Relationship between ankle range of motion and Biodex Balance System in females and males

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This study examined whether there are differences between range of motion (ROM) and balance in lower extremities according to gender. A total of 31 male and 28 female students measured plantar flexion (PF), dorsiflexion, inversion (IV), eversion (EV), hip flexion (HF), hip internal rotation (HIR), and hip external rotation (HER) and tested on the Biodex Balance System. ROM of PF and HF were significantly high the female group and ROMs of IV, EV, HIR, and HER were significantly higher the

male group than in the female group. Low ROM of PF may be more negative related to overall balance, especially, back balance in males; therefore, it is necessary to assess and plan the training program for PF ROM in male students.

Keywords: Gender identity, Lower extremity, Postural balance, Range of motion

INTRODUCTION

The balance is very important component to prevent elderly fall and to improve rehabilitation after injury in low extremity. There are various factors for optimal balance, which are sensorimotor, visual acuity, vestibular function, central and peripheral sensor, cerebellar function, muscle strength of both lower extremities, and between male and female (Bok et al., 2013). Most previous studies demonstrated that optimal balance can improve postural control and decrease the injury risk of low extremity (Goldie et al., 1994; McCluskey et al., 1976; Tropp et al., 1985).

Several studies have examined gender differences in balance performance. They reported that male have a worse balance and a greater instability in low extremity than female (Bryant et al., 2005; Era et al., 2002) and another study reported that it exists gender differences in balance performance and there has been a higher incidence of falling in female than in male (Menz et al., 2005; Mika et al., 2012). Moreover, several studies demonstrated that possible explanation for gender differences might be the intrinsic differences of anthropometric characteristics (Taimela et al.,

1990). The ankle joint of range of motion (ROM) is an important part of the human kinetic chain, playing an important role in posture balance and gait (Murray et al., 1985) and it is an intrinsic factor involved in low extremity injury and ankle injury in sports. Other studies reported that lack of dorsiflexion (DF) can be caused by many ankle joint impairments, such as weakness of dorsiflexors, spasticity of plantar flexors, passive stiffness of the plantar flexors, or walking disabilities (Crenna, 1998). Decreasing of ankle joint ROM influences many aspects of function and balance (Bennell and Goldie, 1994). Ankle is focused primarily on plantar flexion (PF) and DF and flexibility and strength of toe plantarflexor muscle strength are significantly associated with posture balance and physical functional ability (Menz et al., 2005). Movement of the DF and PF is necessary to allow optimal force generation and balance strategy execution to decrease fall risk (Studenski et al., 1991). In addition, foot and ankle characteristics, which are plantar flexor strength of toe and of ankle inversion (IV)-eversion (EV) ROM, are important for sway balance and functional ability in elderly people (Spink et al., 2011). Mecagni et al. (2000) reported the ankle IV-EV ROM was also found to be significantly

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Received: October 26, 2017 / Accepted: January 16, 2018

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associated with balance and functional test performance. In order to minimize the fall risk and prevent of ankle injury, it is essential to confirm the differences of balance with low extremity according to ROM between females and males. Murray et al. (1985) described that there are minimal differences of ROM between females and males. However, there is a lack of studies regarding the ROM in low extremity and the difference in males and females. Thus, the purpose of our study was to examine the differences of ankle ROM and balance between healthy female and male students.

MATERIALS AND METHODS

Subjects

Thirty-one male and 28 female students completed to participate in this study. Subjects were moderately trained students. They had previously been screened and diagnosed by an orthopedic surgeon. All subjects did not present neurological signs of pathological importance in the clinical examination and they have previous experience with balance training on the Biodex Balance System (BBS). Before of the study, all participants were informed about the purpose, procedures and possible risks of the study and written informed consent was obtained from each participant.

Active ankle ROM

Subjects lay supine with outstretched legs on an examination table without any pad, cushion or pillow underneath for PF, DF, IV, EV, hip flexion (HF), hip internal rotation (HIR), and hip external rotation (HER). The testing position of ankle started 90° for ankle joint and stated supine position with anatomical position for HF, HIR, and HER. The active ROM, like self-stretching, was calculated by the summation of degrees of PF, DF, HF, HIR, and HER. The greater degree means the higher flexibility.

Biodex Balance Test

To assess balance of postural stability, limits of stability and fall risk the subjects received postural stability test with the BBS (Biodex Medical Systems, Shirley, NY, USA). Postural stability test were measured 20-sec trials with 1-min intervals between them and simulated particular movement patterns by fixed platform. This platform stability was set to moderately stable and in each session, the subjects sway is used to assess the postural stability. The BBS software calculated a subject's functional balance ability of the anterior/posterior index, medial/lateral index, and overall stability index during a given task. These indices were cal-

culated using the degree of oscillation of the platform and low values showed that the subjects had good posture stability. The average of three tests was considered the subject index. Limits of stability for static and dynamic standing balance can be showed that posture stability can be achieved as maximum angle from vertical without losing balance. The test includes 14 items and those results of integration with sensory and motor control aspects for posture balance can play an important role in daily life. For the fall risk test, the platform is unstable and the subject's test was measured with fall risk test protocol. According to the BBS software, 2 trials of 20 sec each at a stability level of 8 were measured with 10-sec rest between set. Fluctuations around the zero point, established prior to testing when the platform is stable, are presented as the findings of this test (Ibrahim et al., 2016).

Statistical analysis

Data processing and analysis was used IBM SPSS Statistics ver. 22.0 (IBM Co., Armonk, NY, USA). Descriptive analysis was used mean and standard deviation for general characteristics. Independent *t*-test was used to determine the difference ROM in lower extremities and balance in male and female students. All data was presented using mean values with standard deviation. The statistical significance level was less than 0.05 in *P*-value.

RESULTS

Thirty-one males (age, 20.63 ± 1.67 years; height, 176.19 ± 6.31 cm; weight, 77.33 ± 11.97 kg; body mass index [BMI], 24.24 ± 5.02 kg/m²) and 28 female students (age, 20.31 ± 1.31 years; height, 161.90 ± 6.17 cm; weight, 62.40 ± 13.20 kg; BMI, 23.88 ± 5.46 kg/m²) were participated in this study (Table 1). This study showed differences ROM of low extremities (ankle and hip ROM) according to gender. ROM of PF and HF were significantly higher female group (right, $54.10^\circ \pm 9.36^\circ$; left, $56.13^\circ \pm 10.73^\circ$ in PF and right, $121.91^\circ \pm 8.00^\circ$; left, $121.93^\circ \pm 8.66^\circ$ in HF) than male group (right, $49.30^\circ \pm 8.43^\circ$; left, $48.87^\circ \pm 7.49^\circ$ in

Table 1. General characteristics of subjects

Characteristic	Male (n=31)	Female (n=28)
Age (yr)	20.63 ± 1.67	20.31 ± 1.31
Height (cm)	176.19 ± 6.31	161.90 ± 6.17
Weight (kg)	77.33 ± 11.97	62.40 ± 13.20
Body mass index (kg/m ²)	24.24 ± 5.02	23.88 ± 5.46
Dominant leg, right:left	29:2	26:2

Values are presented as mean $\pm$ standard deviation or number.

Table 2. Differences of range of motion of lower extremities in male and female students (n=59)

Characteristic	Male (n=31)	Female (n=28)	P-value
Dorsiflexion			
Right	17.71 ± 4.97	17.39 ± 5.68	0.82
Left	17.32 ± 4.89	17.37 ± 4.72	0.97
Plantarflexion			
Right	49.30 ± 8.43	54.10 ± 9.36	0.04*
Left	48.87 ± 7.49	56.13 ± 10.73	0.004*
Inversion			
Right	37.73 ± 10.54	31.54 ± 8.01	0.02*
Left	38.54 ± 10.12	33.30 ± 6.95	0.03*
Eversion			
Right	26.21 ± 5.92	20.10 ± 5.98	0.001*
Left	24.84 ± 6.87	20.41 ± 7.54	0.02*
Hip flexion			
Right	117.38 ± 7.49	121.91 ± 8.00	0.03*
Left	117.03 ± 8.12	121.93 ± 8.66	0.03*
Hip internal rotation			
Right	39.13 ± 10.98	32.86 ± 11.69	0.04*
Left	40.05 ± 12.08	32.58 ± 11.95	0.02*
Hip external rotation			
Right	52.44 ± 10.65	46.15 ± 9.35	0.02*
Left	52.24 ± 9.26	47.06 ± 10.61	0.05*

Values are presented as mean ± standard deviation (°).

* $P < 0.05$, statistically significant.

PF and right, $117.38^\circ \pm 7.49^\circ$; left, $117.03^\circ \pm 8.12^\circ$ in HF ($P < 0.05$). ROM of IV, EV, HIR, and HER were significantly higher male group (right, $37.73^\circ \pm 10.54^\circ$; left, $38.54^\circ \pm 10.12^\circ$ in IV; right, $26.21^\circ \pm 5.92^\circ$; left, $24.84^\circ \pm 6.87^\circ$ in EV; right, $39.13^\circ \pm 10.98^\circ$; left, $40.05^\circ \pm 12.08^\circ$ in HIR; right, $52.44^\circ \pm 10.65^\circ$; left, $52.24^\circ \pm 9.26^\circ$ in HER) than female group (right, $31.54^\circ \pm 8.01^\circ$; left, $33.30^\circ \pm 6.95^\circ$ in IV; right, $20.10^\circ \pm 5.98^\circ$; left, $20.41^\circ \pm 7.54^\circ$ in EV; right, $32.86^\circ \pm 11.69^\circ$; left, $32.58^\circ \pm 11.95^\circ$ in HIR; right, $46.15^\circ \pm 9.35^\circ$; left, $47.06^\circ \pm 10.61^\circ$ in HER) ($P < 0.05$). However, there is no significant difference of DF was founded between male and female students (Table 2). Moreover, female group had a significantly better limits of stability than male group in back ward (male, 71.35 ± 16.96 ; female, 60.68 ± 20.11) and backward-left (male, 61.61 ± 12.98 ; female, 47.68 ± 13.67), back ward-right (male, 61.90 ± 17.70 ; female, 49.93 ± 13.98) ($P < 0.05$) (Table 3). Furthermore, female group had a significantly better of visual stability during eye close (male, 1.38 ± 0.77 ; female, 0.99 ± 0.31) and of fall risk (male, 1.73 ± 0.95 ; female, 0.77 ± 0.29) than male group ($P < 0.05$) (Table 3).

Table 3. Differences of global balance parameters in male and female students (n=59)

Characteristic	Male (n=31)	Female (n=28)	P-value
Postural stability			
Anterior-posterior	0.27 ± 0.09	0.26 ± 0.08	0.45
Medial-lateral	0.20 ± 0.13	0.18 ± 0.06	0.51
Limits of stability			
Forward	55.35 ± 19.19	57.18 ± 17.46	0.71
Backward	71.35 ± 16.96	60.68 ± 20.11	0.03*
Left	65.19 ± 15.65	59.54 ± 20.22	0.23
Right	65.00 ± 17.38	60.71 ± 15.53	0.32
Forward-left	57.65 ± 15.87	55.79 ± 17.94	0.67
Forward-right	59.71 ± 16.50	52.07 ± 16.33	0.08
Backward-left	61.61 ± 12.98	47.68 ± 13.67	0.001*
Backward-right	61.90 ± 17.70	49.93 ± 13.98	0.006*
Visual stability			
Eye open	0.43 ± 0.14	0.45 ± 0.12	0.57
Eye close	1.38 ± 0.77	0.99 ± 0.31	0.02*
Fall risk	1.73 ± 0.95	0.77 ± 0.29	0.001*

Values are presented as mean ± standard deviation.

* $P < 0.05$, statistically significant.

DISCUSSION

The primary aim of this study was to investigate the relationship between ROM in lower extremities and postural-, limits-, visual-stability and fall risk with BBS in female and male students. To the best of our knowledge, the present study is the first to evaluate the relationship between postural balance and ROM of lower extremities in female and male students. The BBS is a reliable and reproducible method for evaluating postural-, limits-, and visual-stability and fall risk from the posture's center of mass that can be made while maintaining postural stability (Cachupe et al., 2001). Several studies have examined gender differences in balance performance. They reported that males have a worse balance and a greater instability in low extremity than females (Bryant et al., 2005; Crenna, 1998; Denegar et al., 2002; Era et al., 2002). Furthermore, they also reported that female have higher incidence of falling risk than male (Menz et al., 2005; Mika et al., 2012). Moreover, several studies demonstrated that possible explanation for gender differences might be the intrinsic differences of anthropometric characteristics. Kejonen et al. (2003) demonstrated that body anthropometric characteristics influence the variations of body-balancing movements in balance and body mass are related to postural balance between obese and nonobese subjects (McGraw et al., 2000). However, few studies have reported gender differences with ROM of lower extremity and balance.

Therefore, in the present study, we found that females have a better balance and also a better ROM of PF and HF than males. These results are consistent with Spink et al. (2011) who reported that foot and ankle characteristics, which are plantar flexor strength of toe and of ankle IV-EV ROM, are important of sway balance and walking functional ability in elderly people (Spink et al., 2011). Congruently, in Mecagni et al. (2000) the ankle IV-EV ROM was also found to be significantly associated with balance and physical functional performance test. Our results show that low IV and EV ROM have a negative influence on balance in males. Specifically, one of various ROMs, PF, plays an important role in supporting weight of body and providing stability at the ankle and feet for standing and gait, whereas dorsiflexor muscle against gravity during the swing phase of gait clears the feet from the floor and those authors carefully suggested that static balance may be related to more plantarflexor strength than dorsiflexor (Bok et al., 2013). Menz et al. (2005) also reported ankle flexibility and strength of toe plantarflexor muscle strength to be significantly associated with balance and functional ability. This gender difference of PF ROM is supported by Mika et al. (2012) who found that that high-heeled shoes increased knee flexion and decreased ankle EV. Consistently with our results on PF that positively influence the overall balance, this finding provides further evidence that females have a higher ROM of EV and HF than males.

In conclusion, this study demonstrates that the gender difference of ankle ROM and balance. Specifically, our results show that females have a better ankle ROM of PF than males and males have a higher ROM of IV, EV, HIR, and HER than females. Low ROM of PF may be more negative related to overall balance, especially, back balance in males; therefore, it is necessary to assess and plan the training program for PF ROM in males. Further research is needed for intervention programs to improve the PF flexibility in males; furthermore, IV, EV, HIR, and HER flexibility in females would be beneficial for improving balance and prevention of falls.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

ACKNOWLEDGMENTS

The authors thank all the participants which, without their help, we were not able to conduct the study.

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