Evaluation of skeletal muscle activity while walking in symptomatic and asymptomatic patients with knee osteoarthritis using positron emission tomography

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INTRODUCTION: Despite the presence of femoral or tibial deformities on radiographic images, asymptomatic knee osteoarthritis (knee OA) may indicate that bone deformities are not necessarily a factor in knee pain. However, the factors determining symptomatic or asymptomatic knee OA remain unclear. Several studies on gait in patients with knee OA have evaluated motion and skeletal muscle activity using electromyography (EMG), which is the gold standard technique for evaluating skeletal muscle activity. However, this study focused on using positron emission tomography-computed tomography (PET-CT) with 18F-fluorodeoxyglucose (FDG) to evaluate whole-body skeletal muscle metabolism. Understanding the patterns of lower extremity skeletal muscle metabolism during gait is important to define the role of each body part and consider rehabilitation to obtain a pain-free gait. This study aimed to evaluate whole-body skeletal muscle metabolism during gait exercise in symptomatic and asymptomatic patients with knee OA using FDG-PET-CT. Based on previous EMG-based studies, we hypothesized that skeletal muscle metabolism would relatively decrease around the quadriceps muscles during gait exercise in the symptomatic group.

METHODS:

Voluntary applicants with unilateral or bilateral mild-to-moderate (Kellgren/Lawrence (K/L) grades between 1 - 2) knee OA were enrolled in the study. The K/L grade of individuals with knee OA was defined using radiographs of the identified osteophytes and narrowing of the joint space in the standing position.

Patients with complaints in the lower extremities, except for knee pain, diabetes, history of medical conditions that prevented exercise testing, and could not provide written consent were excluded. This study was approved by the ethics committee of our hospital, and all patients provided informed consent before participation. A total of 22 participants (11 males and 11 females) who understood the study were included. They were divided into two groups according to symptomatic (10 participants) or asymptomatic (12 participants) knee OA. Table 1 presents the characteristics of the participants. The participants walked on a treadmill for 10 min at 3.5 km/h. Subsequently, 37 MBq of FDG was injected intravenously, and the participants again walked on a treadmill for 10 min at 3.5 km/h, followed by 25 min of rest in the sitting position. Participants then underwent PET to detect FDG accumulation. Regions of interest (ROI) were manually segmented into 38 skeletal muscles from the pelvis to the foot. An experienced orthopedic specialist defined all the ROI using plain CT images. The standardized uptake value (SUV) was calculated via overlapping the defined ROI and fusion images to quantitatively examine the FDG uptake of the muscle tissue per unit volume using the following equation: SUV = {mean ROI count (counts per second [cps]/pixel) × calibration factor (cps/Bq)}/ {injected dose (Bq)/body weight (g)}. ROI was defined for the right and left sides of the 38 skeletal muscles (Figure 1), and the mean SUV was calculated using the following equation: mean SUV = SUV/muscle area. All statistical analyses were performed using the Statistical Package for the Social Sciences software package version 25 (IBM Corp. Armonk, New York). Data are presented as means and standard deviations.

RESULTS:

Table 2 shows the mean SUVs of the symptomatic and asymptomatic groups and the P-values with effect size for all muscles. The mean SUVs of the symptomatic and asymptomatic groups were normally distributed, allowing the use of t-tests. The mean SUVs of the hip abductor muscle were lower in the symptomatic group than in the asymptomatic group and displayed a medium effect size (gluteus medius P=0.281; d=0.482, gluteus minimus P=0.079; d=0.793). The mean SUVs of quadriceps muscle was higher in the symptomatic group than in asymptomatic group and displayed either a small or medium effect size (rectus femoris P=0.454; d=0.299, vastus lateralis P=0.303; d=0.392, vastus intermedius P=0.300; d=0.434, vastus medialis P=0.191; d=0.597).

DISCUSSION AND CONCLUSION:

This is the first study to evaluate muscle activity during treadmill walking in patients with knee OA. There was a trend toward less hip abductor muscle activity in symptomatic knee OA. Hip abductor muscle activity may be associated with knee symptoms. Contrary to our expectations, quadriceps activity during treadmill walking tended to be higher in the symptomatic group than in the asymptomatic group.

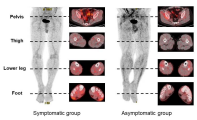

Figure 1. Representative positron emission tomography images of symptomatic, asymptomatic and control groups.

Table 1. Physical characteristics in symptomatic and asymptomatic groups

	Symptomatic group (n = 10)	Asymptomatic group (n = 12)	P value
Sex (male/female)	3/7	8/4	
Age (yr)	66.1±5.6	63.4±6.1	0.301
Height (cm)	160.2±8.3	163.8±7.2	0.288
Weight (kg)	62.6±10.9	62.8±10.8	0.963
BMI (kg/m^2)	25.9±4.4	23.3±3.3	0.137
K–L grade (0 / I / II)	0/2/8	0/10/2	-

BMI, body mass index; K-L, Kellgren-Lawrence
Data are displayed as a mean ± standard deviation.

Table 2a. Comparison of mean SUVs in symptomatic and asymptomatic groups (Pelvis and thigh)

Body area	Muscles	Mean SUVs		P value	Effect size
		Symptomatic group (n = 10)	Asymptomatic group (n = 12)		
Pelvis	Iliacus	1.08±0.17	0.87±0.16	0.036	0.826
	Obturus internus	1.02±0.43	0.95±0.42	0.536	0.270
	Obturus externus	1.11±0.45	1.33±0.56	0.261	0.402
	Gluteus minimus	1.11±0.26	1.01±1.16	0.776	0.250
	Piriformis	0.62±0.22	0.66±0.25	0.736	0.023
	Gluteus maximus	0.83±0.15	0.93±0.14	0.231	0.614
	Gluteus minimus	0.90±0.25	1.03±0.15	0.035	0.724
	Tensor fasciae latae	0.94±0.27	0.93±0.24	0.925	0.047
Thigh	Rectus femoris	0.65±0.11	0.57±0.09	0.404	0.356
	Vastus lateralis	0.85±0.13	0.93±0.08	0.502	0.762
	Vastus intermedius	0.84±0.20	0.77±0.11	0.938	0.434
	Vastus medialis	0.86±0.21	0.82±0.08	0.542	0.242
	Sartorius	0.82±0.25	0.69±0.15	0076	0.670
	Gracilis	0.84±0.25	0.77±0.20	0.666	0.322
	Semimembranosus	0.93±0.11	0.89±0.44	0.936	0.124
	Semitendinosus	0.78±0.16	0.77±0.22	0.904	0.056
	Biceps femoris	0.67±0.25	0.69±0.41	0.955	0.026
	Adductor complex	0.87±0.17	0.88±0.15	0.918	0.062

Data are displayed as a mean±standard deviation.

Table 2b. Comparison of mean SUVs in symptomatic and asymptomatic groups (Lower leg and foot)

Body area	Muscles	Mean SUVs		P value	Effect size
		Symptomatic group (n = 10)	Asymptomatic group (n = 12)		
Lower leg	Popliteus	1.09±0.23	1.09±1.21	0.972	0.742
	Tibialis anterior	1.09±0.68	1.79±1.22	0.207	0.719
	Extensor hallucis longus	1.57±1.04	1.93±0.68	0.621	0.545
	Extensor digitorum longus	1.61±0.54	1.70±0.39	0.919	0.247
	Peroneus longus	1.30±0.55	1.29±0.52	0.937	0.133
	Peroneus brevis	1.12±0.54	1.18±0.56	0.730	0.111
	Flexor digitorum longus	1.19±0.51	1.23±0.56	0.967	0.362
	Tibialis posterior	1.39±0.62	1.25±0.53	0.520	0.338
	Flexor hallucis longus	1.35±0.45	1.09±0.44	0.307	0.556
	Triceps surae	1.16±0.56	1.29±0.52	0.944	0.556
Foot	Abductor hallucis	1.76±0.53	2.04±0.83	0.551	0.402
	Quadratus plantae	1.25±0.56	1.59±0.56	0.256	0.606
	Flexor digitorum brevis	1.91±1.04	2.83±1.91	0.216	0.722
	Extensor digitorum brevis	1.79±0.58	1.93±0.64	0.660	0.230
	Flexor hallucis brevis	2.15±0.61	2.12±0.52	0.997	0.042
	Adductor hallucis	2.19±1.13	2.21±1.62	0.991	0.902
	Interosseus	1.78±1.08	1.64±0.46	0.938	0.302

Data are displayed as a mean±standard deviation.