Med & Health Dec 2018; 13(2): 145-157 https://doi.org/10.17576/MH.2018.1302.14

ORIGINAL ARTICLE

Proximal Stability Assessment of Knee Osteoarthritis Patients

D MARYAMA AD[1,2,3], NUR RASYIQAH AR[3]

[1]*Human Performance Laboratory, Faculty Psychology and Education, Universiti Malaysia Sabah, Kota Kinabalu, 88400 Sabah, Malaysia*
[2]*Physical Fitness Rehab Centre, Faculty Psychology and Education, Universiti Malaysia Sabah, Kota Kinabalu, 88400 Sabah, Malaysia*
[3]*Sports Science Department, Faculty Psychology and Education, Universiti Malaysia Sabah, Kota Kinabalu, 88400 Sabah, Malaysia*

ABSTRAK

Kestabilan proksimal yang terdiri daripada kestabilan otot teras dan pinggul, memainkan peranan penting dalam menyokong berat badan dalam keadaan statik dan bergerak. Seterusnya, kestabilan proksimal boleh menyumbang kepada osteoarthritis lutut. Justeru, kajian ini dilaksanakan untuk menentukan kestabilan teras dan pinggul pesakit osteoarthritis lutut (OA lutut). Seramai 32 orang wanita berumur antara 45 hingga 60 tahun yang terdiri daripada 16 orang pesakit OA lutut dan 16 orang normal telah bersetuju menyertai projek kajian ini. Kestabilan pinggul diuji menggunakan ujian "Hip Crossover" dan kestabilan otot teras dinilai menggunakan ujian daya tahan otot teras, ujian kekuatan otot teras dan ujian kelenturan otot teras. Data kestabilan pinggul, kekuatan dan kelenturan otot teras dianalisa menggunakan ujian chi-square; dan daya tahan otot teras dianalisis menggunakan ujian-t tidak bersandar. Kajian ini mendapati pesakit OA lutut mempunyai pinggul yang kurang stabil [Hip Crossover Test (λ=0.500, p=0.033)] dan kestabilan otot teras yang lebih rendah berbanding dengan subjek normal. Kestabilan otot teras dinilai berdasarkan kepada kekuatan otot teras [abdominal muscles (χ=12.157, p<0.001); quadriceps and gluteal muscles (χ=13.364, p<0.001); hip muscles (χ=17.936, p<0.001); latissimus dorsi and quadriceps (χ=15.906, p<0.001)]; daya tahan otot teras [plank endurance (t=4.719, p<0.001); trunk flexion (t=2.824, p=0.008); trunk extension (t=1.364, p=0.193)]; dan kelenturan otot teras [Ely's test (λ=0.438, p=0.010)]. Kestabilan proksimal pesakit OA lutut jelas lebih lemah berbanding subjek normal. Oleh itu, latihan untuk meningkatkan kestabilan pinggul dan otot teras perlu dipertimbangkan dalam program rehabilitasi OA lutut, bukan sahaja bagi mengurangkan symptom OA lutut, tetapi juga memperbaiki

Address for correspondence and reprint requests: D. Maryama binti AG. Daud. Physical Fitness Rehab Centre, Faculty Psychology and Education, Universiti Malaysia Sabah, Kota Kinabalu, 88400 Sabah, Malaysia. Tel: +6010-9310913 Email: dmaryama@ums.edu.my

pergerakan berfungsi pesakit OA lutut.

Kata kunci: *kestabilan proksimal, kestabilan pinggul, kestabilan otot teras, osteoarthritis lutut*

ABSTRACT

Proximal stability consists of core and hip stability play a significant role in supporting the body weight in stationary and in motion. Thus, proximal stability could contribute to knee osteoarthritis (OA). Therefore, this study was carried out to determine the core stability and hip stability of knee OA patients. A total of thirty-two women aged between 45 to 60 years had volunteered to participate in this study, comprised of 16 knee OA patients and 16 normal. Hip stability was assessed using hip crossover test and core stability was assessed using core muscle endurance, core muscle strength and core muscle flexibility. Data of hip stability, core muscle strength and flexibility were analyzed using chi-square; and core muscle endurance data were analyzed using independent sample t-test. Compared to normal subjects, knee OA patients have poor hip stability [Hip Crossover Test (λ=0.500, p=0.033)] and core stability. Core stability was assessed based on core muscle strength [abdominal muscles (χ=12.157, p<0.001); quadriceps and gluteal muscles (χ=13.364, p<0.001); hip muscles (χ=17.936, p<0.001); latissimus dorsi and quadriceps (χ=15.906, p<0.001)]; core muscle endurance [plank endurance (t=4.719, p<0.001); trunk flexion (t=2.824, p=0.008); trunk extension (t=1.364, p=0.193)]; core muscle flexibility [*Ely's* test (λ=0.438, p=0.010)]. The proximal stability of knee OA patients appears to be significantly weaker than normal subjects. Thus, core stability and hip stability training have high potential not only to lessen the symptoms of knee osteoarthritis but to improve the functional movement of knee OA patients.

Keywords: core stability, hip stability, knee osteoarthritis, proximal stability

INTRODUCTION

Knee osteoarthritis (OA) is a degenerative joint disease that affects older people (Silverwood et al. 2015). It is caused by the destruction of the knee cartilage (Bertrand et al. 2010). Functional capacities of the knee OA patients impair significantly (Mizner 2003), including their muscle strength. Previous researches found that knee OA leads to a decrement in muscle strength (Rice et al. 2011; Segal & Glass 2011). From meta-analysis research by Alnahdi et al. (2012) concluded that quadriceps, hamstrings, and hip muscles were significantly impaired in patients with knee OA compared with age-matched controls (Alnahdi et al. 2012). Quadriceps, hamstrings and hip muscles also part of core muscles. However, most researches have focused on the individual lower body muscles such as quadriceps, hamstrings, and hip muscles but hardly any on core body muscles as a whole comprising the trunk muscles. This is due to a subjective definition and lack of gold standard assessment of core body muscles strength, power and endurance (Waldhelm 2011). Therefore, terminology used in this study is core stability and proximal stability that were proven by Waldhelm (2011) to be reliable and valid assessment of core muscles.

Core muscles comprised of erector spinae, plantar flexor evertor, soleus, gluteus maximus, gluteus medius, transversus abdominis, multifidus, rectus abdominis, and oblique abdominals (Biabanimoghadam et al. 2016). According to Kibler et al. (2006), core muscles are important for stabilization, to maximise force generation as well to minimise joint loads. Hence, core body muscles involve in providing stability particularly proximal stability for both during stationary and in motion. Proximal stability is the ability to stabilise and actively control the spine, pelvis, and trunk (Palmer 2012). Core stability stabilises the spine during both dynamic and static tasks (Panjabi 2003; Waldhelm & Li 2012). Hence, proximal stability can be represented by core stability and hip stability.

'Core stability' is the ability to control the position and motion of the trunk over the pelvis (Kibler et al. 2006) and hence it has an impact on the knee function (Biabanimoghadam et al. 2016). Chuter and Janse de Jonge (2012) also discovered that increased risk of lower limb injuries because of proximal dysfunction due to a weak lumbo-pelvic hip complex. Thus, moderate knee OA patients with Western Ontario and McMaster Universities OA Index (WOMAC Index) ranges from 26 to 78 will be at risk for lower limb injuries that will lead to functional deficiencies. Therefore, this study was carried out to further confirm if moderate knee OA patients have poor proximal stability compared to a control group, by investigating the strength, endurance, and flexibility of their core muscles and hip stability.

MATERIALS AND METHODS

SUBJECTS

This study was approved by the Universiti Malaysia Sabah research ethics committee (UMS/SPU6.13/100-6/1/95) and *National Medical Research Registration (NMRR ID: 14432).* Only female subjects were chosen in this study. Previous studies by Litwic et al. (2013) and Hame & Alexander (2013), females more prone to have a knee OA compared to males, which is affected by several factors such as hormones and anatomical abnormalities of knee. Thus, thirty-two adult female subjects aged 45 to 60 years, comprised 16 outpatients with a diagnosis of the knee OA and 16 controls, were agreed to participate this study by signing the written informed consent. With the same sample size knee OA patients and controls of 16 subjects each; calculated effect size d of 1.93; and type 1 error, α of 0.001, the corresponding statistical power of this study is 0.95, which is calculated using G*Power 3.1.9.2. The patients were recruited from Hospital Kudat and Physiotherapy Department, Klinik Kesihatan Luyang and controls were also from community nearby. All subjects were excluded if they were encountered by any of the following condition: (i) traumatic injury to the knee joint within 6 months; (ii) oral corticosteroid used (within 6 months); (iii) suffer from Cardio-Respiratory disorders and peripheral vascular disease; (iv) local signs or inflammation to or around knee joint or systemic arthritic conditions; (v) undergone lower limb surgery, (vi) any other muscular, joint, or neurologic condition affecting lower extremity function; (vii) inability to walk or climb staircase without assistive device; (viii) altered limb length; (ix) pregnant; (x) unable to perform the tests.

Diagnosis of knee OA was performed by a rheumatologist. In the knee OA group, self-reported knee pain and difficulty with physical function were measured using the WOMAC Osteoarthritis index, where higher scores indicated worse symptoms. Pain scores ranged from 0–20; stiffness ranged from 0-8, and physical functioning ranged from 0-68. Inclusion criteria for the patients were a diagnosis of moderate knee OA using the clinical and radiographic evidence and with WOMAC index ranging from 26 to 78. On the other hand, control subjects were without any knee, hip, or back pain for the last 6 months. Control subjects did not undergo radiographic evaluation due to financial and ethical constraints.

We carried out all the proximal and core stability assessments in the Hospital Kudat and Klinik Kesihatan Luyang. Before the core muscle stability tests, all subjects underwent an informal guided interview using medical screening questionnaire; this was to get information about patient's background, health history, previous injuries, and medication taken. Knee OA patients were guided to fill in the WOMAC form to assess knee pain, stiffness, and physical function in the previous week. An assessment form containing data on personal characteristics: age, occupation, other diseases, previous injury, measurement of weight and height, BMI (Body Mass Index), and lower limb dominance (preference for kicking).

INSTRUMENTS

WOMAC

The Western Ontario and McMaster Universities OA Index (WOMAC) consists of three subscales: pain, stiffness and physical function. Scores range from 0 to 96, with higher scores indicating greater disease severity. Self-reported knee pain and difficulty with physical function of knee OA patients were measured using the WOMAC index, whereby higher scores indicated worse symptoms.

HIP MUSCLES STABILITY

In this study, stability of the hip muscles was evaluated using Hip Crossover

Test, with interrater reliability of ICC = 0.89 - 0.96 (Kivlan et al. 2013).

HIP CROSSOVER TEST

The subject was asked to stand on his single leg followed by crossing another leg (non-supporting) across in front of the supporting leg and then followed by leg abduction bringing non-supporting leg away from mid-line. Symmetrical body position was examined during leg adduction and abduction. Score 0 for symmetrical position, and score 1 for non-symmetrical position or unstable symmetrical position.

CORE MUSCLE STRENGTH

Core muscle strength was assessed through observation by giving scores for each indication following ACSM guidelines on four different testing movements including trunk curl, lunges, single leg squat, and squats. Each movement assessed specific muscle group including abdominal muscles (rectus abdominis, transversus abdominis, internal oblique and external oblique); back muscles (including latissimus dorsi); quadriceps and hamstring muscles; and hip muscles. Scores recorded and total scores for each test was calculated for both groups, knee OA patients and controls. Interrater reliability for all test was ICC = 0.62 - 0.96 (Waldhelm 2011)

Trunk Curl

Subject was asked to lay down with knees were flexed at 45° and feet placed securely on the floor. The subject was asked to perform sit up without lifting the heels. The movement was recorded using a video camera to ensure scoring given correctly by looking for three (3) indications: (i) Clear Scapulae; (ii) Heel Elevation; and (iii) Abdominal yoking. For each indication, scoring 0 or 1 given, 0 = not present; 1 = present. Total scores of 3 indicated weak abdominal muscles. Contrary, less than 3 denoted strong abdominal muscles.

Lunges

Lunges used to assess quadriceps and gluteal muscles strength. This test required subject to stand with one leg in front of the other leg. The subject would slowly kneel using the front leg up to 90° of the knee angle. A video camera was used to record to ensure scoring 0 only given for a correct body posture by looking for these 3 indications: (i) body posture in the upright position; (ii) without hip adduction; (iii) lunges with the front knee at 90°. Score = 1 for an incorrect body posture. Total scores of 3 indicated weak quadriceps and gluteal muscles. Scores less than 3 denoted strong quadriceps and gluteal muscles.

Single Leg Squat

Single leg squat test was used to assess hip muscles strength by doing squat on one leg with upright body position by flexing the knee slowly till 90° and return to the standing position. Video camera was used to record the movement to ensure scoring 1 only given for incorrect body posture and the body movement by looking for 2 indications: (i) dysfunctional movement pattern of the knee; (ii) Opposite hip drop down (trendeleburg sign). Score

= 0 for correct body posture and body movement. Total scores of 2 indicated weak hip muscles. Scores less than 2 denoted strong hip muscles.

Squat

Squat test was used to assess quadriceps and back muscles strength. Subject was asked to perform squat using both legs with upright body position by flexing the knee slowly till 90˚ and return to the standing position. A video camera was used to record the movement recorded to ensure scoring 0 only given for correct body posture and the body movement by looking for this 3 indications: (i) spine position towards pelvis was in a straight line; (ii) hip moving backwards; (iii) knee flexion not exceeding the toes. Score = 1 for incorrect body posture and body movement. Total scores of 3 indicated quadriceps and back muscles were weak. Scores less than 3 signified a strong quadriceps and back muscles.

CORE MUSCLE FLEXIBILITY

***Ely's* test**

Ely's test was used to evaluate core muscles flexibility specifically hamstrings and rectus femoris. Interrater reliability for *Ely's* test was ICC = 0.64 - 0.84 (Waldhelm 2011). Subject was asked to lay down with a face downward and leg was flexed towards the glutes. Score = 1 was given when subject felt tightness at their hip or low back, or heels do not touch the glutes. Score 1 indicated hamstrings and rectus femoris muscles were tight.

CORE MUSCLES ENDURANCE

Plank Test

Subject performed plank by laying down with a face downward. By using forearms and toes to support with elbows and ankles at 90˚ followed by raising up upper body, hips, and legs off the floor with a straight body alignment from shoulder through hip, knee, and, ankle. Using a stopwatch, time (seconds) was recorded as soon as the torso was lifted off the mat. If the participant was unable to keep the position, she would be given a maximum of two warnings to re-establish the position. The test was stopped when subject unable to keep the body position with two warnings given or unable to perform.

Trunk Flexion Endurance Test

Subject positioned the body in a hook-lying position. Using a medicine ball to support the trunk at 60˚ of trunk flexion with knees and hips were flexed at 90˚, arms crossed over the chest and feet secured. Using a stopwatch, time (seconds) was recorded as soon as after the support was removed. Subject was asked to hold the position as long as possible.

Trunk Extension Endurance Test

Subject lay prone on a mat with the pelvis, hips, and knees secured to the floor. With arms crossed over the chest, a medicine ball was used to support trunk and upper extremities. Subject was required to hold a horizontal body position for as long as possible after the support was removed. Using a stopwatch, time (seconds) was recorded until the subject unable to maintain the body position.

Table 1: Anthropometry Data

	Knee OA (n=16)	Controls (n=16)	Independent-t Test	
	mean ± S.E.	mean ± S.E	t	P
Mass, kg	65.88 ± 11.735	56.44 ± 4.553	2.966	.006
BMI	27.19 ± 4.753	23.97 ± 1.875	2.530	.017

n (knee OA) = 16; n(controls) = 16; OA = osteoarthritis; BMI = Body Mass Index; S.E. = Standard Error

DATA ANALYSIS

Statistical analyses were performed using the IBM SPSS version 20 software. Since hip stability, strength and flexibility of core muscles were nominal data, differences in hip stability, core muscles strength and flexibility between knee OA patients and controls data were analysed using crosstabulation analysis with chi-square. On the other hand, core muscles endurance which is a numerical data, variation between knee OA patients and controls was analysed using independent t-test. Significant level for this study was set at $p<0.05$.

RESULTS

As presented in Table 1, both control (age = 49.88 ± 3.008 years) and knee OA (age = 50.63 ± 3.364 years) patients groups were significantly different in body mass and BMI with knee OA group was heavier and had slightly higher BMI. The mean WOMAC Index of knee OA patients (Table 2) that participated in this study was 51.88 ± 2.451 and ranged from 28 to 64 had fulfilled the inclusion criteria which WOMAC index ranged from 26 to 78.

As displayed in Table 2, knee OA patients had reported moderate levels of pain and stiffness with a mean Pain Score of 10.75 ± 0.750 out of 20, and mean Stiffness Score of 4.06 ± 0.392 out of 8. Difficulty with physical function of knee OA patients in this study had also reported a moderate level of physical functioning with a mean score of 37.06 ± 1.865 out of 68. All those criteria were fulfilled as according to inclusion criteria of this study.

Core stability in this study was analysed using core muscle strength, core muscle endurance, and core muscle flexibility. Core muscle strength was assessed through observation by giving scores for each indication

Table 2: Womac Osteoarthritis Index of Knee OA Patients

Womac Osteoarthritis Index	Mean ± SE	Minimum Score	Maximum Score
Pain subscore (0-20)	**10.75 ± 0.750**	**4**	**16**
Stiffnesss subscore (0-8)	4.06 ± 0.392	0	6
Physical function subscore (0-68)	37.06 ± 1.865	21	47
Total womac score (0-96)	51.88 ± 2.451	28	64

N= 16; SE = Standard Error

Table 3: Comparison of Core Muscles Strength between Knee OA Patients and Control Subjects

Core Muscles		Scores				Chi-Square Test Linear-by-Linear Association		
		0	1	2	3	χ	df	p value
Abdominal Muscles	Knee OA	1	2	8	5	12.157	1	p<0.001*
	Control	6	7	3	0			
Quadriceps and Gluteal	Knee OA	0	3	8	5	13.364	1	p<0.001*
	Control	7	5	4	0			
Hip Muscles	Knee OA	0	5	11	-	17.936	1	p<0.001*
	Control	7	9	0	-			
Latissimus dorsi and Quadriceps	Knee OA	0	1	5	10	15.906	1	p<0.001*
	Control	4	6	6	0			

*Significant at p≤0.05 (2-sided); n (knee OA) = 16; n (Control) = 16

following ACSM guidelines with four different testing movements including trunk curl, lunges, single leg squat, and squats. The scores were recorded and total scores for each test was calculated for both groups, as presented in Table 3. Significant weakness was evident in knee OA patients across all core muscles strength test. Abdominal muscles (χ=12.157, p<0.001); Quadriceps and Gluteal muscles (χ=13.364, p<0.001); Hip Muscles (χ=17.936, p<0.001); Latissimus dorsi and Quadriceps (χ=15.906, p<0.001) of knee OA patients were significantly weaker than controls.

Table 4 presents the second part of core stability assessment which is the core muscle endurance tests. This study showed that knee OA patients were significantly weak in plank (t=4.719, p<0.001) and trunk flexion (t=2.824, p=0.008). There was 76.9% to 89.2% deficit in core endurance of knee OA patients compared to controls.

This study also found knee OA patients had significantly poor flexibility of hamstring and rectus femoris muscles (λ=0.438, p=0.010) and poor hip stability (λ=0.500, p=0.033) as compared to control subject as signified by *Ely's* test and Hip Crossover test respectively (Table 5).

Table 4: Comparison of Core Endurance between Knee OA and Control Subjects

	Control (n=16)	**With Knee OA** (n=16)	**Independent-t Test**		**% diff**
	Time (sec)	**Time (sec)**	**T**	**p value**	
Plank	5.71 ± 1.035	0.6175 ±0.3026	4.719	p<0.001*	89.2%
Trunk flexion	10.389 ± 1.744	2.398 ± 2.228	2.824	0.008*	76.9%
Trunk extension	0.8806 ± 0.645	0.0006 ± 0.00063	1.364	0.193	99.9%

*Significant at p ≤ 0.05; Values are the mean ± S.E. (Standard Error); Time (sec) = time taken to perform the test; df = 30; OA = osteoarthritis; % diff = [(mean value of control group – mean value of osteoarthritis group)/mean value of control group] x100.

Table 5: Comparison of Core Muscles Flexibility and Hip Stability between Knee OA Patients and Control Subjects

Variables		**Scores**		**Crosstabs Directional Measures**	
		Relax 0	**Tight 1**	**λ**	**p value**
Hamstrings & Rectus Femoris	Knee OA	1	15	0.438	0.010*
	Normal	8	8		
		Symmetry 0	**Asymmetry 1**	**λ**	**p value**
Hip Stability	Knee OA	4	12	0.500	0.033
	Normal	12	4		

*significantly different at p≤0.05

DISCUSSION

Core muscles play an important role in providing core stability during both static and dynamic tasks (Behm et al. 2010; Hu et al. 2012). In other words, core stability contributes towards proximal stability for both during stationary and in motion. According to Kibler et al. (2006), a proximal to distal patterning of generation of force and the creation of interactive moments that move and protect distal joints including knee. Proximal muscle weakness and altered motor control have also been implicated in the development of numerous lower limb injuries (Chuter & Janse de Jonge 2012). Therefore, this research was comparing the proximal stability of adult females with and without knee OA (control). Our findings appeared to show that moderate knee OA patients had poor proximal stability compared to control subjects, indicating they have poor core stability and hip stability.

This finding is consistent with previous researches by Chang et al. (2005) and Mündermann et al. (2005) that both found hip abductor muscles were associated with the knee OA development and progression. Hip abductor muscles consist of sartorius, tensor fascia latae, and gluteus medius which are also categorised as core muscles (Bliss & Teeple 2005). The lumbo-pelvic-hip complex muscles strength contributes in controlling hip abduction, subsequent internal rotation of the femur, and distal movement (Chuter & Janse de Jonge 2012). Poor core and hip stability cause the force transfer from the proximal section to the distal section to be decreased.

As pointed out in this study, moderate knee OA patients had weaker abdominal muscles, quadriceps, gluteal muscles, latissimus dorsi, and hip muscles. Loading rate on the lower body in healthy women corresponds with quadriceps muscle strength and higher loading rates are often associated with a weaker quadriceps (Mikesky et al. 2000; Liikavainio et al. 2007). It is clearly explained in previous researches the roles of quadriceps, hamstrings, vastus lateralis, and gastrocnemius muscles to the knee joint stability as well as in shock absorbing function (Bennell et al. 2008). Thus, loading in the knee joint will increase that leading to the biochemical and structural changes of the cartilage, including increase in water content and matrix macro molecules (Inchai & Mahakkanukrauh, 2017).

This study also found moderate knee OA patients had poor muscle flexibility particularly hamstring and rectus femoris. Since rectus femoris muscles are involved in flexion at the hip joint and extension at the knee joint (Hagio et al. 2012), tight rectus femoris muscles will pull the hip and knee joint closer to each other. Hence, tight muscles will increase the compression of the joint space in knee OA patients. Furthermore, we found that knee OA patients had poor core muscle endurance by 76.9% to 89.2% deficiency compared to controls. Poor core muscles endurance leads to altered standing postural control, reduction in trunk proprioception, and a decrease in neural activation of the quadriceps (Colston 2012). Core muscle endurance deficient also leads to an increase in loading of the knee (Sritharan et al. 2012) as well as in the knee joint contact force during dynamic movement (Pandy & Andriacchi 2010; Sasaki & Neptune 2010).

Higher mean body mass among knee OA patients in this study, also contributes to the increased loading on the core muscles (Mbada et al. 2008; Mbada et al. 2009; Mayer et al. 2012). All the core muscle endurance tests performed in this study were depended on gravity's action on body mass for the entire load and the ability to support body mass against gravity for an extended period of time (Mayer et al. 2012). Thus, there will be a disadvantage to individuals with high body mass value when performing these core muscle endurance test because of higher loads that need to be supported against the gravity. A few researches have further confirmed that the core muscles play a significant role in the loading of the tibia-femoral joint (Pandy & Andriacchi 2010; Sasaki & Neptune 2010; Sritharan et al. 2012). Thus, weaker core muscles strength, poor core muscles endurance, and flexibility will increase loading of the knee during dynamic movement in which will potentially elevate the knee OA symptom. Core muscles, lower limb muscles, and hip muscles play an important role in knee OA pathogenesis (Costa et al. 2010). Sustaining the poor core stability, the severity of knee OA will further progress due to the loading increment on the knee.

A possible mechanism of core muscles weakness can be similar with quadriceps weakness in which it is associated with the inhibition of muscle activation (Borghuis et al. 2008) and muscle fibre atrophy (Bennell et al. 2013). Knee OA disease causes patients to gradually withdraw from any physical activity due to chronic pain and structural problem. Reduction in physical activity will potentially lead to core muscles weakness and over time it can cause muscles disuse (Bodine 2013). The core muscles are involved in supporting body weight and in decreasing loads of the knee joint (Creps 2014). However, a study by Winters and Rudolph (2014) found that not only quadriceps strength but also rate of force development affected gait and knee joint power. Kean et al. (2017) further confirmed that change in quadriceps strength only explains 4% of variance change in maximal loading response.

This research output has supported to include neuromuscular training of core and hip muscles as well as strengthening training into rehabilitation programmes for knee OA. Future research is recommended to study the efficiency of core and hip muscles strengthening in reducing the load of the knee joint as well as improving the knee joint space. These either slows down or stops the narrowing process on the knee joint space. They might even increase the joint space by improving the knee joint space, which will slow down the progression of knee OA (Segal et al. 2010).

There were a few limitations in our study. There was no classification of knee OA (medial or lateral) and there was also lacked radiograph scan for the control group due to ethical and financial constraints. Hence, we cannot conclusively rule out the presence of knee OA in our control group. The selection of our control group was merely based on individual subject claims. However, we did assure that these people had no knee symptoms or any history of injury or trauma that likely to predispose to knee OA. In spite of that, it was not clear from this cross-sectional study, whether core and hip muscles weakness that may lead to the development of knee OA or may due to result of the knee OA disease.

CONCLUSION

The findings demonstrated poor core and hip stability in the presence of knee OA and suggested that a comprehensive exercise rehabilitation programme is aimed at improving core and hip stability and should be appropriate in the management of knee OA.

ACKNOWLEDGEMENT

The authors would like to thank all the volunteers who participated in this study. This study was supported by the Ministry of Higher Education, Malaysia (Grant No.: TRGS0004-SG-12/2014).

REFERENCES

Alnahdi, A.H., Zeni, J.A., Snyder-Mackler, L. 2012. Muscle Impairments in Patients with Knee Osteoarthritis. *Sports Health* **4**(4): 284-92.

Behm, D.G., Drinkwater, E.J., Willardson, J.M., Cowley, P.M. 2010. The use of instability to train the core musculature. *Appl Physiol Nutr Metab* **35**(1): 91-108.

Kivlan, B.R., Carcia, C.R., Clemente, F.R., Phelps, A.L., Martin, R.L. 2013. Reliability and validity of functional performance test in dancers with hip dysfunction. *Int J Sports Phys Ther* **8**(4): 360-9.

Bennell, K.L., Hunt, M.A., Wrigley, T.V., Lim, B.-W., Hinman, R.S. 2008. Role of muscle in the genesis and management of knee osteoarthritis. *Rheum Dis Clin North Am* **34**(3): 731-54.

Bennell, K.L., Wrigley, T.V., Hunt, M.A., Lim, B.-W., Hinman, R.S. 2013. Update on the Role of muscle in the genesis and management of knee osteoarthritis. *Rheum Dis Clin North Am* **39**(1): 145-76.

Bertrand, J., Cromme, C., Umlauf, D., Frank, S., Pap, T. 2010. Molecular mechanisms of cartilage remodelling in osteoarthritis. *Int J Biochem Cell Biol* **42**(10): 1594-601.

Biabanimoghadam, M., Motealleh, A., Cowan, S.M. 2016. Core muscle recruitment pattern during voluntary heel raises is different between patients with patellofemoral pain and healthy individuals. *Knee* **23**(3): 382-6.

Bliss, L.S., Teeple, P. 2005. Core stability: the centerpiece of any training program. *Curr Sports Med Rep* **4**(3): 179-83.

Bodine, S.C. 2013. Disuse-induced muscle wasting. *Int J Biochem Cell Biol* **45**(10): 2200-8.

Borghuis, J., Hof, A.L., Lemmink, K.A. 2008. The importance of sensory-motor control in providing core stability. *Sports Med* **38**(11): 893-916.

Chang, A., Hayes, K., Dunlop, D., Song, J., Hurwitz, D., Cahue, S., Sharma, L. 2005. Hip abduction moment and protection against medial tibiofemoral osteoarthritis progression. *Arthritis Rheum* **52**(11): 3515-9.

Chuter, V.H., Janse de Jonge, X.A. 2012. Proximal and distal contributions to lower extremity injury: a review of the literature. *Gait Posture* **36**(1): 7-15.

Colston, M.A. 2012. Core stability, part 2: the core-extremity link. *International Journal of Athletic Therapy and Training* **17**(2): 10-15.

Costa, R.A., Oliveira, L.M.d., Watanabe, S.H., Jones, A., Natour, J. 2010. Isokinetic assessment of the hip muscles in patients with osteoarthritis of the knee. *Clinics* **65**(12): 1253-9.

Creps, J.M. 2014. An Investigation of simulated core muscle activation during running and its effect on knee loading and lower extremity muscle activation using opensim. *PhD thesis*. The Ohio State University

Hagio, S., Nagata, K., Kouzaki, M. 2012. Region specificity of rectus femoris muscle for force vectors in vivo. *J Biomech* **45**(1): 179-82.

Hame, S., Alexander, R. 2013. Knee osteoarthritis in Women. *Curr Rev Musculoskelet Med* 6(2): 182-7.

Hu, H., Meijer, O.G., Hodges, P.W., Bruijn, S.M., Strijers, R.L., Nanayakkara, P.W., van Royen, B.J., Wu, W.H., Xia, C., van Dieën, J.H. 2012. Control of the lateral abdominal muscles during walking. *Hum Mov Sci* **31**(4): 880-96.

Inchai, C., Mahakkanukrauh, P. 2017. Biological markers associated osteoarthritis. *Med & Health* 12(1): 18-26.

Kean, C.O., Hinman, R.S., Wrigley, T.V., Lim, B.W., Bennell, K.L. 2017. Impact loading following quadriceps strength training in individuals with medial knee osteoarthritis and varus alignment. *Clin Biomech* **42**: 20-4.

Kibler, W.B., Press, J., Sciascia, A. 2006. The role of core stability in athletic function. *Sports Med* **36**(3): 189-98.

Litwic, A., Edwards, M.H., Dennison, E.M., Cooper, C. 2013. Epidemiology and burden of osteoarthritis. *Br Med Bull* (105): 185-99.

Liikavainio, T., Isolehto, J., Helminen, H.J., Perttunen, J., Lepola, V., Kiviranta, I., Arokoski, J.P., Komi, P.V. 2007. Loading and gait symmetry during level and stair walking in asymptomatic subjects with knee osteoarthritis: importance of quadriceps femoris in reducing impact force during heel strike? *Knee* **14**(3): 231-8.

Mayer, J.M., Nuzzo, J.L., Chen, R., Quillen, W.S., Verna, J.L., Miro, R., Dagenais, S. 2012. The impact of obesity on back and core muscular endurance in firefighters. *J Obes* **2012**: 729283.

Mbada, C.E., Ayanniyi, O., Adedoyin, R.A. 2008. Influence of relative adiposity on static back extensor muscle endurance in apparently healthy adults. *Hong Kong Physiotherapy Journal* **26**(1): 2-8.

Mbada, C.E., Ayanniyi, O., Adedoyin, R.A. 2009. Reference values of static back extensor muscle endurance in healthy nigerian adults. *Med Princ Pract* **18**(5): 345-50.

Mikesky, A.E., Meyer, A., Thompson, K.L. 2000. Relationship between quadriceps strength and rate of loading during gait in women. *J Orthop Res* **18**(2): 171-5.

Mizner, R.L. 2004. Quadriceps femoris weakness and functional outcome in individuals with end-stage knee osteoarthritis. http://search.ebscohost.com/login.aspx?direct=true&db=c8h&AN=109844558&site=ehost-live [7 July 2018].

Mündermann, A., Dyrby, C.O., Andriacchi, T.P. 2005. Secondary gait changes in patients with medial compartment knee osteoarthritis: increased load at the ankle, knee, and hip during walking. *Arthritis Rheum* **52**(9): 2835-44.

Palmer, T.G. 2012. Effects of proximal stability training on sport performance and proximal stability measures. ProQuest Dissertations and Theses, 168.

Pandy, M.G., Andriacchi, T.P. 2010. Muscle and joint function in human locomotion. *Annu Rev Biomed Eng.* **12**: 401-33.

Panjabi, M.M. 2003. Clinical spinal instability and low back pain. *J Electromyogr Kinesiol* **13**(4): 371-9.

Rice, D.A., McNair, P.J., Lewis, G.N. 2011. Mechanisms of quadriceps muscle weakness in knee joint osteoarthritis: the effects of prolonged vibration on torque and muscle activation in osteoarthritic and healthy control subjects. *Arthritis Res Ther* **13**(5): R151.

Sasaki, K., Neptune, R.R. 2010. Individual muscle contributions to the axial knee joint contact force during normal walking. *J Biomech* **43**(14): 2780-4.

Segal, N.A., Glass, N.A. 2011. Is quadriceps muscle weakness a risk factor for incident or progressive knee osteoarthritis? *Phys Sportsmed* **39**(4): 44-50.

Segal, N.A., Glass, N.A., Torner, J., Yang, M., Felson, D.T., Sharma, L., Nevitt, M., Lewis, C.E. 2010. Quadriceps weakness predicts risk for knee joint space narrowing in women in the most cohort. *Osteoarthritis Cartilage* **18**(6): 769-75.

Silverwood, V., Blagojevic-Bucknall, M., Jinks, C., Jordan, J., Protheroe, J., Jordan, K.P. 2015. Current evidence on risk factors for knee osteoarthritis in older adults: a systematic review and meta-analysis. *Osteoarthritis Cartilage* **23**(4): 507-15.

Sritharan, P., Lin, Y.C., Pandy, M.G. 2012. Muscles that do not cross the knee contribute to the knee adduction moment and tibiofemoral compartment loading during gait. *J Orthop Res* **30**(10): 1586-95.

Waldhelm, A. 2011. Assessment of core stability: developing practical models. *PhD thesis*. Louisiana State University

Waldhelm, A., Li, L. 2012. Endurance tests are the most reliable core stability related measurements. *Journal of Sport and Health Science* **1**(2): 121-8.

Winters, J.D., Rudolph, K.S. 2014. Quadriceps rate of force development affects gait and function in people with knee osteoarthritis. *Eur J Appl Physiol* **114**(2): 273-84.

Received: 7 Jul 2018
Accepted: 28 Nov 2018