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Characteristics of internal oblique muscle activity during walking in healthy and patients with hip osteoarthritis

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Abstract

Background and purpose: In a clinical setting, patients with hip osteoarthritis often complain of trunk instability during the gait, therefore, this study aims to determine the characteristics of left and right internal oblique muscle activities during walking in healthy individuals and patients with hip osteoarthritis (OA).

Methods: Participants included 17 healthy males and 10 (2 males and 8 female) with hip OA. The characteristics of muscle activity in one walking cycle were compared using integrated EMG analysis (% IEMG) and co-contraction index (CCI), which is an index of simultaneous muscles.

Results: The %IEMG and CCI values were greater and less, respectively, in patients with hip OA than in healthy individuals.

Conclusion: It is important to increase the CCI of the left and right internal oblique muscles to improve the trunk stability during walking in patients with hip OA.

Keywords: Inner oblique muscle, Hip osteoarthritis, Co-contraction index

Introduction

The prevalence rate of hip osteoarthritis in Japan is 1.0%–4.3% [1], and the number of patients is estimated to be 1.2–5.1 million. The age of onset is usually 40–50 years, and hip osteoarthritis is considered one of the representative diseases of the hip joint [2]. In hip osteoarthritis, X-ray images often show sclerosis of the sacroiliac joint [3,4], accounting for about 26% of the cases of back pain [5]. In addition, it has been reported that about 20% of patients with osteoarthritis associated with sacroiliac joint pain have sacroiliac joint instability [6]. Thus, hip pain and back pain are closely related and are important characteristics of hip–spine syndrome [7]. From this background, it is increasingly important to adopt a whole-body perspective, in addition to a local perspective, when evaluating and implementing physical therapy in motor disease [8]. Particularly, slight movement of the trunk, which accounts for approximately one-half of the total bodyweight, can have a significant influence on the whole-body balance. Additionally, the trunk is an important foundation, from which the limbs function, and it provides static stability such as attitude retention, and dynamic stability required to perform various motions [9]. Snijders [10] reported that the internal oblique muscle, which is located in the trunk, relieves the shear loading force of the sacroiliac joint, and contributes to stabilization of the pelvis. The pelvic stabilization is further supported by co-contraction of the agonist and antagonist muscles (ie, the right and left internal oblique muscles). However, excessive co-contraction may hinder joint motion, resulting in inefficient muscle function and increased energy consumption during exercise [11]. Conversely, low co-contraction may destabilize the joint, decreasing the supply of biomechanical force, which protects the joint [12]. Over time, this may contribute to problems, such as sacroiliac joint or low back pain. In the present study, surface electromyogram (EMG) analysis was used to determine the muscle activity and co-contraction index (CCI) of the right and left internal oblique muscles during walking in healthy individuals and patients with hip osteoarthritis (OA).

Methods

Participants

The participants included in this study were 17 healthy students

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enrolled at Kyushu University of Nursing and Welfare, and 10 in-patients who were diagnosed with unilateral hip OA, hospitalized for physical therapy. Exclusion criterion for healthy participants was hospital visit for treatment within the past year. Exclusion criteria for patients were individuals diagnosed with an orthopedic disease other than OA, a central nervous system disorder, and respiratory or cardiovascular disease within the past year. The characteristics of included patients are shown in **Table 1**. The research protocol was reviewed and approved by the Kyushu University of Nursing and Social Welfare and the Fukuoka Wajiro Hospital ethics committees (approval number: 26-019, 27-20). In addition, all patients were completely informed of the relevance and purpose of the research, and they provided consent prior to participation.

Table 1. Physical characteristic of participants.

	Healthy (n = 17)	hip OA (n = 10)
Gender (Male/Female)	17 / 0	2 / 8
Affected side (left / right)	—	6 / 4
Age(year)	19.1 ± 0.7	64.2 ± 9.7
Height (cm)	170.3 ± 10.7	163.2 ± 49.0
Weight (kg)	68.4 ± 10.7	53.0 ± 10.1
BMI (kg/m^2)	23.7 ± 7.7	19.3 ± 6.8
JOA score	—	80.9 ± 12.8
K/L score	—	Ⅰ:3, Ⅱ:4, Ⅲ:3

mean±SD
BMI: body mass index
Japanese Orthopaedic Association hip score (JOA score)
K/L score: KellgrenLawrence grade

Gait collection

An EMG signal was obtained from the left and right internal oblique muscles using the blue sensor (P-00-S; Medicotest Inc., Denmark) disposable electrodes. In accordance with a previous study [13], the electrode attachments were positioned 2 cm inside and below the Anterior superior iliac spine (ASIS). Following appropriate skin preparation, to reduce impedance, the electrodes were placed 30-mm apart (measured from their centers) on the muscle belly. Moreover, an earth electrode was attached to the ASIS.

Next, pressure sensors (Tekscan Inc., USA) were attached to the heel of individuals to identify one walking cycle. Specifically, a thin piezoelectric sensor with a sensitivity of 2 kg was used to identify one walking cycle. The piezoelectric element sensor was affixed to the participant's heel, and the participant was allowed to walk. The point when the piezoelectric element sensor voltage was 30 mV was considered as heel contact.

Data analysis

The EMG Master (Mediarea support Inc., Japan) surface electrometer was used to measure the muscle activity using a sampling frequency of 1 kHz. The maximum voluntary contraction (MVC) of the left and right internal oblique muscles was measured over 3 seconds, and the middle 2 seconds of data were used for analyses [14]. Measurements were obtained during 10-m of free walking four times, which did not include any special instructions. All EMG signals were filtered using a high-pass Butterworth filter with a cutoff frequency of 15 Hz to remove motion artifacts. After that, following full-wave rectification processing by spreadsheet software excel (Microsoft Inc., USA), integrated EMG (IEMG) analysis was performed with this software. The stride time on one side was the time from when the heel touched the floor to when the same heel touched the floor again. The stride times for all trials were normalized to a 100% gait cycle to allow direct comparisons across different speeds. The IEMG was processed with normalized data. Five gait cycles were randomly selected from four times walks per subject, and the IEMGs during gait were divided by the muscle activity of MVC, and normalized (%IEMG). The %IEMG at 5% interval of the walking cycle was calculated. Moreover, the mean %IEMG over one walking cycle was calculated from the obtained %IEMG, and the muscle activities of healthy individuals and patients with hip OA were compared. To evaluate the simultaneous contraction of the left and right internal oblique muscles during walking, the CCI was calculated using the method described by Falconer et al [15] (**Figure 1**).

$$I_{emg} = \int_{t1}^{t2} \%IEMG_{right\ IE}(t)dt + \int_{t2}^{t3} \%IEMG_{left\ IE}(t)dt$$

t1-t2: gray area, t2-t3: gray area

$$I_{total} = \int_{t1}^{t3} [\%IEMG_{right\ IE} + \%IEMG_{left\ IE}](t)dt$$

t1-t3: black + white + gray area

$$CCI = \frac{2I_{emg}}{I_{total}} \times 100$$

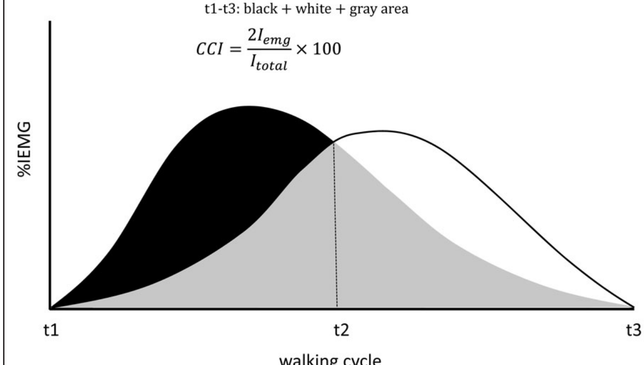

Figure 1. Co-contraction index (CCI).
The black area indicates the right internal oblique muscle (right IE), and the white area indicates the left internal oblique muscle (left IE). The gray area indicates overlapping of the two lines, indicating simultaneous contraction.
CCI was calculated as follows; CCI = 2 gray/(black + white + 2 gray).

Statistical analyses

Statistical analyses were performed using IBM SPSS statistics software version 23 (IBM Inc., Japan). The %IEMG and CCI were assessed using Tukey's test for multiple comparisons after confirming normal distribution of data using Shapiro–Wilk test. Statistical significance was defined as a p-value of <0.05.

Results

In healthy individuals, the right internal oblique muscle activity was 13.2±8.2% at 50% of the walking cycle, which was significantly greater than the value of 7.0% obtained at 100% of the walking cycle. The left internal oblique muscle activity was 13.5±6.0% and 13.4±7.4% at 40% and 50% of the walking cycle, respectively. These values were significantly greater than the values of 7.3±4.4% obtained at 100% of the walking cycle (p<0.05) (**Figure 2**). In patients with unilateral hip OA, there were no significant differences in left or right internal oblique muscle activity values measured during all phase of the walking cycle. The right and left internal oblique muscle activity levels during all phases of the walking cycle were, respectively, 9.7±1.7% and 12.7±2.3% among healthy individuals, 38.2±6.2% and 49.1±10.6% among patients with right hip OA, and 56.2±21.5% and 89.4±20.8% among those with left hip OA; the values for patients with left or right hip OA were significantly greater than in healthy individuals (p<0.01; **Table 2**).

The CCI of the internal oblique muscles during walking was 80.1±7.5% among healthy individuals, 65.7±10.4% among patients with right OA, and 63.4±14.8% among those with left OA. The CCI of healthy individuals was significantly greater than that of patients with either right or left hip OA (p<0.01; **Table 3**).

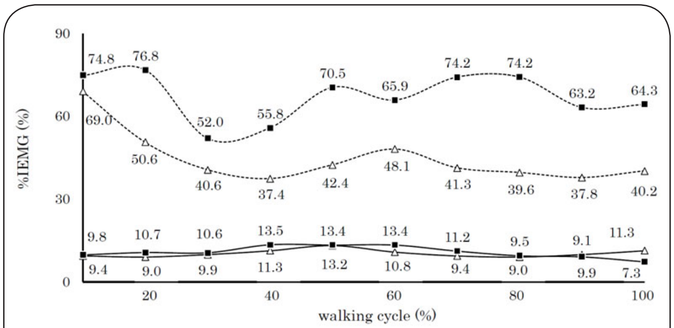

Figure 2.%IEMG during of the walking cycle.
Straight line is shown healthy subject. Dashed line is shown patients with hip OA. Triangle is shown right internal oblique muscle. Square is shown left internal oblique muscle.

Table 2. %IEMG during all phases of the walking cycle.

	healthy	right hip OA	left hip OA
right internal oblique muscle (%IEMG)	9.7 ± 1.7	38.2 ± 6.2 **	56.2 ± 21.5 **
left internal oblique muscle (%IEMG)	12.7 ± 2.3	49.1±10.6**	89.4 ± 20.8**

**: healty VS right or leflt OA, p<0.01, mean±SD.

Table 3. CCI in the internal oblique muscles.

	healthy	right OA	left OA
CCI(%)	80.1 ± 7.2	65.7 ±10.4 *	63.4 ± 14.8 *

*: healty VS right or leflt OA, p<0.05, mean±SD.

Discussion

When performing physical therapy for osteoarthritis patients in a clinical setting, it is important to evaluate and treat from a whole-body as well as a local perspective. Among them, the trunk exists at the center of the body and is an important part that becomes the basis of movement. The spine that constitutes the trunk and the hip joint, which is the adjacent joint, are closely related, and one pathology affects the other pathology [7]. But the functional characteristics of the trunk of patients with hip OA are still unclear. Therefore, in the present study, the EMG analysis were used to determine the muscle activity and CCI of the right and left internal oblique muscles during walking in healthy individuals and patients with hip osteoarthritis.

The results of this study demonstrated greater activity in the left and right oblique muscles in healthy individuals during 50% of the walking cycle phase. This corresponds with the right lower-limb Terminal stance (TSt), a subphase of one walking cycle, in the Rancho Los Amigos walking classification [16], demonstrating the greatest pelvic rotation angle. There were no significant differences in the activities of the left and right internal oblique muscles during each phase of the walking cycle in patients with hip OA; however, their muscle activity levels were significantly greater than those of healthy individuals. Furthermore, in line with this finding, Crawford et al. [17] reported no age difference in the peak activity of the internal oblique muscles during walking in healthy adults. Therefore, the result of this study may be unique to hip OA patients.

Consequently, we considered CCI. The present results demonstrated that the CCI of patients with hip OA was significantly less than that of healthy individuals. This muscular activity during one gait cycle may not be consistent with CCI shown in the previous study, but there is no doubt that the co-contraction functions of at least the left and right internal oblique muscles were reduced. A previous study has reported that the muscle activity time of the internal oblique muscle is prolonged [17], and the CCI of the back-extensor muscles is increased during walking in healthy elderly individuals [18]. Considering these reports, this study showed that the CCI of elderly patients with hip OA was less than, indicating the opposite characteristics to those in healthy elderly individuals. If the CCI is too large, smooth movement is impaired, and if the CCI is too small, joint stability decreases. Therefore, it was suggested that patients with hip OA were unable to maintain adequate CCI of the internal oblique muscles, and the trunk was stabilized by increasing the %IEMG.

This study aimed to compare the muscular activity characteristics of the internal oblique muscles during walking in patients with hip osteoarthritis and healthy individuals. There was a characteristic difference between the two groups. However, the mean age of the healthy individuals was low and the effects of age could not be excluded. In addition, the sex of the patients with hip osteoarthritis could not be unified because of limited clinical data collection. In the future, it will be necessary to conduct joint research at multiple institutions, increase the amount of data, and perform a comparative study that considers age and sex.

Competing interests

The authors declare that they have no competing interests.

Authors' contributions

Authors' contributions	KO	HK
Research concept and design	✓	✓
Collection and/or assembly of data	✓	--
Data analysis and interpretation	✓	✓
Writing the article	✓	✓
Critical revision of the article	✓	✓
Final approval of article	✓	✓
Statistical analysis	✓	--

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