2.42 ± 0.42 1.7 ÷ 3.61	t = 0.766; p = 0.448 d = 0.24; [–0.38; 0.85]
	NC of the contralateral limb	2.99 ± 0.6 1.96 ÷ 3.98	2.87 ± 0.51 1.92 ÷ 4.29	t = 0.697; p = 0.49 d = 0.22; [–0.4; 0.83]
	ΔM; [95% CI] t, p drm; [95 % CI]	ΔM = –0.46; [–0.51; –0.41] t = –18.316; p < 0.001 drm = –0.165; [–0.183; –0.147]	ΔM = –0.44; [–0.49; –0.39] t = –19.014; p < 0.001 drm = –0.208; [–0.23; –0.186]	—

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group, a statistically significant difference in strength was found between the affected and contralateral limbs ($t = 37.439$; $p < 0.001$), accompanied by a medium effect size ($d_rm > 0.6$). For the remaining muscle groups, despite statistically significant differences ($p < 0.001$), effect size coefficients remained close to 0.1, indicating that the observed differences lacked clinical significance.

One month after THA, normalized muscle strength coefficients of the contralateral limbs did not differ between groups ($p > 0.05$) (Table 2). However, differences were observed between groups in the recovery of thigh muscle strength in the operated limbs. The NC of adductor muscle strength was higher after the direct anterior approach compared with the lateral approach ($p = 0.014$), and this difference was supported by a large, clinically significant effect size ($d = –0.82$).

No statistically significant difference was found for the abductor muscle group (Table 2), which may be explained by incomplete recovery from the preoperative persistent reduction in strength and by muscle injury associated with the lateral approach, which additionally reduces adductor muscle strength.

One month after THA, the NC of flexor muscle strength was significantly higher ($p = 0.026$) in Group I compared with Group II, and the difference was supported by a clinically significant effect size ($d = 0.71$) (Table 2). Similarly, the NC of extensor muscle strength was significantly higher ($p = 0.035$) in Group I than in Group II, with the effect size indicating clinical significance ($d = 0.67$) (Table 2). The lower muscle strength coefficient in Group II may be explained by greater trauma to the flexor muscles and restricted movement (often due to symptomatic pain) during flexion and extension.

Three months after THA, no differences in NC of the contralateral limb were identified between the groups ($p > 0.05$) (Table 3). Differences between the operated and contralateral limbs remained significant for all muscle groups except the extensors in Group I ($p = 0.094$). The clinical difference between

Table 2

Assessment of the normalized thigh muscle strength coefficient one month after THA depending on the surgical approach used

Muscle group	Normalized muscle strength coefficient	HA (M ± SD) / (min ÷ max)	DAA (M ± SD) / (min ÷ max)	Student's t-test (t, p) Cohen`s d; [95 % CI]
Adduction	NC of the prosthetic limb	1.17 ± 0.29 0.67 ÷ 1.61	1.42 ± 0.32 0.9 ÷ 2.26	t = –2.575; p = 0.014 d = –0.82; [–1.46; –0.17]
	NC of the contralateral limb	2.43 ± 0.57 1.45 ÷ 3.33	2.27 ± 0.5 1.51 ÷ 3.59	t = 0.977; p = 0.335 d = 0.30; [–0.32; 0.92]
	ΔM; [95% CI] t, p drm; [95 % CI]	ΔM = –1.26; [–1.39; –1.14] t = –21.097; p < 0.001 drm = –0.129; [–0.141; –0.117]	ΔM = –0.85; [–0.94; –0.76] t = –19.984; p < 0.001 drm = –0.188; [–0.207; –0.17]	—
Abduction	NC of the prosthetic limb	0.97 ± 0.19 0.64 ÷ 1.29	1.04 ± 0.18 0.7 ÷ 1.56	t = –1.162; p = 0.253 d = –0.36; [–0.98; 0.26]
	NC of the contralateral limb	2.39 ± 0.57 1.34 ÷ 3.25	2.31 ± 0.48 1.31 ÷ 3.5	t = 0.493; p = 0.625 d = 0.15; [–0.47; 0.77]
	ΔM; [95% CI] t, p drm; [95 % CI]	ΔM = –1.42; [–1.58; –1.26] t = –17.93; p < 0.001 drm = –0.472; [–0.526; –0.417]	ΔM = –1.27; [–1.42; –1.12] t = –18.294; p < 0.001 drm = –0.604; [–0.675; –0.533]	—
Flexion	NC of the prosthetic limb	1.64 ± 0.33 1.09 ÷ 2.18	1.43 ± 0.25 0.97 ÷ 2.14	t = 2.318; p = 0.026 d = 0.71; [0.07; 1.34]
	NC of the contralateral limb	2.87 ± 0.56 1.93 ÷ 3.81	2.75 ± 0.48 1.89 ÷ 4.11	t = 0.733; p = 0.468 d = 0.23; [–0.39; 0.84]
	ΔM; [95% CI] t, p drm; [95 % CI]	ΔM = –1.23; [–1.33; –1.13] t = –25.392; p < 0.001 drm = –0.09; –[0.097; –0.083]	ΔM = –1.32; [–1.43; –1.21] t = –24.725; p < 0.001 drm = –0.107; [–0.115; –0.098]	—
Extension	NC of the prosthetic limb	1.89 ± 0.37 1.25 ÷ 2.51	1.66 ± 0.29 1.12 ÷ 2.48	t = 2.178; p = 0.035 d = 0.67; [0.03; 1.3]
	NC of the contralateral limb	2.87 ± 0.86 1.21 ÷ 4.01	2.8 ± 0.7 1.18 ÷ 4.32	t = 0.281; p = 0.78 d = 0.09; [–0.53; 0.7]
	ΔM; [95% CI] t, p drm; [95 % CI]	ΔM = –0.98; [–1.2; –0.77] t = –9.343; p < 0.001 drm = –0.474; [–0.579; –0.369]	ΔM = –1.14; [–1.36; –0.93] t = –11.315; p = 0 drm = –0.738; [–0.884; –0.592]	—

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the limbs decreased, as indicated by a reduction in the d_rm value. A noticeable difference between the limbs remained for the abductor and adductor muscle groups (Table 3). Depending on the surgical approach used, the most pronounced difference among all muscle groups was observed in the NC of abductor muscle strength ($p = 0.003$). Specifically, this value was higher in Group II than in Group I, with a strong clinical effect ($d = –1.03$). The NC of flexor muscle strength ($p = 0.009$) was higher in Group I than in Group II, with a clinically significant effect ($d = 0.83$).

To better understand muscle strength recovery, changes in strength from baseline to the 3-month postoperative assessment were analyzed (Table 4). Mixed ANOVA did not reveal differences between the study groups ($p > 0.05$) (Table 4). A statistically significant time effect was identified for all muscle groups ($p < 0.001$), indicating changes in muscle strength during rehabilitation. A significant side effect was also found ($p < 0.001$), confirming differences between the prosthetic and contralateral limbs.

For all muscle groups except the extensors, significant interactions of group × time, group × side, time × side, and group × time × side ($p < 0.001$) indicate substantial differences in the dynamics of recovery between surgical approach groups and between the prosthetic and contralateral limbs. The graph illustrating changes in normalized muscle strength coefficients is presented in Figure 1.

One month after THA, active physical rehabilitation was initiated. To evaluate the effectiveness of the rehabilitation program, the parameters between the 1-month and 3-month follow-up assessments were compared (Table 5). The results demonstrated a statistically significant increase ($p < 0.001$) in normalized muscle strength coefficients for all muscle groups in both patient groups (Table 5).

The NC of both adductor muscle strength and extensor muscle strength increased similarly in groups with different surgical approaches ($p = 0.506$;

Table 3

Assessment of the normalized thigh muscle strength coefficient 3 months after THA depending on the surgical approach used

Muscle group	Normalized muscle strength coefficient	HA (M ± SD) / (min ÷ max)	DAA (M ± SD) / (min ÷ max)	Student's t-test (t, p) Cohen's d; [95 % CI]
Adduction	NC of the prosthetic limb	1.73 ± 0.47 0.89 ÷ 2.41	1.95 ± 0.47 1.11 ÷ 3.12	t = –1.448; p = 0.156 d = –0.46; [–1.08; 0.17]
	NC of the contralateral limb	2.46 ± 0.57 1.48 ÷ 3.37	2.29 ± 0.5 1.54 ÷ 3.63	t = 0.992; p = 0.328 d = 0.31; [–0.32; 0.93]
	ΔM; [95% CI] t, p drm; [95 % CI]	ΔM = –0.73; [–0.78; –0.68] t = –29.207; p < 0.001 drm = –0.587; [–0.63; –0.544]	ΔM = –0.34; [–0.38; –0.31] t = –19.428; p < 0.001 drm = –0.614; [–0.683; –0.546]	—
Abduction	NC of the prosthetic limb	1.52 ± 0.38 0.86 ÷ 2.09	1.95 ± 0.47 1.17 ÷ 3.12	t = –3.19; p = 0.003 d = –1.03; [–1.68; –0.37]
	NC of the contralateral limb	2.41 ± 0.58 1.34 ÷ 3.28	2.42 ± 0.5 1.38 ÷ 3.67	t = –0.050; p = 0.96 d = –0.02; [–0.63; 0.6]
	ΔM; [95% CI] t, p drm; [95 % CI]	ΔM = –0.89; [–0.99; –0.8] t = –19.054; p < 0.001 drm = –0.762; [–0.852; –0.672]	ΔM = –0.47; [–0.55; –0.39] t = –11.922; p < 0.001 drm = –0.908; [–1.088; –0.728]	—
Flexion	NC of the prosthetic limb	2.56 ± 0.57 1.53 ÷ 3.45	2.15 ± 0.38 1.45 ÷ 3.21	t = 2.77; p = 0.009 d = 0.83; [0.18; 1.47]
	NC of the contralateral limb	2.90 ± 0.57 1.93 ÷ 3.85	2.78 ± 0.49 1.89 ÷ 4.15	t = 0.718; p = 0.477 d = 0.22; [–0.4; 0.84]
	ΔM; [95% CI] t, p drm; [95 % CI]	ΔM = –0.33; [–0.36; –0.31] t = –28.135; p < 0.001 drm = –0.56; [–0.603; –0.518]	ΔM = –0.63; [–0.68; –0.58] t = –24.722; p < 0.001 drm = –0.05; [–0.054; –0.046]	—
Extension	NC of the prosthetic limb	2.78 ± 0.63 1.67 ÷ 3.99	2.45 ± 0.54 1.46 ÷ 3.92	t = 1.818; p = 0.077 d = 0.56; [–0.07; 1.19]
	NC of the contralateral limb	2.90 ± 0.87 1.21 ÷ 4.05	2.83 ± 0.71 1.18 ÷ 4.37	t = 0.276; p = 0.784 d = 0.08; [–0.53; 0.7]
	ΔM; [95% CI] t, p drm; [95 % CI]	M = –0.12; [–0.26; 0.02] t = –1.753; p = 0.094 drm = –0.105; [–0.222; 0.013]	ΔM = –0.38; [–0.51; –0.26] t = –6.336; p < 0.001 drm = –0.425; [–0.562; –0.287]	—

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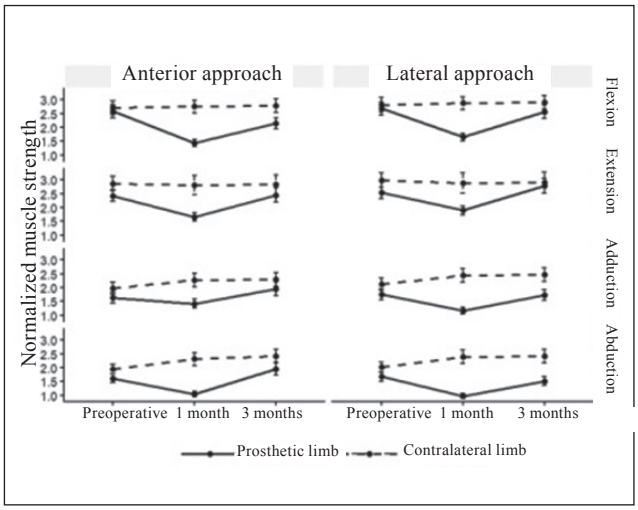


Fig. 1. Dynamics of changes in the normalized thigh muscle strength coefficient during the 3-month follow-up period after THA depending on the type of surgical approach

p = 0.223) at 3 months compared with 1 month after surgery (Table 6). A significantly greater increase in the NC of abductor muscle strength between 3 months and 1 month after THA was observed in Group II compared with Group I (p < 0.001) (Table 6).

Flexor muscle strength in the lateral approach group increased significantly more at 3 months after THA than in the anterior approach group (p = 0.002) compared with the first postoperative month (Table 6).

Discussion

According to the literature, a substantial reduction in muscle strength throughout the operated limb is commonly observed during the first 8 days after total hip arthroplasty [16, 17].

Table 4

Results of mixed analysis of variance (Mixed ANOVA) of patients' normalized muscle strength coefficients

Muscle group	Ефект	num_df	den_df	MSE	F	η^2	p_value
Adduction	Group	1.00	39.00	1.2596	0.02	0.0005	0.8856
	Time	1.140	44.30	0.0072	468.01	0.0702	< 0.001
	Group × time	1.140	44.30	0.0072	43.40	0.0070	< 0.001
	Side	1.004	39.00	0.0262	974.00	0.3336	< 0.001
	Group × side	1.004	39.00	0.0262	43.84	0.0220	< 0.001
	Time × side	1.110	43.25	0.0103	470.96	0.0954	< 0.001
	Group × time × side	1.110	43.25	0.0103	40.54	0.0090	< 0.001
Abduction	Group	1.000	39.00	0.9594	0.14	0.0033	0.7063
	Time	1.030	40.32	0.0216	294.76	0.1372	< 0.001
	Group × time	1.030	40.32	0.0216	42.20	0.0223	< 0.001
	Side	1.000	39.00	0.0494	768.50	0.4779	< 0.001
	Group × side	1.000	39.00	0.0494	12.0279	0.0141	0.0013
	Time × side	1.440	56.14	0.0219	329.31	0.2006	< 0.001
	Group × time × side	1.440	56.14	0.0219	13.49	0.0102	< 0.001
Flexion	Group	1.004	39.00	1.4236	1.37	0.0329	0.2483
	Time	1.110	43.10	0.0174	642.93	0.1769	< 0.001
	Group × time	1.110	43.10	0.0174	13.71	0.0046	< 0.001
	Side	1.001	39.00	0.0184	1302.29	0.2944	< 0.001
	Group × side	1.001	39.00	0.0184	13.73	0.0044	< 0.001
	Time × side	1.340	52.26	0.0098	1050.12	0.1941	< 0.001
	Group × time × side	1.340	52.26	0.0098	17.52	0.0040	< 0.001
Extension	Group	1.000	39.00	2.0505	0.72	0.0160	0.4072
	Time	1.230	47.84	0.0474	160.23	0.0951	< 0.001
	Group × time	1.230	47.84	0.0474	1.31	0.0009	0.2667
	Side	1.003	39.00	0.1204	174.34	0.1916	< 0.001
	Group × side	1.003	39.00	0.1204	2.34	0.0032	0.1343
	Time × side	1.453	56.603	0.0291	172.13	0.0758	< 0.001
	Group × time × side	1.453	56.603	0.0291	4.66	0.0022	0.0221

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Table 5

Change in the normalized muscle strength coefficient of the prosthetic limb between the first and third months of follow-up after THA

Muscle group	G	1 month M ± SD	3 months M ± SD	Δ M [95 % CI]	t, p	Cohens_dz [95 % CI]
Adduction	HA	1.17 ± 0.29	1.73 ± 0.47	0.56; [0.49; 0.64]	t = 14.971; p < 0.001	–3.12; [–4.12; –2.11]
	DDA	1.42 ± 0.32	1.95 ± 0.47	0.53; [0.45; 0.61]	t = 14.546; p < 0.001	–3.43; [–4.65; –2.19]
Abduction	HA	0.97 ± 0.19	1.52 ± 0.38	0.55; [0.47; 0.63]	t = 13.757; p < 0.001	–2.87; [–3.80; –1.93]
	DDA	1.04 ± 0.18	1.95 ± 0.47	0.91; [0.76; 1.06]	t = 12.950; p < 0.001	–3.05; [–4.16; –1.93]
Flexion	HA	1.64 ± 0.33	2.56 ± 0.57	0.92; [0.81; 1.03]	t = 17.544; p < 0.001	–3.66; [–4.80; –2.50]
	DDA	1.43 ± 0.25	2.15 ± 0.38	0.72; [0.65; 0.78]	t = 23.896; p < 0.001	–5.63; [7.56; –3.70]
Extension	HA	1.89 ± 0.37	2.78 ± 0.63	0.89; [0.77; 1.02]	t = 14.743; p < 0.001	–3.07; [–4.06; –2.08]
	DDA	1.66 ± 0.29	2.45 ± 0.54	0.79; [0.67; 0.91]	t = 13.511; p < 0.001	–3.18; [–4.33; –2.02]

Table 6

Comparison of changes in normalized muscle strength of the prosthetic limb between the first and third months of follow-up after THA

Muscle group	Surgical approach group (ΔM / min ÷ max)		Difference between mean changes Δ(ΔM [95 % CI]	t, p Cohen_dz [95% CI]
	I	II		
Adduction	0.56 ± 0.18 0.22 ÷ 0.8	0.53 ± 0.15 0.21 ÷ 0.87	0.04 –[0.07; 0.14]	t = 0.671; p = 0.506 0.207; [–0.413; 0.824]
Abduction	0.55 ± 0.19 0.22 ÷ 0.8	0.91 ± 0.3 0.47 ÷ 1.57	–0.36 [–0.53; –0.2]	t = –4.492; p < 0.001 –1.49; [–2.182; –0.783]
Flexion	0.92 ± 0.25 0,44 ÷ 1,27	0.72 ± 0.13 0.48 ÷ 1.07	0.20 [0.08; 0.33]	t = 3.389; p = 0.002 0.99; [0.33; 1.639]
Extension	0.89 ± 0.29 0.42 ÷ 1.47	0.79 ± 0.25 0.34 ÷ 1.44	0.10 [–0.07; 0.27]	t = 1.239; p = 0.223 0.382; [–0.243; 1.002]

From approximately the sixth postoperative week, a significant increase in thigh muscle strength occurs; however, the extent of recovery may differ depending on the surgical approach [16]. At 1 month after THA, flexor and extensor muscle strength decreases by approximately 15 %, while abductor and adductor muscle strength decreases by 25–27 % [16] due to surgical trauma [17].

The abductor muscles, particularly the gluteus medius, are more extensively damaged during the lateral approach than during the anterior approach, which determines subsequent differences in their recovery. In a prospective study comparing three surgical approaches (lateral, anterior, and posterior), patients who underwent the anterior approach demonstrated greater muscle strength 6 weeks after surgery compared with those who underwent the lateral approach [16]. At the same time, abductor strength of the operated limb did not recover to the required level even 1 year after THA in patients treated with the lateral approach, whereas complete recovery after the anterior approach was observed at 3 months [12, 16]. These findings for the anterior approach are consistent with our results.

In the study by J. S. Christensen et al. [18], patients undergoing the direct anterior approach demonstrated stronger abductor muscles at week 10 compared with patients who underwent the posterior approach.

For hip abductor muscles, the literature describes approximate threshold values of the normalized strength coefficient (around 2), which may be associated with the ability to maintain pelvic stability in the frontal plane [14, 15]. In our study, this condition was nearly achieved in the anterior approach group, where the NC of muscle strength was 1.95, whereas it remained slightly lower in the lateral approach group. This may indicate a tendency toward better functional recovery of the abductor muscles in the anterior approach group. In the lateral approach group, this value was slightly below 2, indicating poorer balance support, as the abductor muscles play an important role in frontal plane stability. At the same time, in both groups before surgery, normalized coefficient values were below the mentioned level, which is consistent with data demonstrating a marked deficit in abductor muscle strength in patients with hip osteoarthritis [10]. It is also known that the initial condition of the muscles is directly associated with

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functional outcomes after THA and consequently affects the rate of rehabilitation [19, 20].

According to our results, after 1 month, the operated limbs in groups with different surgical approaches differed in the strength parameters of the adductor muscles, extensors, and flexors, whereas after 3 months, differences were observed in the abductors and flexors. During postoperative recovery, an increase in the strength of the adductor muscles and extensors was observed in patients from both groups. In the lateral approach group, no differences between the operated and contralateral limbs were detected for the extensor muscle group after 3 months, indicating achievement of interlimb symmetry for this muscle group. At the same time, the anterior approach group demonstrated more pronounced improvement in abductor muscle strength, whereas the lateral approach group showed greater improvement in flexor muscle strength. Overall, complete functional recovery was not achieved in either group within 3 months, as indicated by the persistence of asymmetry in the other investigated muscle groups.

Conclusions

Recovery of thigh muscle strength in patients after total hip arthroplasty demonstrated positive linear dynamics regardless of the surgical approach used during the 3-month follow-up period.

The pattern of recovery of individual muscle groups depended on the surgical approach. With the direct anterior approach, more pronounced increases in the strength of the lateral thigh muscle groups (abductors and adductors) were observed; however, recovery of flexor muscle strength was somewhat delayed during the postoperative period. In patients who underwent the modified lateral approach, flexor muscle strength recovered more rapidly, whereas recovery of the lateral muscle groups (abductors and adductors) was slower.

Thus, both surgical approaches provide overall improvement in muscle strength 3 months after total hip arthroplasty; however, differences exist in the rate of recovery of individual muscle groups. With the anterior approach, lateral hip stabilizers recovered more rapidly, whereas with the lateral approach, flexor muscles demonstrated faster recovery.

Conflict of interest. The authors declare no conflict of interest.

Future research. Further studies should investigate asymmetry of strength among different thigh muscle groups in patients after total hip arthroplasty depending on the type of surgical approach used throughout the rehabilitation process.

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COMPARATIVE ANALYSIS OF NORMALIZED HIP MUSCLE STRENGTH ACCORDING TO SURGICAL APPROACH IN TOTAL HIP ARTHROPLASTY

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