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Effect of Gluteus Medius Strengthening on Pain, Function, and Muscle Macromorphology in Nonspecific Chronic Low Back Pain: Randomized Controlled Trial

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SUMMARY

Background and purpose. Low back pain (LBP) is a common health problem that hinders patients' daily activities. During hip physical examination on LBP patients, gluteus medius (GMed) weakness and tenderness were found. Therefore, in patients with non-specific chronic low back pain (NSCLBP), this study examined the effect of adding specific GMed strengthening to the APTA-guided program on pain, back disability, GMed macromorphology, strength, and functional performance.

Methods. This study is a randomized controlled trial involving 58 patients with NSCLBP aged between 20 and 45 years. The pain was measured by a numerical pain rating scale, functional disability was estimated by the Oswestry disability index, and Ultrasonography evaluated GMed thickness. A hand-held dynamometer measured GMed strength, and its functional performance was assessed by a single-leg squat test (SLST). Patients were randomly assigned to group A received the APTA program and group B received the same program plus selected GMed strengthening.

Results. For groups A and B, the percentage of change in pain was 40%, and 66.67% and that of disability level was 45.24 %, and 61.5 %, in favor of group B. The between-group comparison revealed significant differences for pain ($p = 0.001$) but not for functional disability ($p = 0.12$). There was a significant difference in GMed thickness for average relaxed ($p = 0.009$), and average contracted ($p = 0.043$) in both groups post-treatment but not for activation ($p = 0.063$). GMed strength changed by 13.1% and 21.8% in groups A and B respectively but no significant differences were observed between groups ($p = 0.44$). The percentage of change in the SLST was 20.6% and 58.8% for Groups A and B respectively, with a significant between-group comparison ($p = 0.04$).

Conclusions. GMed strengthening exercises improved GMed macromorphology, reduced disability, and pain, and enhanced functional performance. It may therefore be advised that patients with NSCLBP incorporate strengthening of the GMed muscle in their treatment program.

Study registration. This study was registered in ClinicalTrials.gov (NCT05521165).

KEY WORDS
Exercise therapy; gluteus medius; hip joint; low back pain; ultrasonography.

INTRODUCTION

Low back pain (LBP) is one of the main health issues facing people globally. It affects people of all ages, even young children and the elderly. The costs of medical care for LBP differ between nations and have been affected by societal and healthcare practices (1).

There are two categories of LBP: specific LBP and nonspecific LBP (NSLBP), which was defined as LBP without obvious pathologies. It may begin in the lower spine and progress to other regions, like the hip region (2). It is considered chronic if the symptoms last longer than 12 weeks (3).

The spine and lower limb muscles might undergo various structural and functional alterations as a result of back pain. The endurance of the core muscles was eliminated in patients with LBP in different professions and lifestyles (4). Additionally, there was a significant deterioration in hip and knee muscle strength in patients with LBP in comparison to the healthy control (5).

Furthermore, Sadler *et al.* (6) and Cooper *et al.* (7) reported that gluteus medius (GMed) muscle strength was reduced, and multiple trigger points were found in LBP patients, however, the findings on fatigability, level of activity, and macromorphology were insignificant compared to normal. Pain from GMed muscle trigger points may radiate to the iliotibial band, gluteal and lumbosacral regions, and sacroiliac joint (8).

Gluteus Medius dysfunction was thought to be a predictor and initiator of LBP. To clarify, it causes many Patho mechanical implications, including abnormal spinal loading, decreased force production from hip abduction, and an abnormal activation pattern as compared to healthy control. It also causes lateral pelvic instability that increases dynamic lateral trunk flexion and causes abnormal compression over the intervertebral disc (9, 10).

Therefore, this study was conducted to explore if the effect of adding targeted GMed strengthening exercises to the APTA-guided program may positively affect pain, functional disability level, hip muscle strength, and GMed macromorphology and its functional performance in patients with NSCLBP according to the recommendations provided in the published literature (11, 12).

METHODS

Design overview

This study is a randomized controlled trial conducted at the out-patient clinics of the Faculty of Physical Therapy, Cairo University. It was carried out according to the standards for research of the Ethics Committee of Cairo University's Faculty of Physical Therapy (number: P.T.REC/012/003770 – date of approval: May 17, 2022). Patients were asked to provide written informed consent after their approval to participate in the current research. Before any analyses were performed, a thorough and up-to-date analysis plan was registered.

Participants and randomization

Fifty-eight patients with NSCLBP (for more than 12 weeks) aged between 20 and 45 years were recruited for this study. Individuals experienced symptoms that were bilateral or unilateral, with one side being worse than the other. Patients were excluded if they had any of the following: a history of significant injuries, persistent night pain, bowel or bladder disorders, or a neurological deficiency affecting the lower extremities. In addition, a history of lower limb fractures as well as surgery on the back, pelvis, or hip.

A random computer-generated list specific to each center would be used to assign study participants to either Group A or Group B. An external person who was not involved in the treatment would manage the randomization. The allocation mechanism would be concealed in sequentially numbered, sealed envelopes.

Assessment procedures

Assessment of pain intensity

We would ask the patient to provide the number that most properly represents their level of pain using the Numerical Pain Rating Scale-Arabic Version (NPRS-AR) (13). The scale has 11 points, where 0 represents no pain and 10 represents the worst pain (14).

The numerical pain rating scale is a sensitive and highly reliable tool for assessing pain, especially in the case of chronic pain. The validity of the NPRS-AR was excellent and positive when correlated with the visual analog scale ($r = 0.943$ when $p < 0.01$) even with the verbal rating scale ($r = 0.932$ when $p < 0.01$). Furthermore, the test-retest reliability of the NPRS-AR as assessed by the ICC was 0.89 (0.84-0.92) with a 95% confidence interval (CI) (14).

Assessment of functional disability

Back pain-related impairment was assessed using the Oswestry Disability Index the Arabic version (ODI-AR), which has been cross-culturally adjusted for Arabic speakers. Ten domains were included in it: walking, carrying, pain, sleep, sitting, social and sexual life, self-help, and travel. Each domain was scored 0-5, for a total score of 0-50, with a high score indicating severe dysfunction (15).

The intra-observer reliability of ODI was excellent. Good construct validity was demonstrated by correlations between the index and the visual analog pain scale ($r = 0.708$, $p < 0.01$), the Roland-Morris Disability Questionnaire ($r = 0.656$, $p <$

0.01), and the Quebec Back Pain Disability Scale ($r = 0.792$, $p < 0.01$) (12).

Assessment of Gluteus Medius strength

The patient would be positioned in a side-lying, with the examined hip in a neutral position. Following familiarization, the subject would perform 5 seconds of maximal abductor isometric contraction (see **supplements**). This method would be performed three times, with 15-second intervals between trials. To motivate individuals to exert maximum effort, verbal encouragement would be provided. The GMed muscle torque is calculated as the result of average strength measurements standardized by weight (Nm/kg) (16).

Functional performance assessment of gluteus medius muscle

The single-leg squat test (SLST) was divided into two phases. The first phase was an assessment of the overall impression of patient performance, such as balance, gross arm deviation, and test performance. The second one required that four of the five specific criteria (posture of trunk movement, the posture of pelvis, hip, knee, and depth of squat) be negative for deviation. It was necessary to receive a passing score on one of the three tests (see **supplements**) (17).

The intra-rater agreement of SLST was reported to be between 87% and 73% with kappa from 0.800 to 0.613, and higher hip abduction torque was also demonstrated by the top performers (mean difference: 0.47; 95%CI 0.10-0.83 N.m. Bw-1) (17).

Assessment of gluteus medius muscle thickness

A single skilled sonographic investigator would gather all sonographic images through LOGIQ E9 which is a mobile diagnostic ultrasound system, software version: R4.3.1 marketed by GE Medical Systems Ultrasound. The patient would be side-lying with the examined leg elevated and the hip in a neutral posture.

The transducer would be located on the side of the hip, on the lower half of a coronal line that starts at the peak of the greater trochanter and goes to a point that is 25% of the distance between the ASIS and PSIS perpendicular to the muscle (18). Following ultrasound image optimization, a still image would be obtained, and the machine software's caliper-based tools would be used to quantify the GMed thickness. The procedure would be done three times, and the mean of all three measurements would be recorded (19).

The GMed thickness was recorded in two different states: relaxed when the patient was side-lying and the lower limb was in a neutral position and contracted when the patient abducted the hip and their feet were 25.4 cm above the table while enduring a maximum isometric resistance (see **supplements**) (20).

By determining the broadest point between the muscle's superior border and inferior aspect, the thickness measurements (in centimeters) were measured. The activation ratio was calculated by dividing the average muscle thickness during contraction by the average muscle thickness during relaxation (20). Before beginning treatment sessions, all assessment procedures were completed, and the final assessment was carried out following the completion of 12 intervention sessions after six weeks of treatment.

Treatment procedures

All patients would follow various exercises guided by the APTA 2021 Practice Guidelines for patients with NSCLBP would be provided for 30-45 minutes, twice per week for six weeks (12 sessions).

APTA guided program

The exercises would be demonstrated as mentioned by Bello *et al.* (22).

Stretching exercises:

- Hamstring muscle: with the patient lying supine, the physiotherapist would flex the hip at 90 degrees and extend the ipsilateral knee passively for three repetitions for 30 seconds.
- Back and trunk muscles: the patients performed three repeats of thirty seconds each while sitting on their heels, with their trunk flexed and their abdomen resting on the front of both legs.

Strengthening exercises:

- Abdominal curl exercise: the patient was instructed to elevate their head and trunk simultaneously for two sets of five repetitions while they were in the supine laying position.
- Back extension exercise: active back and trunk extension was done for three sets of five repetitions with the patient in a prone lying position.

Stabilizing exercises:

- in a quadrupedal posture, the patient was asked to elevate his contralateral upper and lower limbs off the ground in three sets of ten repetitions, holding each position for three to five seconds. If the patient was unable to move both limbs simultaneously, the exercise might be performed gradually, moving the upper limb first, then the lower limb.

The selected GMed strengthening exercise program

The selected exercise program would cause the GMed's electromyographic activity to be at least very active or high level (> 40% maximal voluntary isometric contraction) (22, 23). Additional exercises, such as clamshell (see **supplements**) and bridging, were performed if the patient was unable to perform the exercises without substitutions. The exercise program would be described as the following:

- Side-lying hip abduction: for stability, the patient was asked to assume side-lying with their bottom hip and knee flexed and lift his upper leg into abduction. Hold the position for three to five seconds while performing three sets of ten repetitions with the hips neutral and slightly extended (see **supplements**) (24).
- Unilateral hip bridge: the patient would be resting supine with one knee bent and the other hip extended to align the spine in a neutral position. He was asked to elevate the trunk and lower limb simultaneously for one set of 15 repetitions for each side (see **supplements**) (24).
- Side-lying hip bridge: the patient was asked to elevate his body off the ground while lying on his side, distributing his weight evenly between his forearm and his foot and maintaining a straight posture for one set of 15 repetitions on each side (see **supplements**).
- Unilateral Wall squat: the patient was asked to stand against the wall on the dominant leg in a single-leg stance. While the distance from the wall to the heel of the dominant leg was 30.48 cm, the other limb would be fully extended not touching the floor during exercise for three sets of ten repetitions, holding for three to five seconds (see **supplements**) (25).

Outcome measures

Primary outcome measures were the pain intensity measured using NPRS-AR, back functional disability measured using ODI-AR, and GMed muscle thickness in both its relaxed, and contracted states, and its contraction ratio would be examined using an ultrasound device. Secondary outcomes were GMed strength evaluated by HHD and functional performance assessed by SLST.

Data analysis

Sample size calculation

To find an 80% power (alpha = 0.05) Cohen's d = 0.40 effect size. According to the G*power program (version 3.1.9.7, Franz Faul, Universität Kiel, Germany), 52 participants (26 in each group) would be required for the one-way ANOVA test.

Statistical analysis

For parametric continuous variables, descriptive statistics were shown as mean (SD), categorical variables as count (%), and non-parametric variables as median (IQR). The independent t-test (for continuous data) and the Chi-square test (for categorical data) were used to compare the demographic differences between the groups. Differences within and between groups in pain and functional disability were tested using Wilcoxon signed rank and Mann Whitney U tests respectively, as they were non-parametric and/or non-normally distributed. Differences within and between groups in SLST (Analyzed as proportions of pass) were tested using the Chi-square test. Differences within and between groups in GMed thickness and GMed strength were tested using mixed MANOVAs as they were ordinal variables.

RESULTS

Fifty-eight patients with NSCLBP were included in groups A (n = 29) and group B (n = 29) as shown in the study flowchart (**figure 1**). Descriptive statistics for the demographic data (age, weight, height, and BMI) for the included patients are shown in **table I** which reveals no significant differences between groups.

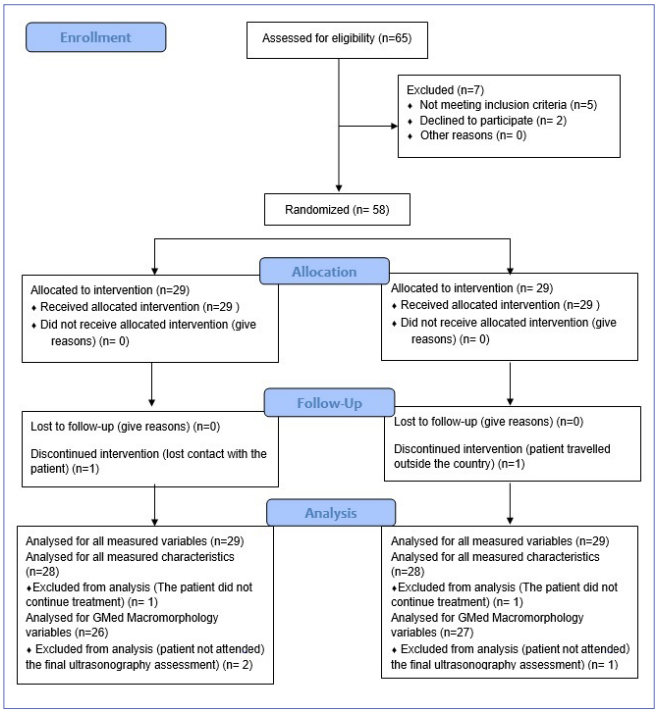


Figure 1. Flow chart of the study.

Table I. Comparison of demographics between group A and group B (n = 58).

Demographics	Group A n = 29	Group B n = 29	P-value	Sig.
	Mean ± SD	Mena ± SD		
Age (years)	25.07 ± 4.7	26.48 ± 5.7	0.31	NS
Weight (kg)	70.55 ± 5.9	73.4 ± 10.1	0.19	NS
Height (cm)	167.76 ± 7.8	169.8 ± 7.5	0.32	NS
BMI (kg/m²)	25.35 ± 2.8	25.4 ± 3.04	0.94	NS

SD: Standard deviation; P-value: probability value; NS: Non-significant; BMI: body mass index.

Primary outcomes

The percentage of change as well as the median (IQR) value of paint intensity of both groups before and after treatment were shown in **table II** and **figure 2**.

The median (IQR) values of back functional disability scores pretreatment and post-treatment for both groups are shown in **table III** and **figure 2**. There was a significant decrease in back functional disability of group A and group B post-treatment compared with pretreatment ($p < 0.001$). The functional disability scores of group A and group B pretreatment and posttreatment were not significantly different ($p = 0.06$, $p = 0.12$, respectively) as presented in **table III**.

Mixed MANOVA was conducted to investigate the effect of treatment on GMed thickness. There was a significant main effect for treatment ($p = 0.016$) and time ($p = 0.01$). There was a non-significant interaction effect of treatment and time ($p = 0.23$). The mean ± SD values of GMed thickness (AR, AC, and ratio) pre- and post-treatment of both groups are presented in **table IV** and **figure 3**.

Secondary outcomes

The effect of the therapy on the GMed strength was examined using a mixed MANOVA. The main effect of time was substantial ($p = 0.001$). Treatment and time had an interaction effect ($p = 0.58$), but treatment had a non-significant main impact ($p = 0.36$) as shown in **table V** and **figure 4**.

There was a significant difference in the GMed strength of groups A and B post-treatment compared to the pre-treatment ($p = 0.001$). There was no significant difference in GMed strength between groups pretreatment and posttreatment ($p > 0.05$).

Table II. Pain intensity scores pre- and post-treatment of both groups.

NPRS-AR scores	Pre-treatment	Post-treatment	% of change	W-value	P-value	Sig.
	Median (IQR)	Median (IQR)				
Group A (n = 28)	5 (2.25)	3 (2)	40	-4.8	< 0.001	**S**
Group B (n = 28)	6 (2)	2 (1)	66.67	-4.66	< 0.001	**S**
U-value	488	186				
P-value	0.28	0.001				
Sig.	NS	S				

IQR: Inter quartile range; P-value: probability value; S: significant; NS: non-significant.

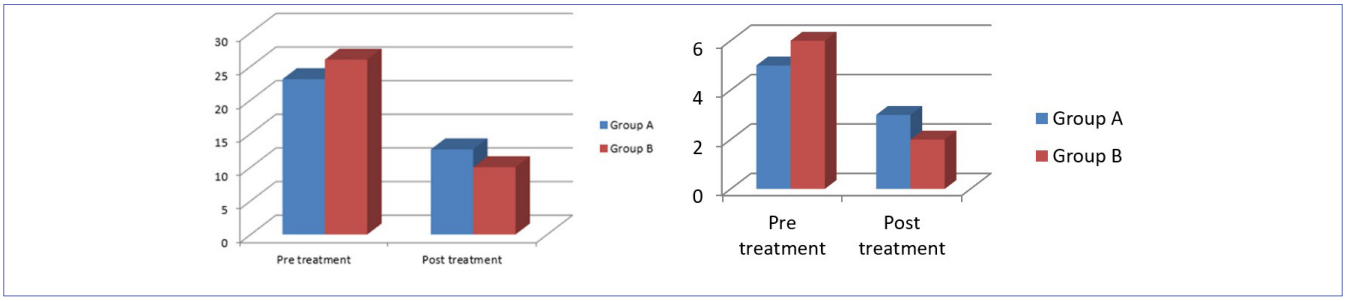


Figure 2. Median pain intensity and functional disability scores pre- and post-treatment for both groups.

Table III. Back functional disability scores pre- and post-treatment of both groups.

ODI scores	Pre-treatment	Post-treatment	% of change	W-value	P-value	Sig.
	Median (IQR)	Median (IQR)				
Group A (n = 28)	23.1 (13.3)	12.65 (13.95)	45.24	-4.54	< 0.001	S
Group B (n = 28)	26 (18)	10 (8.9)	61.5	-4.63	< 0.001	S
U-value	542	298				
P-value	0.06	0.12				
Sig.	NS	NS				

Table IV. Mean GMed thickness pre- and post-treatment of both groups.

GMed thickness		Pre-treatment	Post-treatment	MD	% of change	P-value	Sig.
		Mean ± SD	Mean ± SD				
Average relaxed (AR)	Group A (n = 26)	3.7 ± 0.53	3.96 ± 0.47	-0.25	8.88	< 0.001	S
	Group B (n = 27)	3.75 ± 0.42	4.34 ± 0.55	-0.58	5.74	< 0.001	S
MD		-0.056	-0.38				
P-value		0.68	0.009				
Sig.		NS	S				
Average contracted (AC)	Group A (n = 26)	4.42 ± 0.68	4.63 ± 0.75	-0.2	8.88	0.02	S
	Group B (n = 27)	4.65 ± 0.4	5.05 ± 0.71	-0.4	5.74	<0.001	S
MD		-0.18	-0.42				
P-value		0.25	0.043				
Sig.		NS	S				
Activation ratio (AC/AR)	Group A (n = 26)	1.19 ± 0.1	1.18 ± 0.12	0.019	8.88	0.5	NS
	Group B (n = 27)	1.23± 0.13	1.15 ± 0.11	0.075	5.74	0.032	S
MD		-0.027	0.016				
P-value		0.38	0.63				
Sig.		NS	NS				

SD: Standard deviation; MD: Mean difference; P-value: probability value; S: significant, NS: non-significant.

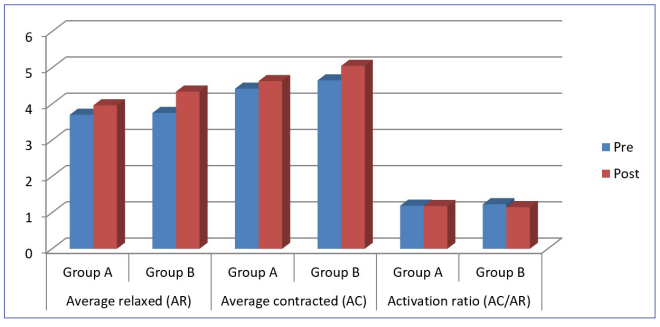


Figure 3. Mean GMed morphological parameters pre- and post-treatment of both groups.

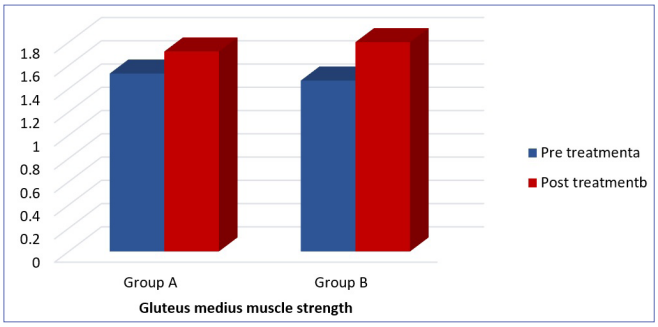


Figure 4. Mean GMed muscle strength pre-and post-treatment of both groups.

Table V. Mixed MANOVA for the effect of treatment on hip muscle strength.

Mixed MANOVA	F	P-value	Sig.	ES
Interaction effect (treatment × time)	0.3	0.58	NS	0.008
Effect of time	11.8	0.001	S	0.098
Effect of treatment	0.83	0.36	NS	0.003

The functional performance pre- and post-treatment of groups A and B (pass) was shown in **table VI** and **figure 5**. The percentage of SLST passes did not differ statistically significantly between groups A and B before treatment (p = 0.26). After treatment, group B's % of SLST passes was statistically significant compared to group A (p = 0.04).

Table VI. Functional performance scores pre- and post-treatment of both groups.

SLST Count (%)		Pre-treatment Count (%)	Post-treatment	% of change	χ^2 value	P-value	Sig.
Group A (n = 28)	Pass	11 (38)	17 (60.7)	20	2.5	0.16	NS
	Fail	18 (82)	11 (39.3)				
Group B (n = 28)	Pass	7 (24)	24 (82.8)	58.8	20.03	< 0.001	S
	Fail	22 (76)	5 (17.2)				
χ^2 value		1.3	4.1				
P-value		0.26	0.04				
Sig.		NS	S				

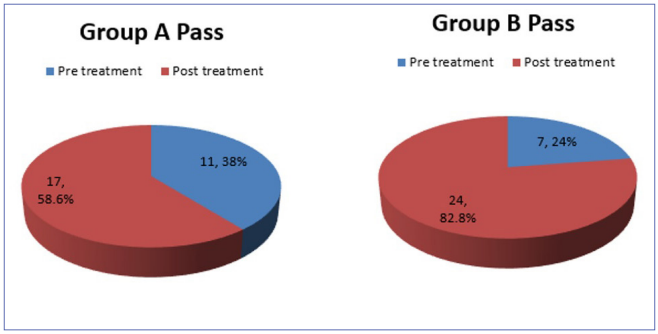


Figure 5. Count and percentage of functional performance assessment (pass) scores pre-and post-treatment of both groups.

DISCUSSION

In patients with non-specific low back pain, this study examined how adding specific GMed strengthening exercises to an APTA-guided program affected pain, back functional disability, GMed macromorphology, strength, and functional performance. Before the start of treatment sessions and after 12 sessions in a frequency of two sessions per week for 6 weeks, all outcome measures were evaluated. The key findings demonstrate a significant improvement in terms of pain and morphological characteristics in favor of adding the suggested GMed strengthening with no significant improvement observed in other variables although their results were superior compared to the control group.

All patients in both groups experienced a significant reduction in pain and back functional disability after treatment. But between group comparisons revealed a noticeable improvement of pain in favor of the selected GMed strengthening group while no significant improvement had been observed in the back functional disability. This was consistent with the findings of studies by Olawale *et al.* (27) and Jeong *et al.* (28) who studied the effect of adding GMed strengthening exercises to lumbar stabilization exercises and found a significant improvement in pain, and functional disability, and the quality of life in patients with NSCLBP.

A recent systematic review reported moderate effects on pain and minor effects on disability, but it suggested the need for further high-quality research to examine the effect of hip muscle strengthening in NSCLBP (10). Furthermore, using hip-strengthening exercises as a standard LBP therapy improves pain and back disability levels in a recent systematic review published by Santamaría *et al.* (29), and researchers mentioned that the quality of the included studies was good.

On the other hand, it contradicted the results of Kendall *et al.* (30) who mentioned that there was a non-significant change in pain intensity between groups, but it was consistent with the study on back functional disability. This was also evident in a published systematic review that looked at the impact of hip-strengthening exercises on LBP and found no statistically significant differences in either pain or disability. However, this could be explained by the fact that all included studies had a high risk of bias and small sample sizes (30).

A recent systemic review reported an atrophy of the gluteus maximus, minims, and psoas muscles in patients with LBP with a recommendation of further studies on the GMed micromorphology in that population (11). As a result, this study examining the effect of GMed strengthening exercises on GMed macromorphology in patients with NSCLBP was regarded to be the first of its kind. The previous study solely looked at muscle thickness variations between those with NSCLBP and healthy controls (31, 32).

In a case-control study, researchers compared selected global and local muscle thickness in females with and without CLBP. According to their findings, every muscle under investigation exhibited greater thickness during contraction as compared to the resting state. Compared to healthy patients, the average increase in LBP subjects was lower.

The LBP group's GMed muscle thickness increased more slowly (31).

In a related investigation, the GMed muscle fiber thickness variations in healthy individuals and CLBP with GMed deficit were examined. The study's findings demonstrated that, in comparison to the healthy group, CLBP patients with GMed muscle weakness had decreased posterior fiber thickness and a slower rate of change (32).

According to the results of this study on GMed muscle thickness, there was a significant difference between the thickness of the muscles in their relaxed and contracted states following treatment in both groups, but the thickness change was in favor of the GMed strengthening group. It's interesting to note that only the GMed group posttreatment demonstrated a statistically significant change in the activation ratio of the GMed muscle in the two groups.

It was prevalent that there was weakness of hip muscles in patients with NSCLBP (8). In examining how GMed strengthening exercise, in addition to the APTA-guided program, affected GMed muscle strength, both groups' posttreatment muscle strength differed statistically, but there was no statistically significant difference between them. It was comparable to the findings of Kendall *et al*. (30) who reported that incorporating hip-strengthening exercises into the motor control program improved hip muscle strength.

In the chosen GMed strengthening exercises group, the SLST post-treatment was statistically significant and favored this group over the control group. The SLST represented a simple clinical test to assess the neuromuscular control of GMed muscle (17) and the whole lower limb dysfunction (16). On the other hand, Penney *et al*. (34) reported a positive SLST in both CLBP and control groups as an indicator of limited specificity.

Despite the results that favored the GMed muscle strengthening program over the control program and its importance in the management of NSCLBP, this study may be limited by the small sample size, determination of baseline GMed strength level through different strength protocols to be more specific and individualized in establishing treatment program.

It was advised to set a landmark during the GMed thickness evaluation to guarantee that the muscle thickness was evaluated at the same location both before and after treatment. Comparing contracted thickness to particular resistance is another suggestion that might be taken into account in subsequent research.

The GMed muscle is one of the global core muscles that is essential for maintaining the stability of the lumbar spine, pelvis, and entire lower limb. This could affect patients who received physical therapy sessions for back pain. GMed strengthening exercises helped them reduce their back pain and disability level. As a result, it may induce better results compared to the standard treatment alone.

CONCLUSIONS

The GMed muscle is one of the global core muscles that is essential for maintaining the stability of the lumbar spine, pelvis, and entire lower limb. This could affect patients who received physical therapy sessions for back pain. GMed strengthening exercises helped them reduce their back pain and disability level. As a result, it may induce better results compared to the standard treatment alone.

Implications on physiotherapy practice

The NSCLBP treatment program benefits from the inclusion of GMed strengthening exercises because they reduce pain and functional impairment in those patients and have a good effect on the macromorphology of the GMed muscle, which enhances strength and dynamic control. Physical therapists should thus design their treatment plans appropriately to help patients with low back pain restore and normalize their hip muscle function.

FUNDINGS

None.

DATA AVAILABILITY

Data are available under reasonable request to the corresponding author.

CONTRIBUTIONS

HO: patients physical assessment, outcomes measurement, writing – original draft. HE: morphological measurement. SA: writing – original draft, writing – review & editing. MI: results assessment, writing – original draft, writing – review & editing.

CONFLICT OF INTERESTS

The authors declare that they have no conflict of interests.

REFERENCES

1. Krismer M, van Tulder M. Strategies for prevention and management of musculoskeletal conditions. Low back pain (non-specific). Best Pract Res Clin Rheumatol. 2007;21(1):77-91. doi: 10.1016/j.berh.2006.08.004.
2. Prather H, Cheng A, Steger-May K, Maheshwari V, Van Dillen L. Hip and lumbar spine physical examination findings in people presenting with low back pain, with or without lower extremity pain. J Orthop Sports Phys Ther. 2017;47(3):163-72. doi: 10.2519/jospt.2017.6567.
3. Qaseem A, Wilt T, Mclean R, Forciea M. Noninvasive treatments for acute, subacute, and chronic low back pain: a clinical practice guideline from the american college of physicians. Ann Intern Med. 2017;166(7):514-30. doi: 10.7326/M16-2367.
4. Haddadi N, Dommerholt J, Rezaeian Z. Core muscles endurance in sedentary staffs with and without nonspecific chronic low back: A cross-sectional study. Muscles Ligaments Tendons J. 2021;11(1):136-50. doi: 10.32098/mltj.01.2021.15.
5. De Sousa C, de Jesus F, Machado M, et al. Lower limb muscle strength in patients with low back pain: a systematic review and meta-analysis. J Musculoskelet Neuronal Interact. 2019;19(1):69-78.
6. Sadler S, Cassidy S, Peterson B, Spink M, Chuter V. Gluteus medius muscle function in people with and without low back pain: a systematic review. BMC Musculoskelet Disord. 2019;20(1):463. doi: 10.1186/s12891-019-2833-4.
7. Cooper N, Scavo K, Strickland K et al. Prevalence of gluteus medius weakness in people with chronic low back pain compared to healthy controls. Eur Spine J. 2016;25(4):1258-65. doi: 10.1007/s00586-015-4027-6.
8. Temel M, Erden Y, Bağcıer F. Looking at Low Back Pain from a Myofascial Perspective: Awareness and Treatment Algorithms. Muscles Ligaments Tendons J. 2023;13(1):145-7. doi: 10.32098/mltj.01.2023.16.
9. Ross M, Hooten S, Moore D. Lower leg girth and ankle plantar-flexor endurance after anterior cruciate ligament reconstruction. J. Sport Rehabil. 2002;11(2):128-38. doi: 10.1123/jsr.11.2.128.
10. De Jesus F, Fukuda T, Souza C, et al. Addition of specific hip strengthening exercises to conventional rehabilitation therapy for low back pain: a systematic review and meta-analysis. Clin Rehabil. 2020;34(11):1368-77. doi: 10.1177/0269215520941914.
11. Pourahmadi M, Asadi M, Dommerholt J, Yeganeh A. Changes in the macroscopic morphology of hip muscles in low back pain. J Anat. 2020;236(1):3-20. doi: 10.1111/joa.13086.
12. Algarni A, Ghorbel S, Jones J, Guermazi M. Validation of an Arabic version of the Oswestry index in Saudi Arabia. Ann Phys Rehabil Med. 2014;57(9-10):653-63. doi: 10.1016/j.rehab.2014.06.006.
13. Hawker G, Mian S, Kendzerska T, French M. Measures of adult pain: Visual Analog Scale for Pain (VAS Pain), Numeric Rating Scale for Pain (NRS Pain), McGill Pain Questionnaire (MPQ), Short-Form McGill Pain Questionnaire (SF-MPQ), Chronic Pain Grade Scale (CPGS), Short Form-36 Bodily Pain Scale (SF-36 BPS), and Measure of Intermittent and Constant Osteoarthritis Pain (ICOAP). Arthritis Care Res (Hoboken). 2011;63:S240-52. doi: 10.1002/acr.20543.
14. Alghadir A, Anwer S, Iqbal Z. The psychometric properties of an Arabic numeric pain rating scale for measuring osteoarthritis knee pain. Disabil Rehabil. 2016;38(24):2392-7. doi: 10.3109/09638288.2015.1129441.
15. Guermazi M, Mezghani M, Ghroubi S, et al. The Oswestry index for low back pain translated into Arabic and validated in a Arab population. Ann Readapt Med Phys. 2005;48(1):1-10. doi: 10.1016/j.annrmp.2004.06.055.
16. Thorborg K, Petersen J, Magnusson S, Hölmich P. Clinical assessment of hip strength using a hand-held dynamometer is reliable. Scand J Med Sci Sports. 2010;20(3):493-501. doi: 10.1111/j.1600-0838.2009.00958.x.
17. McGovern R, Martin R, Christoforetti J, Kivlan B. Evidence-based procedures for performing the single leg squat and step-down tests in evaluation of non-arthritic hip pain: a literature review. Int J Sports Phys Ther. 2018;13(3):526-36.
18. Crossley K, Zhang W, Schache A, Bryant A, Cowan SM. Performance on the single-leg squat task indicates hip abductor muscle function. Am J Sports Med. 2011;39(4):866-73. doi: 10.1177/0363546510395456.
19. Whittaker J, Emery C. Sonographic measures of the gluteus medius, gluteus minimus, and vastus medialis muscles. J Orthop Sports Phys Ther. 2014;44(8):627-32. doi: 10.2519/jospt.2014.5315.
20. Gellhorn A, Stumph J, Zikry H, Creelman C, Welbel R. Ultrasound measures of muscle thickness may be superior to strength testing in adults with knee osteoarthritis: a cross-sectional study. BMC Musculoskelet Disord. 2018;19(1):350. doi: 10.1186/s12891-018-2267-4.
21. Koldenhoven R, Fraser J, Saliba S, Hertel J. Ultrasonography of gluteal and fibularis muscles during exercises in individuals with a history of lateral ankle sprain. J Athl Train. 2019;54(12):1287-1295. doi: 10.4085/1062-6050-406-18.
22. Bello A, Quartey J, Lartey M. Efficacy of behavioural graded activity compared with conventional exercise therapy in chronic non-specific low back pain: implication for direct health care cost. Ghana Med J. 2015;49(3):173-80. doi: 10.4314/gmj.v49i3.8.
23. Moore D, Semciw A, Pizzari T. A systematic review and meta-analysis of common therapeutic exercises that generate highest muscle activity in the gluteus medius and gluteus minimus segments. Int J Sports Phys Ther. 2020;15(6):856-81. doi: 10.26603/ijspt20200856.
24. Reiman M, Bolgla L, Loudon J. A literature review of studies evaluating gluteus maximus and gluteus medius activation during rehabilitation exercises. Physiother Theory Pract. 2012;28(4):257-68. doi: 10.3109/09593985.2011.604981.
25. Ekstrom R, Donatelli R, Carp K. Electromyographic analysis of core trunk, hip, and thigh muscles during 9 rehabilitation

exercises. J Orthop Sports Phys Ther. 2007;37(12):754-62. doi: 10.2519/jospt.2007.2471.
26. Ayotte N, Stetts D, Keenan G, Greenway E. Electromyographical analysis of selected lower extremity muscles during 5 unilateral weight-bearing exercises. J Orthop Sports Phys Ther. 2007;37(2):48-55. doi: 10.2519/jospt.2007.2354.
27. Olawale F, Daniel O, Ayoola Ibifubara A, Adeoye K, Blessing N. Effect of gluteus medius strengthening on pain perception, functional disability and quality of life in patients with non-specific chronic low back pain. WJARR. 2020;5(3):18-24 doi: 10.30574/wjarr.2020.5.3.0047.
28. Jeong U, Sim J, Kim C, Hwang-Bo G, Nam C. The effects of gluteus muscle strengthening exercise and lumbar stabilization exercise on lumbar muscle strength and balance in chronic low back pain patients. J Phys Ther Sci. 2015;27(12):3813-6. doi: 10.1589/jpts.27.3813.
29. Santamaría G, Rodríguez I, Rodríguez-Pérez V et al. Effect of hip muscle strengthening exercises on pain and disability in patients with non-specific low back pain—a systematic review. Sports (Basel). 2023;11(9):167. doi: 10.3390/sports11090167.
30. Kendall K, Emery C, Wiley J, Ferber R. The effect of the addition of hip strengthening exercises to a lumbopelvic exercise programme for the treatment of non-specific low back pain: A randomized controlled trial. J Sci Med Sport. 2015;18(6):626-31. doi: 10.1016/j.jsams.2014.11.006.
31. Bernet B, Peskura E, Meyer S, Bauch P, Donaldson M. The effects of hip-targeted physical therapy interventions on low back pain: A systematic review and meta-analysis. Musculoskelet Sci Pract. 2019;39:91-100. doi: 10.1016/j.msksp.2018.11.016.
32. Aboufazeli M, Akbari M, Jamshidi A, Jafarpisheh M. Comparison of selective local and global muscle thicknesses in females with and without chronic low back pain. Ortop Traumatol Rehabil. 2018;20(3):197-204. doi: 10.5604/01.3001.0012.1473.
33. Lee S, Kim S, Yang J, Park S. Comparison of difference of the gluteus medius muscle fiber thickness during maximum muscle contraction between chronic low back pain with gluteus medius weakness and healthy subject. KSPM. 2015;10(1):71-82. doi: 10.13066/KSPM.2015.10.1.71.
34. Penney T, Ploughman M, Austin M, Behm D, Byrne J. Determining the activation of gluteus medius and the validity of the single leg stance test in chronic, nonspecific low back pain. Arch Phys Med Rehabil. 2014;95(10):1969-76. doi: 10.1016/j.apmr.2014.06.009.

SUPPLEMENTS

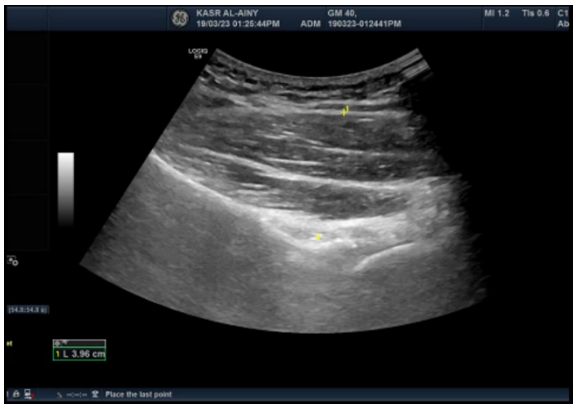
Hip abductor strength assessment by HHD

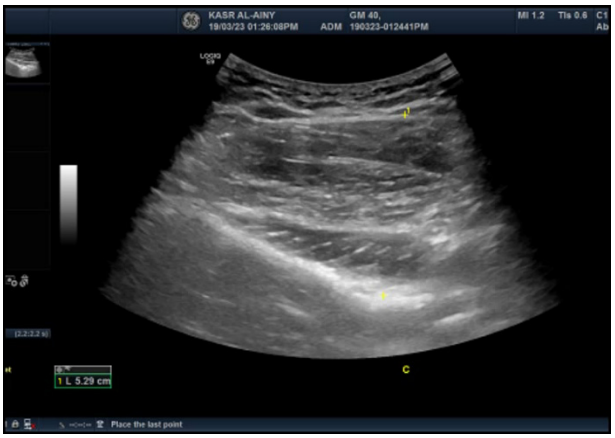


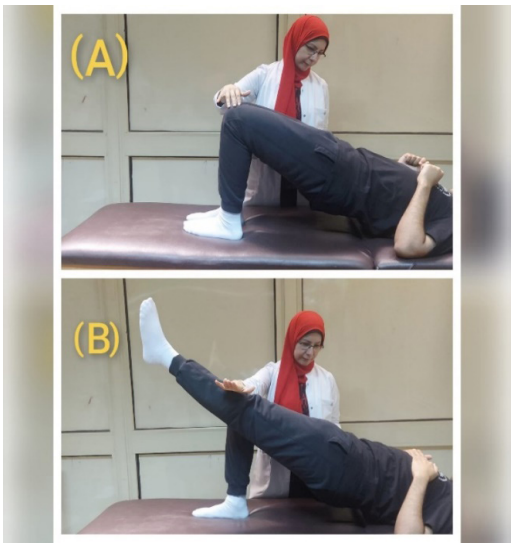
The single leg squat test
(A) the start position; (B) The squat position



GMed muscle thickness measurement
Thickness of muscle in a relaxed state



Thickness of muscle in contracted state	
	GMed strengthening exercises
Clamshell exercise	
Hip abduction exercise	

(A) Hip Bridge Exercise; (B) Unilateral hip bridge exercise	
Side-Lying hip bridge exercise	
Unilateral wall squat	