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Exercise Focused on Multiarticular Movement to Improve Muscle Activity During Gait and Single-leg Standing for Participants with Hip Osteoarthritis by Using Electromyogram and Three-dimensional Motion Analysis

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Abstract. [Purpose] We investigated how two types of exercise affect walking and single-leg standing in people with hip osteoarthritis (OA) using surface electromyogram (EMG) and three-dimensional (3D) motion analysis system. [Subjects and Methods] Participants were 18 female diagnosed as having hip OA. We defined hip abduction movement with a tube band wrapped around the thigh as monoarticular- (Mono-) group and the group using resisted joint extension with rotation movement as multiarticular- (Multi-) group. EMG measured the activity of the gluteus maximus (GMax) and gluteus medius (GMed) of affected side during 10 meters gait and single-leg standing on affected side. 3D motion analysis calculated the total locus length (TL) of anterior superior iliac spine (ASIS) of affected side during single-leg standing. These results were analyzed by t-test. [Results] After each exercise, %IEMG of GMax in Mono-group showed a significant decrease during the stance phase. In Multi group, GMax and GMed were significantly increased during the stance phase, whereas GMax was significantly decreased during the swing phase. TL during single-leg standing in Multi group decreased significantly. [Conclusion] These results indicate that exercise focusing on multiarticular movement improves muscle activity and stability in relation to daily activities.
Key words: Hip OA, EMG, Multiarticular exercise

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INTRODUCTION

The Bone and Joint Decade (BJD) 2000–2010 originated from Sweden was officially launched by the World Health Organization in 2000 and there had been many social activities and reports centering on the BJD worldwide, including Japan[1,2)]. Osteoarthritis (OA), included as one of the topics covered by the BJD is a disease caused by biological degeneration of joint cartilage, resulting in joint destruction[3)]. OA is currently regarded as a worldwide health problem[4)].

One of the exercises for strengthening muscle around the hip and knee in individuals with hip OA has involved the use of an open kinetics chain. For example, hip abduction movement has been performed by wrapping a tube band around the distal thigh to provide resistance (Tube exercise). However, movement such as walking requires the cooperation of multiarticular movement. In this

Table 1. Subjects' characteristics

	Subjects	Age (yrs)	Height (cm)	Weight (kg)	JOA score (points)	10-m gait(sec)
Mono group	9	52.3 ± 2.1	154.8 ± 6.2	55.6 ± 7.2	56.0 ± 22.7	9.4 ± 1.5
Multi group	9	55.3 ± 8.5	155.6 ± 6.0	55.7 ± 7.3	59.6 ± 15.1	9.5 ± 2.8

Mean ± SD, JOA score : Japan osteoarthritis hip rating score.

mind, it is unclear to what degree muscle that has been exercised mono- and multiarticulately is linked to daily activities. Our purpose in this study was to examine mono- and multiarticular movement and clarify the effectiveness of each type of exercises for daily activities such as single-leg standing and walking for participants with hip OA.

SUBJECTS AND METHODS

18 females diagnosed as having hip OA were divided into two groups at random. The subjects' characteristics are detailed in Table 1. This study was based on the Declaration of Helsinki, and the purpose of the study was fully explained to the participants before obtaining their consent to participate.

Muscle activities during 10 meters (10-m) gait and single-leg standing were measured by EMG. EMG employed was a Telemyo 2400T (Noraxon USA Inc.) with a sampling rate of 3 kHz. EMG electrodes were Blue Sensor P-00-S (Medicontest A/S.). EMG recording were obtained for the gluteus maximus (Gmax) and gluteus medius (Gmed). Each electrode was placed about 3 cm from the center of another electrode after adequate skin preparation. Collected value of integrated EMG was normalized as a percent of maximum voluntary contractions (%IEMG). %IEMG during 5 gait cycles was split into a stance phase and a swing phase individually. We also considered the differences in gait time among the subjects, standardized the %IEMG of a gait cycle with a 5% class interval width. During single-leg standing, the area of analysis was a second (60 frames) after the leg on the sound side had been raised from the floor and evasion had been completed. The subjects stood in their bare feet with their eyes open, and then stood on the sound leg first, followed by the affected leg. They also stood with their arms lightly crossed in front of the abdomen. We treated %IEMG before exercise as 100%, then, compared the rate-of-increase- decrease with the %IEMG of after exercise during single-leg standing.

3D motion analysis system calculated the TL of color marker attached to the anterior superior iliac spine (ASIS) on the affected side. 3D motion analysis system we chose was Kinema Tracer (KISSEI COMTEC Co. Ltd.). Four cameras were located within a 2×6 meter square and the sampling rate was 60 Hz.

Software for measurement and analysis we used were MyoVideo version 1.5 and MyoResearch version 2.1 (Noraxon USA Inc.). For measuring the TL by 3D motion analysis, 3D calculator version 2.2 and KineAnalyzer version 2.3 (KISSEI COMTEC Co. Ltd.) tracked the length of the color markers.

For statistical analysis, Student's t-test was used for subjects' characteristics whereas paired t-test was used for %IEMG of single-leg standing and 10-m gait with Statflex version 5.0 (Artech Co. Ltd.). The significance level was set at less than 5%.

We defined Tube exercise as Mono-group whereas registed movement of hip extension, abduction, internal rotation (int.rot) with knee extension simultaneously as multiarticular group (Multi-group). The subjects exercised supine, performing 3 sets (10 times in one set), and were allowed sufficient rest between sets.

RESULTS

Subjects' characteristics (Table 1)

There was no significant difference between the groups.

Rate-of-increase-decrease of %IEMG during single-leg standing (Table 2)

Multi-group showed significant increase. {p=:0.019(Glu max), 0.007 (Glu med)}.

TL of ASIS on the affected side during single-leg standing (Table 3)

There was no significant change in the Mono-group whereas significant decrease was found in the x and y axis in the Multi-group (p=0.008).

%IEMG during gait (Table 4, 5)

Table 2. Rate-of-increase-decrease of %IEMG during single-leg standing

		Post-exercise
Mono-group	GMax	83.2 ± 146.8
	GMed	104.3 ± 65.4
Multi-group	GMax	132.3 ± 85.2*
	GMed	141.6 ± 36.6**

NOTE. Values are Mean ± SD. *: p<0.05, **: p< 0.01. %IEMG before exercise was treated as 100% and compared the rate-of-increase-decrease with the %IEMG of after exercise during single-leg standing.

Table 3. TL of ASIS on the affected side during single-leg standing

	Axis	Pre-exercise	Post-exercise
Mono-group	x	33.5 ± 20.1	34.6 ± 23.7
	y	50.9 ± 15.3	54.6 ± 30.5
	z	26.5 ± 13.4	24.9 ± 15.4
Multi-group	x	26.1 ± 11.9	14.8 ± 8.1
	y	50.6 ± 16.7	31.8 ± 13.9 **
	z	15.6 ± 5.1	11.2 ± 11.7

NOTE. Values are Mean ± SD. **: p<0.01. Unit is mm.

Table 4. %IEMG of GMax during gait

		Stance phase (%)										Swing phase (%)									
		0~10	10~20	20~30	30~40	40~50	50~60	60~70	70~80	80~90	90~100	0~10	10~20	20~30	30~40	40~50	50~60	60~70	70~80	80~90	90~100
Mono-group																					
Pre-exercise	%IEMG	44.2	36.1	30.1	23.4	23.2	19.1	14.2	9.3	8.7	9.4	7.6	7.5	6.9	7.9	11.9	12.6	14.9	24.3	29.2	41.1
	SD	34.5	24.1	22.4	14.7	14.6	12.9	6.9	2.5	3.1	4.1	2.9	2.8	1.8	2.3	8.3	7.5	10.7	22.9	20.5	28.8
Post-exercise	%IEMG	39.3	31.4	25.5	25.9	22.6	17.3	11.6	7.4	8.9	9.5	7.9	6.7	8.5	8.2	9.0	12.0	19.3	26.6	38.4	50.5
	SD	32.0	19.8	15.9	20.2	13.7	9.5	6.4	1.5	2.2	3.3	2.8	2.0	1.5	2.9	3.0	7.8	16.7	24.8	19.4	35.9
	p-value	.229	.264	.102	.368	.724	.390	.059	.006	.795	.938	.786	.438	.057	.625	.269	.546	.203	.259	.091	.245
Multi-group																					
Pre-exercise	%IEMG	34.6	25.6	31.7	25.2	21.8	17.1	10.3	8.4	7.5	7.3	7.9	7.4	9.4	10.5	14.6	18.0	28.2	37.1	42.8	50.6
	SD	28.1	16.2	20.8	12.3	11.6	10.6	3.9	2.6	1.3	1.5	2.6	1.6	2.4	2.7	3.8	5.2	8.9	7.2	33.9	47.6
Post-exercise	%IEMG	50.6	29.6	32.3	29.6	25.4	24.0	13.6	10.1	7.8	8.5	7.4	7.4	7.9	9.1	10.1	13.0	15.0	17.2	39.0	48.7
	SD	41.9	15.5	29.5	17.6	14.7	18.7	4.9	1.6	2.8	3.9	2.6	1.6	2.4	2.7	3.8	5.2	8.9	7.2	33.9	47.6
	p-value	.235	.257	.948	.217	.286	.353	.085	.045	.815	.354	.768	.978	.419	.506	.257	.334	.275	.189	.611	.829

Table 5. %IEMG of GMed during gait

		Stance phase (%)										Swing phase (%)									
		0~10	10~20	20~30	30~40	40~50	50~60	60~70	70~80	80~90	90~100	0~10	10~20	20~30	30~40	40~50	50~60	60~70	70~80	80~90	90~100
Mono-group																					
Pre-exercise	%IEMG	42.9	40.4	34.8	31.6	36.1	30.9	18.4	13.9	11.7	13.0	11.3	13.2	14.3	13.4	15.6	16.8	19.9	28.5	37.6	44.4
	SD	18.5	12.7	9.4	9.0	13.2	12.9	6.8	5.9	4.1	6.8	6.0	6.8	9.5	5.1	7.1	8.1	10.2	16.2	20.2	23.6
Post-exercise	%IEMG	46.6	37.9	36.5	35.2	39.4	30.4	17.2	12.4	12.5	13.5	12.3	13.2	12.5	14.6	14.1	17.9	22.3	31.5	43.1	56.2
	SD	14.7	8.9	10.8	10.3	16.5	11.9	5.7	3.6	3.7	7.1	4.2	6.9	6.5	6.4	5.1	8.6	13.6	19.5	22.2	26.7
	p-value	.499	.461	.496	.189	.387	.819	.620	.451	.471	.747	.461	.987	.356	.377	.503	.706	.463	.414	.351	.222
Multi-group																					
Pre-exercise	%IEMG	54.9	40.4	37.4	40.0	35.3	32.0	21.5	17.4	21.6	19.6	16.5	14.4	14.5	19.4	25.1	26.7	28.6	44.2	59.8	63.8
	SD	34.3	30.8	22.1	20.8	14.5	15.5	7.8	9.4	10.6	7.8	7.6	4.4	3.1	12.6	18.4	10.0	13.1	35.9	42.8	44.9
Post-exercise	%IEMG	70.2	47.4	46.8	44.3	43.6	38.5	25.9	17.7	17.3	15.9	16.2	15.0	14.1	17.3	20.1	17.4	20.2	23.8	47.3	64.8
	SD	42.1	36.9	28.9	23.9	16.8	17.3	10.4	4.9	11.3	4.8	4.0	4.2	4.4	4.7	6.2	5.1	6.8	11.5	26.6	35.7
	p-value	.153	.209	.059	.115	.005	.271	.259	.931	.391	.159	.848	.631	.747	.624	.448	.009	.048	.049	.406	.913

GMax (Table 4)

In Mono-group, there was significant decrease when the latter half of stance phase (70–80%, p=0.006). In Multi-group, there was significant increase when the latter half of stance phase (70–80%, p=0.045).

GMed (Table 5)

There was no significant change in Mono-group. In Multi-group, there were significant changes. One was the former half of the stance phase (40–50%, p=0.005) and the other was the latter half of the swing phase {p=0.009 (50–60%), 0.048 (60–70%), 0.049 (70–80%)}.

DISCUSSION

Subject characteristics showed no significant differences between the groups. In this present study, therefore, these characteristics were considered not to have affected the results.

%IEMG during single-leg standing showed significant increases in the Multi-group. On the other hand, in the Mono-group, no significant change was evident. This may indicate that muscle tension around the hip joint in the Multi-group was much higher than in the Mono-group during single-leg standing. One of the dynamics factors required for maintaining stable single-leg standing under gravity is the generation of hip external moment equal to the force generated from the floor (floor reaction force)[5]. As the primary muscles for generating external moment were GMax, GMed and tensor fascia late, it may say increasing %IEMG of these muscles may generate external moment. TL of ASIS on the affected side showed an obvious decrease on the x-axis and a significant decrease on the y-axis in the Multi-group. These results suggested that stability of the pelvis during single-leg standing was considerably increased in Multi-group. It also seems reasonable to conclude that increased %IEMG of these muscles contributed to stabilization during the period of single-leg standing.

In the gait, the plot of %IEMG of both muscles was similar to before exercise in Mono-group whereas abductor muscles of individual with hip OA had a tendency to show high activity during the swing phase, and this seemed to disrupt the contraction rhythm in Multi- group. The characteristics of GMax and GMed indicated a significant increase during the stance phase, compared with a significant and tendentious decrease during the swing phase. These results suggest approximation to a normal contraction rhythm. Exercise in the Multi-group, therefore, was effective for improving muscle activities during single-leg standing and gait that related to various daily activities. Recently, many articles have described the important relationship between multiarticular exercise and dynamic movement in therapeutic exercises[6,7], and the present results supported these suggestions.

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