Hip flexor muscle dysfunction during walking at self-selected and fast speed in patients with aortoiliac peripheral arterial disease

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ABSTRACT

Objective: Intermittent claudication aggravates physical function and is associated with an increased risk of death in patients with peripheral arterial disease (PAD). Previous studies on kinetic parameters (joint moment and power) of lower limbs in these patients have largely focused on the decline in the ankle plantar flexor moment and power at self-selected (SS) walking speed, which may not be an optimal condition to induce claudication pain. In the present study, we investigated the abnormalities in joint kinetic parameters in patients with PAD at both SS and at fast walking speeds.

Methods: We recruited 16 patients with aortoiliac PAD (4 unilateral and 12 bilateral) and 10 healthy controls. The participants were instructed to walk at SS and fast speeds along a 7-meter walkway embedded with a force plate. Spatiotemporal parameters and joint kinetic parameters of the lower limbs during the stance phase were recorded using a three-dimensional motion analysis device.

Results: Compared with the controls, patients with PAD showed a significant reduction in their walking speed, step length, stride length, and cadence. Further, a reduction in peak hip flexor moment at fast walking speed and in peak hip flexor generation power was observed in both modes of walking. However, no significant between-group differences were observed for the peak ankle plantar flexor moment or power at either walking speed. Multiple regression analysis showed peak hip flexor generation power was a strong contributor to reduction at both SS and fast walking speeds in patients with PAD.

Conclusions: Patients with aortoiliac PAD walk slowly and show reduced kinetic parameters of the hip joint at both SS and fast walking speeds. Our results suggest that hip flexor muscles may be a useful target for exercise training in patients with aortoiliac PAD. (J Vasc Surg 2017;66:523-32.)

Peripheral arterial disease (PAD), which is caused by atherosclerosis of the lower limb arteries, affects an estimated 200 million people worldwide.[1] Major risk factors for PAD are diabetes mellitus, smoking, hypertension, hyperlipidemia, and kidney dysfunction.[2] Symptomatic PAD is associated with a poor prognosis, and cardiovascular and cerebrovascular events are major causes of death in these patients.[3] Intermittent claudication is a classic symptom complex in these patients, wherein exercise induces discomfort in the lower limbs, which is relieved on rest. A decline in physical functions, such as physical activity level, lower limb muscle strength, and walking distance and speed, is associated with higher mortality in patients with PAD.[4-7] Walking speed was shown to be a predictor of prognosis in patients with PAD and also in healthy elderly individuals.[7,8] Further, an increase in walking speed was associated with improved prognosis in the healthy elderly population.[9]

Walking speed is related to kinetic parameters, such as joint moment and power of the lower limbs, which are measured by three-dimensional motion analysis.[10] Joint moment refers to the muscle force required to rotate the limb around a joint[11] and is calculated as the product of the muscle force and the distance from the center of joint. Positive joint moment refers to extension or plantar flexion, and negative joint moment refers to flexion or dorsiflexion. Joint power, which is defined as the rate of work, is calculated as the product of the joint moment and the angular velocity of the joint. Positive joint power implies a concentric muscle contraction, and negative joint power implies an eccentric muscle contraction. Joint power can help assess the gait characteristics of patients with hemiplegia, patients with below-knee amputation, and those with postsurgical osteoarthritis.[12-14]

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Gait cycle is divided into several phases (Fig 1). Because intermittent claudication in patients with PAD is commonly associated with pain in the calf muscles,[15] previous studies have focused on reduction in ankle plantar flexor (AP) moment and positive power (A2).[16-18] However, the accurate joint kinetic parameters of lower limbs were not evaluated in PAD patients because they might walk slowly at a self-selected (SS) speed to avoid claudication pain. Kinetic parameters during fast walking have been used to evaluate potential gait ability in patients with hemiplegia, diabetes mellitus, and elderly individuals with low physical performance.[19-21] Investigating kinetic parameters and spatiotemporal parameters that include walking speed, step, and stride length at a fast walking speed is important to verify essential joint dysfunction in PAD patients. In addition, the study populations in previous studies evaluating PAD patients showed significant heterogeneity with respect to arterial stenoses vs occlusions.[16,17] Lesion heterogeneity may alter the kinetic parameters of lower limbs affected by ischemic skeletal muscles.

We hypothesized that walking at fast speed might enhance the reduction of AP moment and A2 in PAD patients. Thus, to clarify gait characteristics in PAD, we investigated the spatiotemporal and kinetic parameters during walking at SS and fast speed in patients with aortoiliac PAD.

ARTICLE HIGHLIGHTS

- **Type of Research:** Prospective single-center cross-sectional study
- **Take Home Message:** Sixteen patients with aortoiliac peripheral arterial disease walked slower and showed reduced kinetic parameters of the hip joint compared with controls.
- **Recommendation:** The authors suggest that hip flexor muscles might be a focus for exercise training in patients with aortoiliac atherosclerotic occlusive disease and claudication.

METHODS

Study participants. We recruited 16 individuals (14 men and 2 women) with isolated aortoiliac PAD. Both limbs were involved in 12 patients and only one limb (unilateral) was involved in four; thus, 28 limbs affected by claudication were included (Table I). The inclusion criteria for PAD were (1) resting ankle-brachial index (ABI) <0.9, (2) symptomatic intermittent claudication, and (3) aortoiliac disease with stenoses >50% or occlusion. The aortoiliac lesions were identified by computed tomography angiography or ultrasound imaging.

The study excluded patients with critical limb ischemia and those with limitations to walking for reasons other than claudication such as pulmonary, cardiac, nervous, and musculoskeletal disease. These patients were identified from their medical history and results of a treadmill walking test used in conjunction with near-infrared spectroscopy. The wave pattern and time for recovery of oxygenated and deoxygenated hemoglobin from the end of the treadmill test to baseline was evaluated by near-infrared spectroscopy to investigate whether the claudication occurred as a result of ischemia.[22] The probes were attached to the bilateral medial head of the gastrocnemius muscle. The treadmill test was performed at a 12% grade and at a speed of 0.67 m/s. Pain-free walking distance (PWD) and maximum walking distance (MWD) were recorded. Ten individuals were excluded for the following reasons: femoropopliteal disease (n = 3), multiple diseases (n = 2), hemiplegia (n = 1), lumbar spinal canal stenosis (n = 1), chronic obstructive pulmonary disease (n = 1), fracture of the femoral neck (n = 1), and total knee replacement (n = 1).

Ten healthy controls (20 limbs) were recruited from the community. These individuals were comparable to the patients with PAD with respect to age, height, and body weight. Variables for the 20 control limbs were measured. The ABI in healthy control legs was >1.00.

Written informed consent was obtained from all participants before enrollment. The study protocol was approved by Tohoku University Ethics Committee (approval number: 2015-1-718).

Measurement of gait. Spatiotemporal and kinetic parameters were measured by an eight-camera MAC 3D motion analysis system (Motion Analysis Corporation, Santa Rosa, Calif) at a sampling rate of 120 Hz. Reflective markers were placed on anatomical locations suggested by Data Interface File Format (DIFF).[23] Seventeen reflective markers were attached to the following anatomical landmarks: the right and left acromion, anterior and posterior superior iliac spine, greater trochanter, femoral lateral epicondyle, lateral malleolus, fifth metatarsal head, calcaneus, and right angulus inferior scapulae. Four 90- × 60-cm force plates (Anima Corp, Choufu, Tokyo, Japan) were used to collect the ground reaction force at a sampling rate of 1200 Hz.

The participants walked barefoot and wore shorts and sleeveless shirts. Data from five trials were included. First, participants were instructed to walk at SS speed along a 7-m walkway. After completion of the five trials, participants took a break of >5 minutes and were instructed to "walk as fast as you possibly can." If patients felt claudication pain during measurement, the data for that trial were excluded, and the patients were instructed to sit until the resolution of the pain. Mean values of data from the five trials were used for analysis for each limb in stance phase.

Data analysis. All data were low-pass filtered using EVaRT 5.5.4 measurement software (Motion Analysis Corp) with a 20 Hz cutoff frequency. KineAnalyzer (Kissei