

Efficacy of hip strengthening on varus thrust in knee osteoarthritis

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ABSTRACT

The objective of this study was to investigate the effect of hip strengthening exercises on varus thrust in patients with knee osteoarthritis (OA). A double-blind clinical experimental study was carried out. Eighty-eight of the ninety-three eligible subjects participated. Participants were between 45 to 60 years of age, had a body mass index (BMI) of $< 30 \text{ kg/m}^2$, and medial tibiofemoral OA with a radiographic grade of 2-3 according to Kellgren-Lawrence (KL). Participants were randomly allocated to one of the two groups (control and study group). The control group (n=44; 22 men, 22 women) received only quadriceps strengthening exercise, and stretching exercise for hamstring and calf muscles, while the study group (n=44; 22 men, 22 women) received hip abductor, hip extensor, hip external rotator strengthening exercises in addition to the same exercises of the control group. Patients in both groups received 12 sessions of treatment (3 sessions per week for 4 weeks). The primary outcome was frontal plane projection angle (FPPA), which was measured by a digital video camera and analysed with Kinovea software. Secondary outcomes were muscles strength of hip abductor, hip extensor, hip external rotator and quadriceps measured with a handheld dynamometer (HHD). At baseline, there was no statistically significant difference between both groups regarding tested variables ($p > 0.05$). After 4 weeks of treatment, both groups showed statistically significant improvements in FPPA, hip abductors, hip extensors, hip external rotators and knee extensor strength, compared to pre-treatment ($p < 0.05$). However, the study group showed statistically

significant improvements in FPPA, hip abductors, hip extensors, and hip external rotators strength compared with the control group ($p < 0.05$), while there was no statistically significant difference in knee extensor strength between both groups ($p > 0.05$). Hip strengthening exercises can be added to the treatment programme of varus thrust.

KEYWORDS

Knee Osteoarthritis; Varus Thrust; Frontal Knee Instability

1. INTRODUCTION

Knee osteoarthritis (OA) is manifested by cartilage degeneration, subchondral bone loss, synovial inflammation, and damage to the meniscus and ligaments (Loeser et al., 2012). Knee OA is considered a healthcare problem, as each patient in France spends $2,120 \pm 5,275\text{€}$ per year for treatment (Salmon et al., 2019). In addition, workers diagnosed with knee OA leave the workforce prematurely, accounting for $\text{€}180 \pm 1,735$ per year for work discontinuation for every patient (Salmon et al., 2019). Premature mortality in patients complaining of knee pain only or knee pain with radiographic features of knee OA is 35-37% (Leyland et al., 2021). Prevalence of knee OA is common after 60 years of age and is higher in females (Akinpelu et al., 2009). Many risk factors have been found to increase the likelihood of knee OA, such as older age, obesity (Driban et al., 2020), prolonged positions and activities (Khan et al., 2020), and pathology in the knee joint (Harkey et al., 2019).

Varus thrust is characterized by a dynamic displacement of knee alignment during the stance phase and neutral alignment during the swing phase of walking (Chang et al., 2010). Varus thrust is associated with degenerative process of the disease (Wink et al., 2017), static Varus, disease incidence and progression (Kuroyanagi et al., 2012). The degenerative changes as a result of Varus thrust may be due to the fact that greater Varus excursion increases the contact forces in the knee joint (Farrokhi et al., 2016). Varus thrust is also associated with increased muscles co-contraction (Dixon et al., 2018) and knee adduction moment (KAM) (Kuroyanagi et al., 2012). KAM is associated with degenerative changes (Chehab et al., 2014) and can be used as an indicator of medial joint loading (Kean et al., 2012).

Frontal plane gait biomechanics are reliable tools for assessing medial knee OA (Pinto et al., 2020). Varus thrust is more sensitive than KAM, as it is occurred earlier than changes in KAM in

response to disease process (Mahmoudian et al., 2016). So, Varus thrust can be an indicator of prognosis of the disease.

Knee arthroplasty is considered one of the treatment procedures that have a significant reduction effect of KAM, and co-contraction of quadriceps and hamstring (Metcalf et al., 2012). Although this procedure has a significant effect on pain and function, it has not a valuable effect on knee extension range and moment (Levinger et al., 2013). High tibial osteotomy is also one of treatment choice that leads to a significant effect on frontal plane knee alignment and KAM (Ramsey et al., 2007), although, recurrence of Varus deformity is common after this procedure (He et al., 2021).

Many studies investigated the role of quadriceps in knee OA, and neglected the role of hip muscles (Foroughi et al., 2011). Systematic reviews found that hip strengthening was not effective for frontal knee biomechanics. Rathleff et al. (2014) concluded that hip strengthening did not affect frontal knee kinematics. However, the articles included in their review were conducted on asymptomatic subjects. Neelapala et al. (2020) found that hip strengthening was effective for pain and function, although it was not effective for dynamic knee mal-alignment and joint loading. However, the articles included in their review differed in which hip muscles were trained and the dosage of treatment. This is consistent with Ferreira et al. (2015), who reached the same conclusion as Neelapala et al. (2020) that hip training was not effective for KAM. However, they based their systematic review on fewer studies, so external validity is questionable. Recently, Quicke et al. (2020) found that therapeutic exercise was effective for neutral alignment but not for varus thrust, but the articles they included in their study were not of high enough quality. Finally, Li et al. (2021) concluded that hip resistance exercises were effective for gait speed but not for KAM. More studies should be conducted to investigate the effect of hip strengthening on frontal knee kinematics.

Hip and knee pathomechanics affect each other. Greater hip extensor strength reduces knee extensor moment and stresses on the knee joint (Liu et al., 2014; Petrella et al., 2019). Hip abductor is responsible for greater pelvic control, as less pelvic control increases stress on the knee joint in knee OA (Park et al., 2016). Some studies found that higher hip abductor strength protected against disease progression (Chang et al., 2005). Knee OA has also altered screw home mechanism. As medial knee osteoarthritic patients exhibited more femoral internal rotation during weight bearing activities (Bytyqi et al., 2014). So hip strengthening might be effective for maintaining knee kinematics in knee OA. The purpose of this study is to investigate the effect of strengthening the hip abductors, extensors, and external rotators on Varus thrust in patients with knee OA.

2. METHODS

2.1. Study design

Double-blind clinical experimental study (pre-test and post-test control study).

2.2. Participants

This study was conducted in the outpatient clinic of Cairo University. Data were collected before and after treatment from October 2020 to November 2021. Eighty-eight participants (44 males and 44 females) out of ninety-three individuals with knee OA were randomly randomized into two equal treatment groups (control and study group) by using opaque sealed envelopes. Patients were diagnosed and referred from orthopedist. They were assessed and treated at out-patient clinic.

The participants were included if age ranged from 45-60 years (Segal et al., 2015), had medial tibiofemoral OA (Sled et al., 2010) with Grade 2-3 on KL grading scale (Kellgren & Lawrence, 1957), and BMI was $< 30 \text{ kg/m}^2$ (Bryk et al., 2016). The participants were excluded if they received intraarticular corticosteroid injection into knee within the previous 3 months, and had significant comorbidities, history of other medical conditions affecting the knee joint, known hip OA, previous trauma affecting one or both hips, previous replacement of any joint in the lower extremities (Sled et al., 2010), lateral tibiofemoral osteoarthritis (Singh et al., 2016), low back pain (Suri et al., 2010), lumbar degenerative disc disease (Jiang et al., 2010), and cognitive impairment (Tsai et al., 2011).

Each patient signed informed consent before starting the study. Examiner of the participants was a research assistant and blinded about the treatment of the patient, and the subjects also blinded about their group of intervention. Ethical approval obtained from the review board at faculty of physical therapy, Cairo University, before conducting the study [No.: 012/002776] which followed the guidelines of declaration of Helsinki.

2.3. Sample size calculation

A priori power analysis using G*Power (version 3.1.9.2; Franz Faul, Universitat kiel, Germany) (Faul et al., 2009) was conducted to estimate the appropriate sample size. As a result of the power analysis, it was determined that a minimum of 88 participants would be required to ensure observed power equal to 0.82, which gave calculations were made using $\alpha=0.05$, $\beta=0.2$ and an effect size of 0.87.

2.4. Outcome measures

2.4.1. Varus thrust assessment

Frontal plane projection angle (FPPA) was used for assessing dynamic knee stability (Willson and Davis, 2008). 2D analysis of FPPA is valid (Gwynne & Curran, 2014) and reliable (Munro et al., 2012).

Our participants tested without wearing shoes. Each participant stood on a step then unaffected leg took a step forward on the floor (Nadia et al., 2019). The participant placed far from the digital camera at distance 2m, the digital camera was placed at the knee joint height and fixed by tripod. Kinovea software was used to edit the video (Willson & Davis, 2008). Three reflective markers were placed at anterior superior iliac spine, middle of tibiofemoral joint and middle of ankle mortise (Bailon et al., 2016). Participants were asked to squat 60° of knee flexion by their affected leg. Three trials were performed at pretest (Nadia et al., 2019). FPPA was calculated as the intersection of a line from anterior superior iliac spine (ASIS) to knee joint center and the line from the knee joint center to the ankle joint (Raisanen et al., 2018) and the difference from a vertical line (180 degrees) (Ramirez et al., 2018). FPPA is positive, if the knee marker is placed medially to a line from the ankle marker to the thigh marker. The FPPA is negative, if the knee marker is placed laterally to a line from the ankle marker to the thigh marker (Munro et al., 2012). Neutral alignment has zero degree; positive values represent valgus alignment and negative values represent varus alignment (Raisanen et al., 2018).

2.4.2. Hip abduction isometric strength test

Participants were in the lateral position and the hand dynamometer (HHD) was placed 5 cm proximal to the lateral knee joint line with an immovable strap around the thigh and the test table. Hip abduction was performed against maximal effort (lasting 5 s) (Bolgla et al., 2015). Repeated measurements were performed to obtain more reliable results. The test was performed three times and the mean of the three measurements was calculated (Riddle et al., 1989).

2.4.3. Hip extension isometric strength test

The participants were in the prone position. The hands were placed around the base to stabilize the trunk and the knees were bent to 90°. HHD was placed on the distal thigh of the tested limb with an immovable strap around the thigh and the test table. Hip extension was performed against maximal effort (lasting 5 s) (Bolgla et al., 2015). Repeated measures were performed to

obtain more reliable results. The test was performed three times and the mean value of three measurements was calculated (Riddle et al., 1989).

2.4.4. Hip external rotation isometric strength test

Participants sat with their hips and knees flexed to 90°. HHD was placed at 5 cm above the medial malleolus of the tested limb, with an immovable strap around leg and stable object. Hip external rotation was performed against maximal effort (lasting 5 s) (Bolgla et al., 2015). Repeated measures were performed to obtain more reliable results. The test was performed three times and the mean value of three measurements was calculated (Riddle et al., 1989).

2.4.5. Isometric knee extensor strength measurement

Participants sat on chair with their hips flexed to 90° and tested knee flexed 90°. HHD was placed on the anterior aspect of the distal tibia with an immovable strap around leg and the testing table. Knee extension was performed against maximal effort (Bolgla et al., 2015). Repeated measures were performed to obtain more reliable results, while the test was performed three times and the mean value of the three measurements was calculated (Riddle et al., 1989).

2.5. Interventions

2.5.1. Hip strengthening

Resistance training was performed for the abductors, extensors, and external rotators of the hip. Cuff weights were used and these exercises were performed with 3 sets of 8 repetitions with 10-15 s rest between repetitions and 1-2 min rest between sets at 80% of 1 repetition maximum (RM) (Foroughi et al., 2011).

2.5.2. Quadriceps strengthening exercise

Participants performed static exercises with multiple angles. They sat on seats with a weight attached proximal to the ankle and isometrically contracted their quadriceps for 5-10 s at 0°, 30°, 60°, 90°, and 120° angles of knee flexion, respectively (Xie et al., 2018). This exercise was performed with 3 sets of 12 repetitions at 40% of 1RM (Sayers et al., 2012).

2.5.3. Stretching exercise of hamstring and calf muscles

Each participant was positioned supine and asked to actively place their foot in inversion and dorsiflexion and then lift their leg toward the opposite shoulder. The participant's hands clasped

around the back of the thigh to give self-resistance as pushing his straight leg down against his hands for 15 s, and then he participant was asked to flex his leg to relax. This technique repeated was 4 times (Schuback et al., 2004).

- Control group (Group A): Group A received only program according to most evidence-based treatment in form of quadriceps strengthening exercise, and stretching exercise for hamstring and calf muscles.
- Experimental group (Group B): Group B received hip abductors, extensors, and external rotators strengthening exercises in addition to the same exercises of control group (quadriceps strengthening exercise, and stretching exercise for hamstring and calf muscles).

Patients in both groups received 12 sessions (3 sessions per week for 4 weeks). Following randomization, there was no dropping out of subjects from the study (Figure 1).

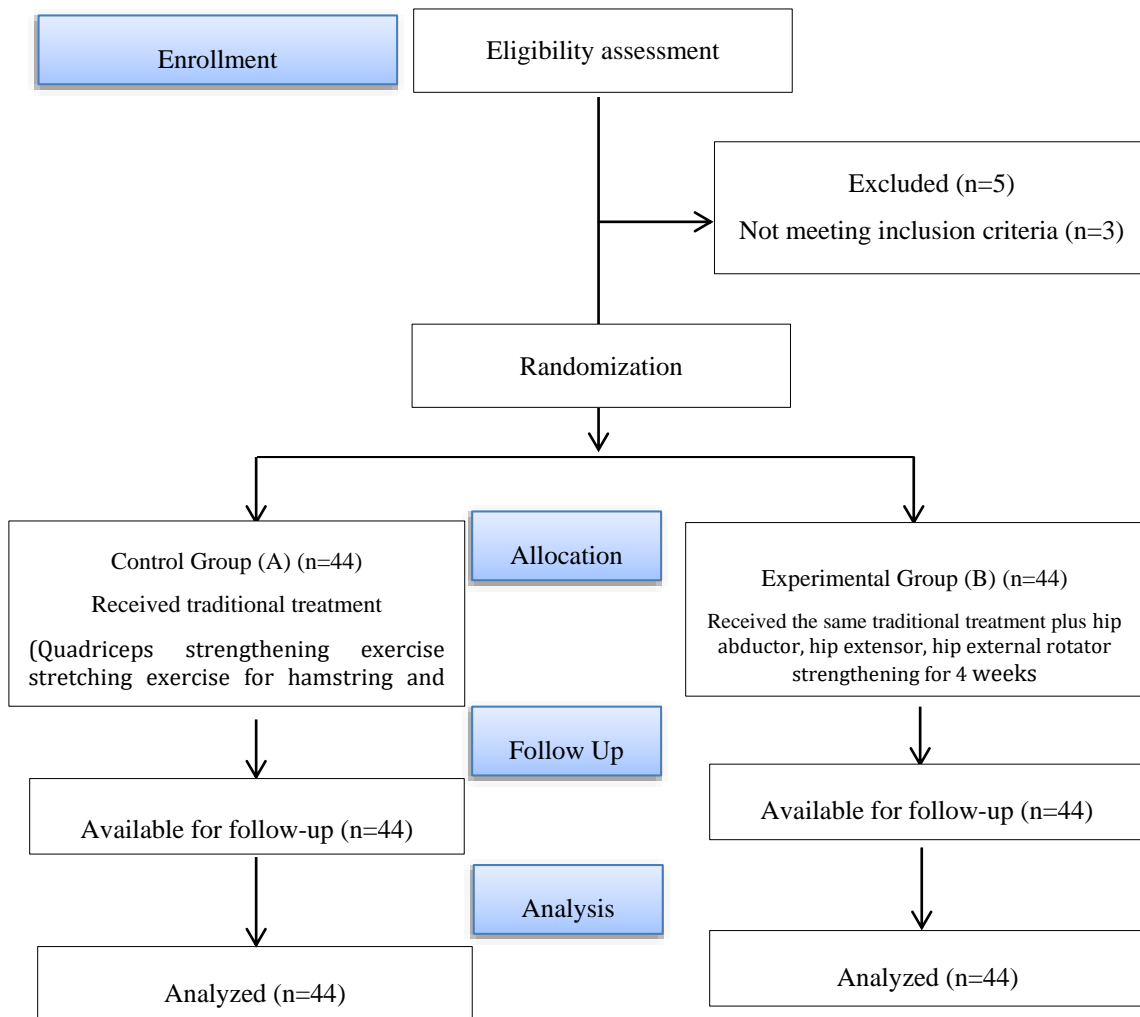


Figure 1. Flow chart

2.6. Data Analysis

SPSS for Windows Version 23 was used to run all statistical tests (Chicago, IL, USA). The Shapiro Wilk test was used to ensure data normality prior to final analysis. It was revealed that FPPA, hip abductors and knee extensors strength were normally distributed while hip extensors and external rotators strength weren't normally distributed. So, descriptive statistics (mean and standard deviation) were generated for normal data while median (inter quartile range (IQR)) for non-normal data. Moreover, inferential statistics and 2x2 mixed design MANOVA were used for within-group and between-group comparisons for normally distributed data, whereas nonparametric tests in the form of Wilcoxon signed rank tests were used for within-group comparisons. Mann-Whitney U tests were used for between-group comparisons for non-normally distributed data. A statistically significant p-value of 0.05 was used.

3. RESULTS

Eighty-eight individuals out of 93 participants eligible for inclusion were randomly assigned to one of the two groups: (1) control group [n=44; 22 men, 22 women) with mean age, and BMI values of 51.59 ± 4.74 years, and 27.7 ± 1.41 kg/m² respectively; (2) study group [n=44; 22 men, 22 women] with mean age, and BMI values of 52.09 ± 5.45 years, and 27.83 ± 1.32 kg/m² respectively. There were no statistically significant differences in age and body mass index (BMI) between groups ($p > 0.05$).

Regarding overall intervention effects, there was a statistically significant effect ($p < 0.05$) of both groups on all dependent variables. Also, there were statistically significant effects of the measuring periods on all dependent variables ($p < 0.05$). Moreover, the interaction between the two independent variables proved to be statistically significant ($p < 0.05$), which means that the effect of both groups on all dependent variables was influenced by the evaluation times (Table 1).

Table 1. Overall interaction indicated by 2x2 mixed MANOVA design for all dependent variables at different measuring periods between both groups.

Source of Variation	F-value	p value	Partial Eta square
Groups	264.255	0.0001a	0.904
Measuring periods	1545.984	0.0001b	0.982
Interaction	528.118	0.001c	0.95

3.1. Frontal plane projection angle, hip abductors, and knee extensors strength

At baseline, there were no statistically significant differences in FPPA, hip abductors and knee extensors strength between both groups ($p > 0.05$). The results of pre- and post-treatment values were compared within each group and showed that the mean values of FPPA, hip abductor strength, and knee extensor strength measured in both groups after treatment improved significantly compared to the corresponding mean values before treatment ($p < 0.05$). After 4 weeks of treatment, it is noted that the study group has a positive value of FPPA and a higher mean value of hip abductor strength than the control group. However, there was no statistically significant difference ($p > 0.05$) in knee extensor strength between both groups (Table 2).

Table 2. Descriptive and inferential statistical results of frontal plane projection angle (FPPA), hip abductors and knee extensors strength for both groups.

Measure	Control group (mean \pm SD)	Study group (mean \pm SD)	F	p**
FPPA				
Pre intervention	-11.86 \pm 5.16	-11.45 \pm 5.02	0.142	0.707
Post intervention	-8.52 \pm 5.01	5.18 \pm 3.84	206.89	0.0001**
P value*	0.0001*	0.0001*		
Hip abductors strength				
Pre intervention	86.27 \pm 5.39	86.72 \pm 4.75	0.172	0.679
Post intervention	92.13 \pm 5.4	135.38 \pm 9.4	699.12	0.0001**
P value*	0.0001*	0.0001*		
Knee extensors strength				
Pre intervention	87.45 \pm 5.03	89.06 \pm 5.11	2.23	0.139
Post intervention	133.15 \pm 7.46	136.07 \pm 9.22	2.67	0.106
P value*	0.0001*	0.0001*		

P value*: within groups comparison, P value**: between groups comparison, FPPA: Frontal Plane projection angle.

3.2. Hip extensors and external rotators strength

At baseline, the Mann-Whitney U test revealed that there was no statistically significant difference in hip extensor and external rotator strength between the two groups ($p > 0.05$). Within group, Wilcoxon Signed Rank test revealed that there was a statistically significant improvement on hip extensors and external rotators strength post-treatment compared to pre-treatment ($p < 0.05$) in both groups. Between groups, there was a statistically significant increase in hip extensor and external rotator strength after treatment with (p value < 0.05) in favor of the study group (Table 3).

Table 3. Descriptive and inferential statistical results for hip extensor and external rotator strength before and after treatment of both groups

	Control group	Study group			
	<i>Median (IQR)</i>	<i>Median (IQR)</i>	U-value	Z-value	p **
Hip extensors strength					
Pre treatment	84.1 (9.72)	89.8 (10.75)	743	-1.878	0.06
Post treatment	90 (7.8)	134.55 (14.82)	0.000	-8.079	0.0001**
Z- value	-5.777	-5.777			
	P value* = 0.0001*	P value* = 0.0001*			
Hip external rotators strength					
Pre treatment	86.25 (8.15)	89.8 (10.75)	909	-0.492	0.622
Post treatment	90.1 (7.15)	135.65 (17.67)	0.000	-8.079	0.0001**
Z- value	-5.777	-5.777			
	P value* = 0.0001*	P value* = 0.0001*			

* P value: within groups comparison, P value**: between groups comparison, IQR: inter quartile range, U-value: Mann-Whitney U, Z-value: Wilcoxon Z value.

4. DISCUSSION

The purpose of this study was to investigate the effect of hip strengthening exercises (hip abductors, extensors, external rotators) on Varus thrust in patients with knee OA. It was found that both groups had statistically significant improvements on FPPA, hip abductors, hip extensors, hip external rotators and knee extensor isometric strength post treatment, compared to pre-treatment ($p < 0.05$). However, the study group showed statistically significant improvements in the strength of the FPPA, hip abductors, hip extensors, and hip external rotators compared with the control group ($p < 0.05$), whereas there was no statistically significant difference in the strength of the knee extensors between the two groups after treatment ($p > 0.05$). It was also found that hip strengthening group had a significant improvement on FPPA post-treatment, compared to pre-treatment ($p < 0.05$). This came in agreement with Stearns and Powers (2014), as they found that hip abductor and extensor strength decreased knee abduction angle and KAM. In addition, increased hip extensor strength had an effect on reduction of knee extensor moment. However, they used 3D motion analysis to measure frontal knee angle during drop-jump task, while we used software to measure the angle. Stickler et al. (2015); Neamatallah et al. (2020) found the positive correlation between hip strength and frontal knee stability. Stickler et al., (2015) concluded that hip strength including hip abductor, extensor, and external rotator was significantly correlated with FPPA during single leg squat. Hip abductor had a

major role on maintaining frontal knee stability. In addition, Neamatallah et al. (2020) concluded that hip abductor and extensor strength was correlated with hip adduction angle, and knee abduction angle and moment. On the other hand, Foroughi et al. (2011); Herman et al. (2008) disagreed with the current study. Foroughi et al. (2011) found that hip strengthening exercises including (hip abductors and adductors) had not a significant effect on knee adduction angle and moment on patients with knee OA. However, they conducted their study on females only and measured dynamic shank and knee adduction angles as parameters for frontal knee stability by 3D motion analysis. They explained their findings as the power of their study was insufficient because of small sample size. Similarly, Herman et al. (2008) found that strengthening exercises including hip abductor and extensor had no significant effect on frontal knee angle during stop jumping task. However, they conducted their study on athletic females. They explained their finding as strength was not sufficient to influence lower extremity kinematics, as other elements such as plyometric, balance, and agility training played a role in maintaining stability of lower extremity. In addition, increased strength with an inappropriate neuromuscular pattern maintained the faulty motion pattern. Sigward et al. (2008) noted that hip abductors, extensors, and external rotators strengthening weren't correlated with frontal knee angle during drop land task. However, they conducted their study on athletes and their sample size was small. They explained their finding as drop land task was insufficient to make changes at lower limb mechanics, whereas single limb squat which was used in the current study, was more demanding for eliciting changes at lower extremity mechanics. In addition, Bandholm et al. (2011) found that higher hip external rotation strength was associated with less frontal knee control. They conducted their study on healthy subjects and small sample size, and tested frontal knee kinematics during drop jumping.

In the current study, it was found that control group which received quadriceps strengthening, had a statistically significant improvement on FPPA post-treatment, compared to pre-treatment ($p < 0.05$). This came in agreement with many previous studies (Lloyd et al., 2005; Jaehee et al., 2016). Lloyd et al. (2005) found that quadriceps counteracted against frontal knee instability during running. However, they conducted their study on healthy subjects. In addition, Jaehee et al. (2016) concluded that quadriceps activation was associated with control of frontal knee alignment during ambulation. However they conducted their study on healthy subjects, and measured frontal knee alignment by radiographic hip knee ankle angle. They explained their finding as hip knee ankle angle changed, made alteration on Q-angle, and so increased quadriceps activation. The current study contradicted with a study by Coury et al. (2006) who found that quadriceps strengthening led to alteration of frontal knee angle.

In the current study, it was also found that hip strengthening group had more statistically significant improvement in FPPA compared to control group ($p < 0.05$). Baldon et al. (2014) stated that hip strengthening had more improvement on decreased ipsilateral trunk lean, contralateral pelvic drop, hip adduction, and knee abduction excursions, compared to quadriceps strengthening. They also measured lower extremity kinematics during single leg squat. However, they conducted their study on females with patellofemoral pain; eccentric hip strength was measured; and their sample size was small. In addition, Saad et al. (2018) concluded that hip strengthening had significant improvement in frontal knee motion, compared to quadriceps strengthening during step up. However, no significant difference was present between hip strengthening and quadriceps strengthening during step down which disagreed with this study. They conducted their study on females with patellofemoral pain, and measured frontal knee motion during step up and down; in addition, their sample size was small. Claiborne et al. (2006) also disagreed with the current study as they found that no statistically significant difference was present between hip strengthening and quadriceps strengthening in frontal knee motion during single leg squat. However, they conducted their study on healthy subjects and measured frontal knee motion by 3-D motion analysis.

Our study also showed a significant improvement in quadriceps strength post treatment in both groups ($p < 0.05$). However, there was no statistically significant difference in quadriceps strength between both groups ($p > 0.05$). Some studies explained the role of quadriceps in maintaining frontal knee alignment through its effect in eliminating KAM (Winby et al., 2009). In addition, increased vastus lateralis activity and rectus femoris activity are present at late stance in order to decrease joint loading and promote stability in knee OA (Hubley-Kozey et al., 2006). Other studies illustrated the effect of quadriceps weakness on frontal knee stability (Marotta et al., 2020; Murdock & Hubley-Kozey, 2012). Marotta et al. (2020) found that delayed quadriceps activation was significantly related to dynamic knee instability. In addition, Murdock & Hubley-Kozey (2012) concluded that quadriceps fatigue led to alteration in knee kinematics and kinetics in both frontal and transverse planes during gait, as higher knee adduction angle, higher KAM, increased tibial external rotation, and decreased knee external rotation moment were consequences of quadriceps fatigue.

Our study showed a statistically significant improvement in hip strength post-treatment in the study group, compared to control group ($p < 0.05$). The reasons can be explained by different reasons. Firstly, hip abductor had a major role in maintaining frontal knee stability (Chaudhari & Andriacchi, 2006), through its effect on preventing pelvic drop, hip adduction, knee adduction excursion (Baldon et al., 2011) and knee abduction moment, as hip abductor weakness causes more hip adduction and lateral pelvic tilt, which shifted ground reaction force laterally, causing higher

knee abduction moment (Ueno et al., 2020). Hip abductor not only maintains frontal knee stability, but also reduces KAM (Thorp et al., 2010). The second reason can be explained through role of hip extensor on frontal knee stability, as decreased hip extensor activation causes greater hip internal rotation excursion, unfortunately leading to changes in frontal knee angle (Nguyen et al., 2011). As increased hip internal rotation excursion is associated with decreased hip abductor and external rotator strength, which increase hip adduction excursion, leading to more knee abduction excursion (Howard et al., 2011). In addition, hip internal rotation excursion is correlated with knee abduction and external rotation excursions, and greater knee abduction moment (Itoh et al., 2016). Hip external rotator strength also maintains whole lower limb stability as it prevents pelvic drop, femoral adduction, and knee adduction range (Baldon et al., 2011). In addition, it decreases stress on knee joint as it is negatively associated with knee internal rotation moment (Malloy et al., 2016), and decreases knee abduction moment (Snyder et al., 2009).

5. LIMITATIONS

The limitation of the current study is, first, that we did not measure the muscle activity of the knee flexors and extensors. However, co-contraction of the knee flexors and extensors prevents varus malalignment during walking to achieve dynamic stability (Schipplein and Andriacchi, 1991). Second, we did not perform a subgroup analysis based on sex differences, although sex is an important factor influencing hip and pelvis geometry (Boissonneault et al., 2014). Therefore, future studies are needed to investigate the role of hip strengthening on frontal knee kinematics in knee OA.

6. CONCLUSION

Adding hip strengthening exercises to the rehabilitation program of knee OA has a significant effect on Varus thrust in medial knee OA.

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CONFLICTS OF INTEREST

The authors declare no conflict of interest.

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