J. Phys. Ther. Sci. 30: 794–799, 2018

The Journal of Physical Therapy Science

Original Article

Relationship between the change in one-leg standing time due to visual information interception and hip joint internal rotation pattern

Heonsoo Han, RPT, PhD[1)*], Junichiro Kaneko, RPT, PhD[1)], Myungchul Kim, RPT, PhD[2)], Masahiro Ishizaka, RPT, PhD[1)], Akira Kubo, RPT, PhD[1)], Hitoshi Maruyama, RPT, PhD[1)]

[1)] *Department of Physical Therapy, School of Health Sciences, International University of Health and Welfare: 2600-1 Kitakanemaru, Ohtawara City, Tochigi 324-8501, Japan*
[2)] *Department of Physical Therapy, Eulji University, Republic of Korea*

Abstract. [Purpose] To clarify the relationship between the laterality of one-leg standing time (OLST) due to blocking of visual information and the laterality of hip internal rotation (IR) range of motion (ROM). [Subjects and Methods] The study included 101 young healthy male and female students. Hip IR ROM was classified into three patterns using left and right differences. Regarding OLST, differences between the left and right measured values with eyes open and closed were classified into three patterns. The matching rate between hip IR ROM laterality pattern and OLST laterality pattern was examined with eyes open and closed. The matching rate of the OLST laterality pattern with hip IR ROM laterality pattern in an imbalanced group was examined. [Results] A significant difference was observed between eyes open and closed conditions in the matching rates of OLST and Hip IR ROM laterality patterns in the imbalanced group. In the imbalanced group, the pattern on the side where the Hip IR is greater changes to coincide with the pattern on the side where the OLST is longer, under the eyes closed condition. [Conclusion] OLST on the side of greater Hip IR ROM tends to be longer due to visual information interception.
Key words: Hip internal rotation, Range of motion, One-leg standing time

(This article was submitted Jan. 24, 2018, and was accepted Mar. 8, 2018)

INTRODUCTION

In Japan, the aging rate (the proportion of the elderly population aged 65 or over) was 26.7% in 2015, resulting in a super-aged society[1)]. Medical and nursing care expenses continue to increase with the aging of society. Falls in the elderly can lead to the need for long-term care. Elderly people often have osteoporosis, and fractures due to falls tend to have severe sequelae.

The causes of falls in the elderly include deficits in muscle strength, equilibrium, vision, and walking ability, as well as co-morbidities, environmental obstacles, and others. Among these, visual function is thought to play a major role in equilibrium function, in combination with vestibular and somatosensory sensation[2)]. Deterioration of visual function due to aging may make it difficult to adjust balance function and increases the risk of falling[3)]. Elderly people with low vision have impaired activities of daily living[4)]. Accordingly, visual function plays an important role in quality of life. To evaluate equilibrium function in the elderly, measurement of the one-leg standing time (OLST) is simple and useful[5)]. The OLST is shorter in those with a tendency to fall[6)]. Measurement of the OLST is useful for early detection of an equilibrium deficit in elderly people. Research on hip internal rotation range of motion (Hip IR ROM) has shown that muscle strength asymmetry is associated with posture[7)]. Therefore, the effect of exercise therapy on asymmetry of Hip IR ROM[8)] should be considered when evaluating low back pain[9)]. However, the effect of Hip IR ROM on other body functions remains unknown. To determine how asymmetry of hip joint ROM is related to other body functions, assessment of the Hip IR ROM laterality pattern[7, 10, 11)]

*Corresponding author. Heonsoo Han (E-mail: han@iuhw.ac.jp)

is considered useful for investigation of the association with OLST. Moreover, assessment of the role of visual information may provide basic data for related research on prediction of fall risk in elderly people whose visual function has deteriorated.

The purpose of this research was to determine whether left/right differences in the OLST are related to the laterality pattern of Hip IR under conditions of visual information blocking. We hypothesized that it would be difficult to detect left and right differences in Hip IR ROM in healthy young people, due to their ability to sustain one-leg standing position with eyes open; however, it is difficult to sustain one-leg standing position with eyes closed, and differences can be easily detected. Therefore, in a person with a left/right difference in Hip IR ROM, the left/right difference in OLST can be detected with eyes closed; moreover, the left/right difference would tend to converge to a certain pattern of Hip IR ROM.

In contrast, in those without a left/right difference in Hip IR ROM, it is thought that the number of different laterality patterns would increase as the rate of change in left/right differences increases with eyes closed.

SUBJECTS AND METHODS

The study included 101 healthy Japanese physical therapy students (54 males, 47 females) with mean age, height, and body weight of 19.5 ± 2.4 years, 165.7 ± 8.5 cm, and 60 ± 10.9 kg, respectively (Table 1). Healthy young people with independence for activities of daily living and walking were included. Those incapable of one-leg standing were excluded. Hip IR ROM was randomly measured 3 times in the prone position using a goniometer, and the average was rounded off. Measurements using goniometers were recorded in increments of 5°. Measurement was performed by students in their 2nd year in the Department of Physical Therapy, who were supervised by a physical therapy instructor.

Hip IR ROM laterality was classified as Balanced or Imbalanced, based on left and right differences.

For group classification, Hip IR ROM laterality ranging from 0 to 9° was considered Balanced. A difference between left and right IR ROM of 10° or more was considered Imbalanced.

The Balanced Group had a left≈right pattern.

The Imbalanced Group was classified into a left side larger pattern (left>right) and a right side larger pattern (left<right) (Table 7). OLST measurements were performed under conditions of eyes open or closed. The subjects were instructed to cross both hands in front of the chest, with the knee of the raised leg bent and fixed at the knee height of the support leg. OLST was measured from the time the foot was lifted from the floor until the foot was returned to the floor. The subjects were instructed to gaze at a fixed point for measurement with eyes open. When measured with eyes closed, subjects were instructed to take the same position as with eyes open. A single measurement of 2 minutes or more was terminated to avoid fatigue. The OLST group was classified into a same group with no left-right differences under eyes both open and closed conditions, and a different group with left/right differences. The same group was classified into the same pattern (left=right), and the different group was classified into a left side longer pattern (left>right) and a right side longer pattern (left<right) (Table 7). Hip IR ROM laterality pattern combined with OLST laterality pattern yielded 9 patterns (Table 7). To determine the general tendency of measurement data, the difference between male and female Hip IR ROM was examined using an unpaired t-test, and the difference between eyes open and closed conditions in the OLST was examined using a paired t-test (Table 1). McNemar's test was used to determine the difference in the number of subjects according to the presence or absence of left and right

Table 1. Subject characteristics

	Males (n=54)	Females (n=47)	Total (n=101)
Age (years)	19.2 ± 0.5	19.8 ± 3.4	19.5 ± 2.4
Height (cm)	171.8 ± 6.2	158.8 ± 4.8	165.7 ± 8.5
Weight (kg)	66.0 ± 11	53.2 ± 5.5	60.0 ± 10.9
Hip IR ROM (°)			
Left	36.3 ± 11*	51.4 ± 10.6*	43.3 ± 13.1
Right	37.2 ± 10.5†	53.1 ± 12.3†	44.6 ± 13.8
OLST (sec)			
Open eyes			
Left	89.1 ± 42.7	94.9 ± 36.8	91.8 ± 40.4*
Right	87.2 ± 42.1	85.9 ± 42.4	86.6 ± 42.4†
Closed eyes			
Left	38.2 ± 40.5	31 ± 34.2	34.9 ± 38.0*
Right	38.7 ± 39.9	22.6 ± 23.6	31.2 ± 34.5†

*,† $p<0.05$.
Mean ± SD.
IR: internal rotation; ROM: range of motion; OLST: one-leg standing time.

OLST differences with visual information blocking (Table 2). Coincidence and inconsistency between eyes open and closed conditions according to Hip IR ROM laterality pattern and OLST laterality pattern (Table 3), and matches and discrepancies between Hip IR ROM Balanced Group equilibrium pattern and OLST equilibrium pattern were examined under eyes open and closed conditions (Table 4). In the Hip IR ROM Imbalanced Group, the laterality pattern matches and mismatches and the OLST pattern were examined with eyes open and closed, according to left side larger (left>right) and right side larger (left<right) patterns (Table 5). For supplementation, the details of common items of Table 3, 4, and 5 are shown in Table 6.

McNemar's test was used for evaluation (Tables 3, 4, 5). IBM SPSS Statistics (ver. 24) was used for analysis, and the significance level was set at 5%. The number of subjects under eyes open and closed conditions were tabulated for each of the 9 patterns and their distribution is shown in Table 7.

This study was approved by the International University of Health and Welfare Ethics Committee (approval number: 13-Io-154-2). Oral information was given and written consent was obtained from participants.

RESULTS

Hip IR ROM showed significantly larger values in females than in males, and OLST showed significantly longer durations with eyes open than with eyes closed (Table 1). Significant differences were observed between eyes open and closed conditions according to the presence or absence of left and right differences in OLST (Table 2). There was a significant difference in the number of coincidences between eyes open and closed conditions in Hip IR ROM laterality pattern and OLST laterality pattern (Table 3). In the OLST laterality pattern in the Hip IR ROM Balanced group, a significant difference was observed in coincidences between eyes open and closed conditions (Table 4). In the OLST laterality pattern in the Hip IR ROM Imbalanced Group, a significant difference was observed in coincidences between eyes open and closed conditions (Table 5). Among those who met or exceeded an OLST set at an upper limit of 2 minutes or more, no left/right difference was observed in 50 subjects measured with eyes open and 3 with eyes closed. Table 7 shows the distribution of 9 patterns, combining the OLST with the left and right difference patterns in Hip IR ROM.

DISCUSSION

In this study, a left/right difference in Hip IR ROM with visual information blocking revealed that the left and right difference in OLST tends to converge to a certain pattern.The number of matches between the OLST laterality pattern and the Hip IR ROM laterality pattern in the Imbalanced Group (left >right pattern and left<right pattern) was significant with eyes closed, with a tendency toward a lack of matches with eyes open (Table 5). Since the Imbalanced Group had two patterns

Table 2. Number of subjects during eyes open and eyes closed according to the presence/absence of OLST laterality

		Closed eyes		
		L=R	L≠R	Row total
Eyes open	L=R	5	55	60
	L≠R	3	38	41
	Column total	8	93	101

McNemar's test: $p<0.05$.

Table 3. Number of matches with open and closed eyes according to Hip IR ROM laterality pattern and OLST laterality pattern

		Closed eyes		
		=ROM pattern	≠ROM pattern	Row total
Eyes open	=ROM pattern	6	47	53
	≠ROM pattern	12	36	48
	Column total	18	83	101

McNemar's test $p<0.05$.

Table 4. Number of matches in the Hip IR balanced group according to OLST laterality pattern during eyes open and closed testing

		Closed eyes		
		=ROM pattern	≠ROM pattern	Row total
Eyes open	=ROM pattern	4	46	50
	≠ROM pattern	3	34	37
	Column total	7	80	87

McNemar's test $p<0.05$.
Laterality of OLST (with less than 10° left/right difference).

Table 5. Number of matches in the Hip IR Imbalanced group according to OLST laterality pattern during eyes open and closed testing

		Closed eyes		
		=ROM pattern	≠ROM pattern	Row total
Eyes open	=ROM pattern	2	1	3
	≠ROM pattern	9	2	11
	Column total	11	3	14

McNemar's test $p<0.05$.
Laterality of OLST (with 10° or more left/right difference).

(left>right and left<right), the proportion corresponding to the left=right pattern of OLST was reduced with eyes closed. This indicates a tendency to converge to the left>right or left<right pattern. Thus, it became clear that in the Imbalanced Group, the OLST on the side with larger Hip IR ROM tended to be longer due to blocking of visual information. In the left side larger pattern (left>right: d, e, f) in the Imbalanced Group, the OLST pattern changed, so that all subjects had a left side longer pattern (left>right: e) with eyes closed (Table 7). With a large pattern on the right side (left<right), the same pattern (left=right: g) decreased with OLST pattern with eyes closed, and increased with left side larger pattern (h) or right side larger pattern (i) in the different group. In particular, the right side longer pattern (left<right: i), i.e., the same side hip IR ROM pattern, increased. The Imbalanced group tended to match the larger side of the Hip IR ROM laterality pattern and the longer side of the OLST laterality pattern with eyes closed.

This indicates that postural adjustment using visual information cannot be corrected due to blocking of visual information, and that postural adjustment ability using other elements develops, so that left and right differences appear. In contrast, in the Balanced group (left≈right) of the Hip IR ROM laterality pattern, the ratio of agreement with the OLST laterality pattern tended to be consistent with eyes open, but did not match with eyes closed (Table 4). Thus, it became clear that left and right differences can be easily detected by blocking visual information, in contrast to the difficulty detecting left and right differences in the OLST with respect to the Hip IR ROM laterality pattern before blocking visual information. Hip IR ROM was larger in females than in males[12, 13], and OLST was shorter with eyes closed than with eyes open[14] (Table 1). The proportion of subjects with left and right differences in OLST increased significantly with eyes closed; left and right differences were prominent with eyes closed, and the proportion of subjects with left and right differences increased (Table 2). Discrepancy between patterns of Hip IR ROM laterality and OLST laterality with eyes closed was significantly greater than with eyes open (Table 3). In all subjects (Table 3) and in the Balanced Group of Hip IR ROM laterality pattern (Table 4), the ratio of coincidence with OLST was high with eyes open but low with eyes closed. However, in the Imbalanced Group of Hip IR ROM laterality pattern (Table 5), the ratio of coincidence of patterns was lower with eyes open and tended to be significantly higher with eyes closed. Because the number of subjects in the Imbalanced Group was small, this tendency could not be determined; however, it was possible to clarify certain tendencies by examining the Imbalanced Group separately. In all subjects, OLST was significantly different on left and right side with eyes closed (Table 2), and the ratio of coincidence between Hip IR ROM laterality pattern and OLST laterality pattern decreased with eyes closed (Table 3). This is because posture control using visual information is possible in one-leg standing position with eyes open for a longer time than with eyes closed; with an upper limit of OLST measurement of 2 minutes, many subjects had an OLST of 2 minutes or more. Many subjects exhibited equilibrium patterns with no left/right differences by exceeding the upper limit of 2 minutes on both sides (Table 2). On the

Table 6. Common items in Table 3, 4, 5: details of Hip IR ROM and OLST match/mismatch patterns

Pattern	ROM pattern		OLST pattern
=ROM pattern	L ≈ R	and	L=R
Matched with Hip IR ROM pattern	L>R	and	L>R
	L<R	and	L<R
≠ROM pattern	L ≈ R	and	L>R or L<R
Not matched with Hip IR ROM pattern	L>R	and	L=R or L<R
	L<R	and	L=R or L>R

IR: internal rotation; ROM: range of motion; OLST: one-leg standing time.

Table 7. Distribution of hip internal rotation range of motion and one-leg standing time patterns, with or without visual information (n=101)

Hip internal rotation range of motion		One-leg standing time		Eyes open	Closed eyes	
Group	Pattern	Group	Pattern			
Balanced (n=87)	left ≈ right	Same	left=right	50	7	a
		Different	left>right	20	41	b
			left<right	17	39	c
Imbalanced (n=14)	left>right	Same	left=right	4	0	d
		Different	left>right	2	6	e
			left<right	0	0	f
	left<right	Same	left=right	6	1	g
		Different	left>right	1	2	h
			left<right	1	5	i

Same: left=right pattern, Different: left>right pattern and left<right pattern.

other hand, in one-leg standing with eyes closed, postural control using visual information feedback was insufficient due to blocking of visual information, along with vestibular sensation and somatosensory sensation[2]. Therefore, left and right differences in postural control ability appeared (Table 2). Owing to the appearance of OLST laterality (Table 2), the different group (left>right pattern, left<right pattern) of OLST increased significantly (Tables 3, 4). All hip external rotation muscle groups, which are limiting factors at the end of Hip IR ROM, are attached to the proximal femur. Hip IR ROM increases as the femoral anterior torsion angle increases[15] during one-leg standing. The hip joint internally rotates to maintain the fit of the femoral head as the anterior torsion angle of the femur increases[16] and the hip joint external rotation muscle group dynamically prevents excessive Hip IR. If the femoral anterior torsion angle is large, an intermediate position is observed during internal rotation and the IR ROM increases[17]. In this study, in the Imbalanced Group of the Hip IR ROM laterality group, the OLST tended to be longer on the hip IR ROM larger side. This is because the OLST may have been lengthened by the activity of external rotator muscles attempting to maintain a femoral head fitted state, to dynamically prevent excessive Hip IR. The muscle activity of the anterior gluteus medius during OLST in IR position is reportedly higher than in the intermediate and external rotation positions[18]. In this research, it became clear that the OLST on the side with larger Hip IR ROM tends to be longer. Increased muscle activity in IR position may reflect this research result. With impaired equilibrium in the elderly, increased muscle weakness, decreased walking ability, and various complications can develop; this study examined the influence of visual information blocking more accurately by targeting healthy young people.

The fact that the OLST on the larger side of Hip IR ROM tended to be longer indicates that the OLST on the smaller side of Hip IR ROM is shorter. OLST also decreases in elderly people whose overall body function declines[14]. The center of gravity movement region reportedly is about 30% of the base of support when moving to the maximum position when standing on both legs[19]. Hence, there is a need to perform postural control in a narrow range in one-leg standing position. It may be difficult to control posture in the elderly in one-leg standing position on a narrower base of support. Therefore, the risk of falls may increase during one-leg standing on the side with the smaller Hip IR ROM. This finding may have predictive value that can be used in fall prevention.

The limitations of this research are as follows. An upper limit of OLST measurement of 2 minutes limited determination of maximum duration, because left and right differences did not appear in those able to exceed 2 minutes on both sides. OLST was measured until the raised foot touched the floor. For that reason, some subjects who adjusted their posture by slightly moving their feet are also included.

Measurement of ROM used increments of 5°, and it may be necessary to increase measurement accuracy because OLST was measured once. Prospects for future research include the following.

The Hip IR laterality pattern in the Imbalanced Group of Hip IR ROM laterality pattern and the OLST laterality pattern showed a tendency to match patterns with eyes closed; however, further study of discordant subjects may be needed. In the Balanced Group of Hip IR ROM laterality pattern, there was a tendency to develop laterality with eyes closed during OLST. Further research is required to clarify the association between Hip IR ROM laterality pattern and OLST laterality pattern. Therefore, further study will require assessment of walking ability and the association with falls.

ACKNOWLEDGEMENTS

This study was supported by the Japan Society for the Promotion of Science and National Research Foundation of Korea under the Japan-Korea Basic Scientific Cooperation Program. We acknowledge the students and faculty who participated in the research.

Presentation at a conference

A part of this research was presented in The 22nd International Meeting of Physical Therapy Science in Korea, Volume 29 (2017) Issue Suppl. 1 Page24, https://doi.org/10.1589/jpts.29.Suppl.1_S1_1.

Conflicts of interest

None.

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