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ORIGINAL ARTICLE

Association Between Transversus Abdominis Activity and Pain, Muscle Strength, and Walking Ability After Total Hip Arthroplasty for Osteoarthritis of The Hip

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Abstract

Objective: We investigated whether transversus abdominis activity in patients with hip osteoarthritis (hip OA) changed after total hip arthroplasty (THA). We also investigated the association between post-THA transversus abdominis activity and pain, muscle strength, and walking ability.

Methods: The study subjects, all female, included 24 healthy volunteers and 14 patients diagnosed with hip OA and admitted for unilateral primary THA. We compared the transversus abdominis contraction ratio of the healthy volunteers and the patients with hip OA before and after THA. We investigated the correlation between the transversus abdominis contraction ratio and pain, muscle strength, and walking ability.

Results: The transversus abdominis contraction ratio was significantly lower in patients with hip OA both pre and post-THA than in healthy volunteers. However, there was no significant difference between the pre and post-THA values. The post-THA transversus abdominis contraction ratio was significantly correlated with hip abductor strength on the operated side, knee extension strength on the non-operated side, and maximum walking speed.

Conclusions: In patients with hip OA, the activity of the transversus abdominis decreased after THA, and this decline in transversus abdominis activity was associated with reduced leg muscle strength and walking speed. We recommend assessing and treating the transversus abdominis.

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Key words: Osteoarthritis of the hip; total hip arthroplasty; transversus abdominis.

Introduction

Osteoarthritis of the hip (hip OA) is a progressive, painful disease involving the degeneration, abrasion, and breakdown of the hip joint cartilage.[1] Many patients in the advanced or end-stage phases of the disease undergo total hip arthroplasty (THA),[2,3] which is effective in improving physical function and quality of life.[4-6] Impaired leg muscle function is the main focus of evaluation and treatment in patients with hip OA undergoing post-THA physiotherapy.[7-17] The existence of the hip–spine syndrome indicates the close relationship between the hip joint and the lumbar-pelvic region.[18-22] As stable lumbopelvic function affects leg muscle function,[23-26] both hip joint and lumbopelvic function must be evaluated and treated.

The activity of the transversus abdominis often declines in patients with hip OA after they undergo THA. The transversus abdominis is the deepest abdominal muscle, contributing to increase of intraabdominal pressure and stabilization of the lumbar-pelvic region.[27,28] Although previous studies have not found any difference in the thickness of the transversus abdominis between patients with hip OA and healthy volunteers, it has been reported that the echogenicity of rectus abdominis on ultrasonography is significantly higher in hip OA patients.[29] This indicates that

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patients with hip OA have changes in the composition of the hip and the abdominal muscles. Taken in conjunction with another study that found that the rate of change in thickness of the transversus abdominis was lower in patients with hip OA than in healthy volunteers, it is suggested that the activity of the transversus abdominis may be reduced.[30)] Stability of the trunk or lumbopelvic region refers to the ability to control the position and motion of the trunk to allow optimum production, transfer and control of force and motion to the terminal segment by the activity of the muscles of the trunk or lumbopelvic region during various motions[31)]. Conversely, instability of the trunk means a lack of this ability. These are assessed by electromyography[27)] and clinical tests.[32,33)] Studies involving healthy volunteers[24,25)] have shown that when the stability of the lumbar-pelvic region is increased by the greater activity of the transversus abdominis, the activity of the muscles around the hip and knee joints also increases. In addition, the transversus abdominis also contributes to the stability of the trunk during walking by coordinating with the external and internal oblique muscles of the abdomen,[34)] thereby enhancing the walking speed and muscle activity.[28,35,36)] The studies described above suggest that transversus abdominis activity may decrease in patients with hip OA. However, the association between the transversus abdominis activity and pain, muscle strength, and walking ability in patients with hip OA following THA is yet to be elucidated. If the transversus abdominis activity decreases after THA, trunk instability may persist, affecting leg movement. Thus, a decrease in transversus abdominis activity may affect the pain, muscle strength, and walking ability of patients with hip OA after THA.

We hypothesized that the activity of the transversus abdominis is lower in patients with hip OA than in healthy individuals and that it remains low after THA. We also considered that the activity of the transversus abdominis might be associated with pain, muscle strength, and walking ability post-THA. This study aimed to investigate whether the activity of the transversus abdominis in patients with hip OA decreased after THA and the association of transversus abdominis activity with post-THA pain, muscle strength, and walking ability.

Methods

1) Subjects

This prospective, cross-sectional study was conducted at the Fukushima Medical University Hospital between February 2018 and May 2021. The study comprised patients with hip OA and healthy volunteers. The inclusion criteria for the patients with hip OA were female sex, age 40–80 years, diagnosis of hip OA in Fukushima Medical University Hospital, and admission for unilateral primary THA. The exclusion criteria for hip OA patients comprised disease of the opposite hip (end-stage coxarthrosis), previous orthopedic surgery of the leg, abdominal or lumbar surgery within the last 10 years, lumbar or leg symptoms at sites other than the operated hip, previous central neurological disease, inability to walk, inability to understand or practice abdominal drawing-in maneuver exercises, body mass index (BMI) ≥30 kg/m^2, and an absence of data required for the study.

The inclusion criteria for the healthy volunteers comprised female sex, age 40–80 years, good health, and willingness to participate in the study. The study subjects were either the employees of the Fukushima Medical University Hospital or the external organizations working at Fukushima Medical University Hospital. The exclusion criteria were abdominal or lumbar surgery within the previous 10 years, symptoms of lumbar disease, inability to understand or practice abdominal drawing-in maneuver exercises, BMI ≥30 kg/m^2, and an absence of data required for the study. The volunteers were recruited using the purposive sampling method (classical method), and the study was announced on posters displayed within the hospital.

Before signing the consent form, the participants were given verbal and written information regarding the study objectives and methods. This study was approved by the Fukushima Medical University Institutional Review Board (reference number 29237) and the Institutional Review Board of the Graduate School of Health Sciences of Hirosaki University (reference number 2021-040).

2) Collection of basic data and measurement of the transversus abdominis contraction ratio

We collected data on age, height, weight, BMI, Japanese Orthopedic Association (JOA) stage, and surgical procedure from medical records.

We measured the transversus abdominis contraction ratio of the patients with hip OA and the healthy volunteers. The measurements were performed twice, preoperatively and 12 weeks postoperatively, for the patients with hip OA. A diagnostic ultrasound unit (MyLab Five, Esaote, Tokyo, Japan) was used for transversus abdominis contraction ratio measurements. The side on which the transversus abdominis was measured was the operated side for the patients with hip OA and the side of the foot used to kick a ball by the healthy volunteers. The diagnostic ultrasound unit image display mode was set to B mode, and scanning was conducted at 15 MHz with a linear probe. Measurements were made while the patient was in the supine position, with the pelvis in the neutral position. Visual inspection and palpation were used to confirm the neutral position of the pelvis, in which the distance between two lines running vertically from the anterior and posterior superior iliac spines to the floor was no greater than two fingers' breadth. In patients with restricted hip

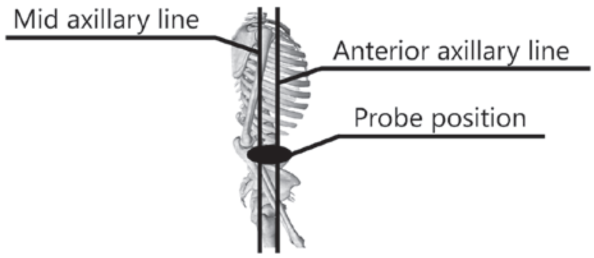

Figure 1 Site of measurement of transversus abdominis

extension, the joint angles of the hips and knees were adjusted until a neutral position of the pelvis was achieved.[30] The measurement site in the transversus abdominis was on the midaxillary line in the center of the space between the lower margin of the ribs and the iliac crest, with the middle portion of the probe positioned perpendicular to the midaxillary line (Figure 1).[37-42] If the transversus abdominis could not be scanned at this site, the probe was moved to the anterior axillary line, and the muscle was imaged at that location.[23,43,44] To standardize the position of the transversus abdominis, its medial part was displayed on the right-hand side of the screen.[38] Resting muscle thickness for the transversus abdominis was defined as the thickness of the muscle at the end of expiration. In contrast, contracted muscle thickness was defined as the thickness of the muscle during the abdominal drawing-in maneuver. Each of these was measured three times (Figure 2). The abdominal drawing-in maneuver has been reported as ideal for evaluating the contraction of the transversus abdominis alone,[39] and was conducted by instructing the subjects to "Pull in your stomach so that it is concave." The muscle thickness at the point of maximum protrusion was measured on still images using the Image-J image analysis software (Version 1.51k, National Institutes of Health, USA). Muscle thickness was measured three times on each image, and the mean value was used to calculate the transversus abdominis contraction ratio, as shown below.[37,38,40,41,44]

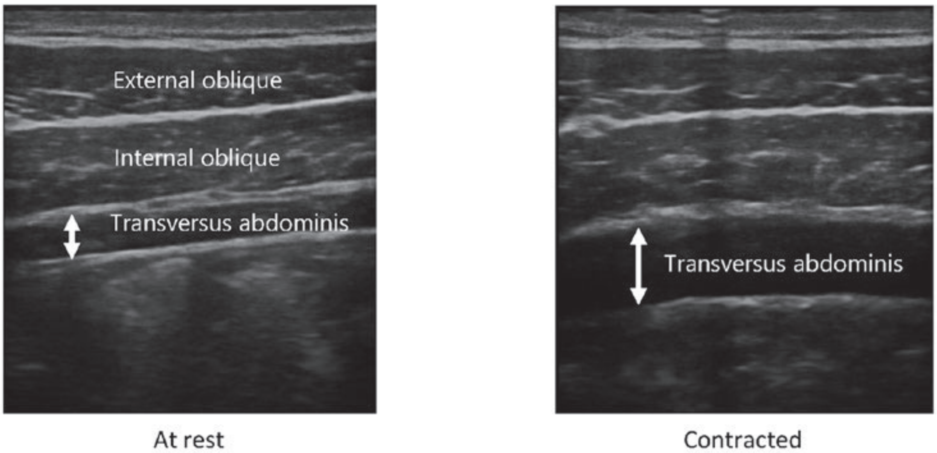

Figure 2 Muscle thickness of the transversus abdominis at rest and during contraction

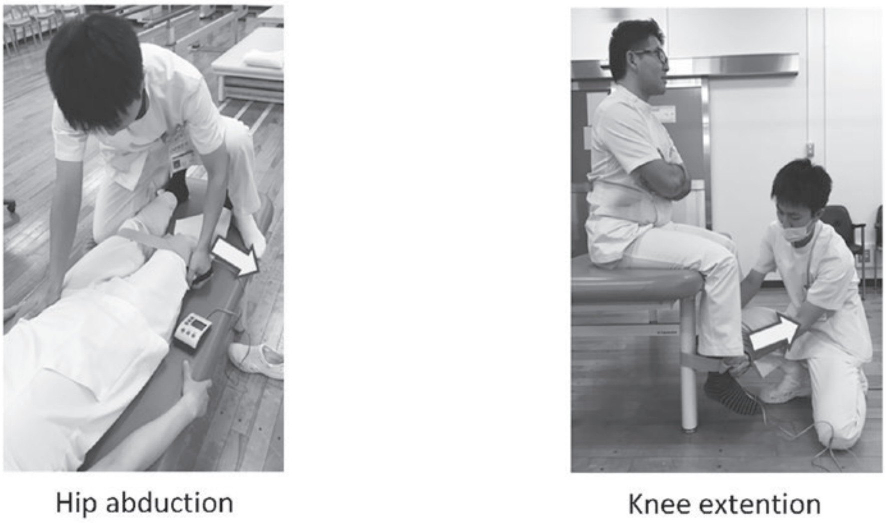

Figure 3 Measurement of lower limb muscle strength
Arrows indicate the direction of the force exerted by the patient.

Transversus abdominis contraction ratio (activity ratio) = Transversus abdominis thickness contracted / Transversus abdominis thickness at rest

The transversus abdominis contraction ratio expresses the activity and capacity for contraction of the transversus abdominis.[45)]

3) Pain, muscle strength, and walking ability measurement/evaluation

We measured the following indices in patients with hip OA 12 weeks postoperatively.

(a) Pain

The pain was investigated by measuring it during walking using a Numerical Rating Scale (NRS).[46,47)] Patients were also asked about the location of the pain.

(b) Leg muscle strength measurements

Isometric strength of hip abductor and knee extensor was measured using a hand-held dynamometer (Power Track II MMT COMMANDER, MF-104AA, Nihon Medix Matsudo, Japan) (Figure 3).[48-52)] Hip abductor strength was measured with the subject in the supine position with the hip joint in the neutral position for both hip abduction and rotation, and the investigator holding down the pelvis on the opposite side. The subject grasped the sides of the bed with both hands. The sensor was placed on the distolateral side of the thigh (5 cm proximal to the knee joint). Knee extensor strength was measured with the subject sitting on the edge of a chair with the knees in a position of 90° extension. The subject kept both arms crossed in front of their chest. The sensor receiving the muscle output was placed on the anterior surface of the distal part of the lower leg. The arm lengths were the distances from the center of the hip or the knee joint to the sensor's center, ascertained with a measuring tape. After the subject had exerted maximum isometric muscle strength once for practice purposes, maximum isometric muscle strength was measured twice consecutively for approximately 3 seconds, first on the non-operated side and then on the operated side, with an interval of approximately 30 s between measurements on the same side and approximately 1 min between measurements on the left and right sides. The mean of the two measurements was calculated and converted to torque/body weight ratio [Nm/kg: force at the sensor site (N) × arm length (m) /body weight (kg)].

(c) Maximum walking speed measurement

Maximum walking speed was measured by asking the subject to walk in a straight line for a distance of 14 m, comprising a 10 m measurement zone with 2 m approaches at either end.[53] The subject was encouraged to exert maximum effort while walking. They were permitted to use a cane if one was required. A stopwatch was started when one of the subject's feet touched or passed over the measurement start line, and it was stopped when they crossed the finish line. After one practice session, the test was conducted twice, and the mean value, expressed as speed in m/s, was calculated.

4) Statistical analysis

A two-sample t-test or Mann-Whitney test was used to compare the transversus abdominis contraction ratio of the healthy volunteers and the patients with hip OA. A paired t-test was performed to compare the pre-and post-THA values in patients with hip OA patients. The association between the transversus abdominis contraction ratio and post-THA physical function in patients with hip OA was investigated by using Pearson's or Spearman's correlation coefficient. The statistical software used was the R software version 4.0.2 (CRAN, freeware), with $p < 0.05$ regarded as significant in all tests.

Results

After subject selection, the study population included 24 healthy volunteers and 14 patients with hip OA (Figure 4). There was no significant difference in age, height, weight, or BMI between the healthy volunteers and the patients with hip OA (Table 1). Measurements made in the healthy volunteers and patients with hip OA pre-and post-THA were found to have no significant difference in terms of resting muscle thickness. However, the thickness of the contracted muscle was significantly lower in the patients with hip OA post-THA compared to the healthy volunteers (Table 2). The transversus abdominis contraction ratio was considerably lower in the patients with hip OA, both pre-and post-THA, than in the healthy volunteers (Table 2). There were no significant differences in pre-THA and post-THA measurements in the patients (Table 2).

Table 3 shows post-THA pain, muscle strength, and walking ability. The post-THA transversus abdominis contraction ratio was significantly correlated with hip abductor strength on the operated side, knee extension strength on the non-operated side, and maximum

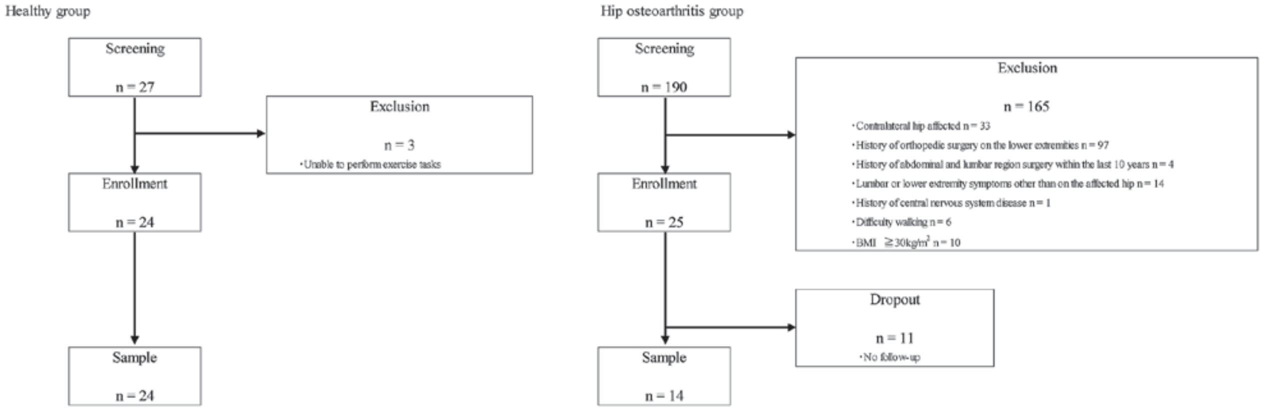

Figure 4 Flowchart of subject selection

Table 1. Characteristics of the healthy volunteers and the patients with hip OA

	Healthy group (n=24)	Hip osteoarthritis group (n=14)	p-value
Age (years)	58.6 ± 7.6	63.0 ± 7.5	0.090
Height (cm)	154.4 ± 4.2	154.2 ± 5.7	0.921
Weight (kg)	51.0 ± 6.1	56.3 ± 9.2	0.072
BMI	21.4 ± 2.5	23.7 ± 3.6	0.051
JOA stage, n		End-stage 14	
Surgical procedure, n		Posterior approach 14	

JOA, Japanese Orthopedic Association
BMI, Body Mass Index

Table 2. The transversus abdominis contraction ratio in the healthy volunteers and the patients with hip OA

	Healthy group (n=24)	pre THA group (n=14)	post THA group (n=14)	Healthy group vs pre THA group		Healthy group vs post THA group		pre THA group vs post THA group
				p-value	effect size (r)	p-value	effect size (r)	p-value
TrA thickness at rest (cm)	0.29 ± 0.09	0.32 ± 0.10	0.30 ± 0.09	0.600		0.792		0.855
TrA thickness contracted (cm)	0.50 ± 0.13	0.42 ± 0.11	0.41 ± 0.12	0.075		<0.05	0.323	0.757
TrA contraction ratio	1.74 ± 0.36	1.35 ± 0.25	1.37 ± 0.27	<0.01	0.512	<0.01	0.488	0.848

TrA, Transversus Abdominis; THA, Total Hip Arthroplasty
Mann-Whitney test (Healthy group vs pre THA group ; Healthy group vs post THA group)
Wilcoxon test (pre THA group vs post THA group)

walking speed (Table 4).

Discussion

This study showed that the transversus abdominis contraction ratio was significantly lower in patients with hip OA before and after THA compared to that in the healthy volunteers. The post-THA transversus abdominis contraction ratio was also significantly correlated with hip abductor strength on the operated side, knee extension strength on the non-operated side, and maximum walking speed.

A previous study that used a diagnostic ultrasound unit to measure the resting muscle thickness of the transversus abdominis found no significant difference between patients with Kellgren/Lawrence grade 3–4 hip OA and healthy individuals.[29] Another cross-sectional study investigated the transversus abdominis in patients with end-stage hip OA and healthy individuals.[30] Although there was no significant difference in resting muscle thickness, muscle thickness and the ratio of change during the

Table 3. Pain, muscle strength, and walking ability in patients with hip OA

	Value at postoperative 12 weeks
Gait pain (NRS)	0.3 ± 0.7
Pain site, n	
Groin	-
Anterior inferior iliac spine	-
Anterior femoral	-
Lateral femoral	-
Buttocks	-
Surgical wound	4
Non-operative hip abductor strength (Nm/kg)	0.65 ± 0.21
Operative hip abductor strength (Nm/kg)	0.52 ± 0.17
Non-operative knee extensor strength (Nm/kg)	0.81 ± 0.29
Operative knee extensor strength (Nm/kg)	0.76 ± 0.24
Maximum Walking Speed (m/s)	1.51 ± 0.25

NRS, Numerical Rating Scale

Table 4. Relationship between transversus abdominis contraction ratio and pain, muscle strength, and walking ability in patients with hip OA

	Gait pain	Non-operative hip abductor strength	Operative hip abductor strength	Non-operative knee extensor strength	Operative knee extensor strength	Maximum Walking Speed
TrA contraction ratio	$r_s = -0.330$	r = 0.508	r = 0.559	rs = 0.643	r = 0.479	r = 0.666
	p = 0.247	p = 0.063	$p < 0.05$	$p < 0.05$	p = 0.082	$p < 0.01$

TrA, Transversus Abdominis

r : Pearson's product moment correlation coefficient
r_s : Spearman's rank correlation coefficient

abdominal drawing-in maneuver were significantly lower in patients with end-stage hip OA. However, no previous study has investigated changes in the thickness of the transversus abdominis after THA.

A novel finding in this study was that the transversus abdominis contraction ratio decreased following THA in patients with hip OA. This result proved our hypothesis. The transversus abdominis stabilizes the trunk and affects leg movements and walking.[26, 35)] Assessing and treating the transversus abdominis is thus very important in patients with hip OA. The fact that the transversus abdominis contraction ratio was significantly lower in patients with hip OA than in the healthy volunteers also suggested that activating the transversus abdominis may be difficult. Hip OA patients avoid physical activity due to joint pain, resulting in lower limb muscle weakness. As a result, the amount of physical activity decreases.[54)] Because the transversus abdominis is closely related adjacent to the hip joint, the activity of the transversus abdominis may have decreased as a result of hip pain, functional decline, and decreased physical activity. Although THA improved joint deformity and symptoms, the preoperative decreased activity of the transversus abdominis may have remained after surgery.

Regarding the association between the transversus abdominis contraction ratio and muscle strength and walking ability in patients with hip OA, when the transversus abdominis contraction ratio was low, then hip abduction strength on the operated side, knee extension strength on the non-operate side, and maximum walking speed were also low. Decreased activity of the transversus abdominis means decreased trunk stability. The hip abductor muscle originates from the pelvis.[55)] When trunk stability is not achieved, lower extremity muscle performance originating from the trunk is reduced.[24)] Therefore, the decrease in trunk stability due to decreased activity of the transversus abdominis may have influenced the decrease in the strength of the operated side hip abductor muscles. The reverse can also be true. Patients with end-stage Hip OA have decreased strength of the abductor muscles[56] and decreased activity of the transversus abdominis.[30] It has also been reported that weakness of the hip abductor muscles remains after THA.[57] Therefore, it is possible that the decreased activity of the transversus abdominis, which was present before THA, may remain as well as the decreased strength of the operated side hip abductor muscles. The knee extensor muscles originate from the pelvis, as well as the hip abductor muscles.[58] Therefore, the decreased stability of the trunk due to decreased activity of the transversus abdominis may have influenced the decreased strength of the knee extensor muscles on the non-operated side. In general, knee extensor strength is necessary for various physical activities, especially walking.[59] These physical activities also require activity of the transversus abdominis.[28,36] Patients with low physical activity may have low knee extensor strength and low transversus abdominis activity. In other words, patients who have decreased knee extensor strength on the non-operated side after THA may have been less physical activity preoperatively and have decreased activity in the transversus abdominis muscle, which may remain after THA. In an interventional study in healthy volunteers[24,25] in which they were asked to contract the transversus abdominis and internal oblique muscles and perform leg movements, the activity of the muscles around the hips and knees was reportedly higher compared with when they performed leg movements without contracting those muscles. In another study of healthy volunteers,[28] the activity of the gluteus maximus during walking increased when they wore a pelvic belt that substituted for transversus abdominis contraction compared with when they were not wearing the belt. These reports also indicate that the transversus abdominis may reflect the stability of the trunk and be deeply involved with the muscles around the hips and knees. The transversus abdominis also has a sustained effect on stabilizing the trunk during walking,[34] and its activity reportedly increases with increased walking speed.[28,36] An interventional study in patients with degenerative lumbar kyphosis[60] also found that percutaneous electrical stimulation of the multifidus, transversus abdominis, and internal oblique muscles increased walking speed compared with the absence of such stimulation. These results indicate that increased transversus abdominis activity stabilizes the trunk and increases the walking speed. Because walking speed has an impact on levels of activity in everyday life, interventions to increase the activity of the transversus abdominis, in addition to the leg muscles, may be effective for patients whose walking speed is slow. However, walking is related to a variety of factors. In the present study, patients with low transversus abdominis contraction ratio also showed lower limb muscle weakness. In general, walking speed is related to lower limb muscle strength.[59] It should be noted that transversus abdominis contraction ratio is not the only factor that affects walking speed and may include lower extremity muscle strength and other factors.

This study has three main limitations. The first is selection bias. Because our subjects were patients with hip OA who had been hospitalized for surgery, their transversus abdominis activity may have been lower than that of patients with hip OA in general. The healthy volunteers were employed at the lead author's hospital. The possibility of them being more health-conscious than regular healthy individuals cannot be discounted. The second is that the examiner who measured muscle thickness by diagnostic ultrasound unit was not blinded to the subjects other data or information. This could have affected the results as an information bias. The third is that we did not adjust for confounders in our analysis of the effect of the transversus abdominis contraction ratio on physical function, nor did we analyze its causal relationship. This research must be extended in the future to encompass the use of matching and multivariate analysis.

Conclusions

We investigated whether the activity of the transversus abdominis decreases in patients with hip OA after THA and found that the transversus abdominis contraction ratio was significantly lower in patients with hip OA both pre- and post-THA than in healthy volunteers. The post-THA transversus abdominis contraction ratio was also significantly correlated with hip abductor strength on the operated side, knee extension strength on the non-operated side, and maximum walking speed. In patients with hip OA, the activity of the transversus abdominis decreased after THA, and this decline in transversus abdominis activity was associated with leg muscle strength and walking speed. We recommend assessing and treating the transversus abdominis to improve muscle strength, walking ability.

Conflicts of interest

The authors have no conflicts of interest to disclose with respect to this study.

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