

Wii balance board exercise improves balance and lower limb muscle strength of overweight young adults

AKKRADATE SIRIPHORN¹⁾*, DANNAOVARAT CHAMONCHANT¹⁾

¹⁾ Department of Physical Therapy, Faculty of Allied Health Sciences, Chulalongkorn University: 154 Rama I Road, Pathumwan, Bangkok 10330, Thailand

Abstract. [Purpose] The potential health benefits of the Nintendo Wii balance board exercise have been widely investigated. However, no study has been conducted to examine the benefits of Wii exercise for overweight young adults. The aim of this study was to investigate the effect of exercise performed on a Nintendo Wii balance board on the balance and lower limb muscle strength in overweight young adults. [Subjects and Methods] Within-subject repeated measures analysis was used. Sixteen young adults (aged 21.87 ± 1.13 years, body mass index 24.15 ± 0.50 kg/m²) were recruited. All subjects performed an exercise program on a Wii balance board for 8 weeks (30 min/session, twice a week for 8 weeks). A NeuroCom Balance Master and a hand-held dynamometer were used to measure balance performance and lower limb muscle strength. [Results] According to the comparison of pre- and post-intervention measurements, the Wii balance board exercise program significantly improved the limit of stability parameters. There was also a significant increase in strength of four lower-limb muscle groups: the hip flexor, knee flexor, ankle dorsiflexor and ankle plantarflexor. [Conclusion] These findings suggest that a Wii balance board exercise program can be used to improve the balance and lower limb muscle strength of overweight young adults.

Key words: Wii balance board, Muscle strength, Overweight

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INTRODUCTION

As in other Asian countries, there is an increasing trend of overweight in the Thai population. This trend may primarily be attributed to rapid changes in lifestyle and sedentary behavior. The results of the national health survey indicate that the average body mass index (BMI) of the Thai population over the age of 18 increased from 22.0 kg/m² in 1991 to 23.2 kg/m² in 2004¹⁾. The increased prevalence of overweight and obesity has socio-economic consequences, due to the cost of treatments for overweight and obesity-related diseases, such as cardiovascular disease, stroke, diabetes type II, and hypertension^{2, 3)}. Accumulated evidence indicates that being overweight is linked to a reduction in lower-limb muscle strength and the alteration several gait parameters, including maximum walking speed⁴⁾. Decreasing muscle power and a decline in the level of physical activity are associated with an increased risk of falls⁵⁾. Deforche et al. divided 8 to 10-year-old boys into normal weight and overweight groups using a body mass index cut-off point and reported that overweight boys had greater sway velocity in the sit-to-stand test, a shorter time of one leg

stance in the balance beam test, and fewer correct steps in the heel-to-toe test⁶⁾. BMI and postural stability have been shown to be negatively correlated in single- and double-leg standing^{7, 8)}. These results suggest that the balance ability of overweight subjects is lower than that of normal weight subjects. Also, Teasdale et al. reported that decreasing body weight improved the balance ability of obese and morbidly obese men⁹⁾.

The Nintendo Wii Fit™, a computer game console, is an interesting example of a new exercise choice that could be used for improving strength, flexibility, fitness, postural stability, and general well-being. Using this device, players receive visual and auditory feedback that provides useful information that helps them to adapt their postural stability. Graves et al. demonstrated that playing with a Wii Fit™ increased energy expenditure and physical activity. They also reported that Wii Fit™ appears to be an enjoyable exergame for adolescents and adults that stimulates light- to moderate-intensity activity through the modification of typically sedentary leisure behavior¹⁰⁾. Previous studies have demonstrated that the Wii Fit™ significantly improves lower-limb muscle activities, strength, and the balance performance of healthy adults^{11, 12)} and elderly¹³⁾.

There have been many studies of Wii Fit™ that have used the Wii balance board as an input device, and it can be used as a modern exercise program for improving physical activity and muscle strength. However, there has been little discussion about the effect of Wii Fit™ exercise on the balance and muscle strength of overweight individuals.

*Corresponding author. Akkradate Siriphorn (E-mail: akkradate@gmail.com)

SUBJECTS AND METHODS

A within-subject repeated measures design was used to determine whether Wii balance board exercise could improve the balance and lower-limb muscle strength of overweight young adults of both genders. Sixteen overweight young adults (aged 21.87 ± 1.23 years, weight 64.03 ± 7.79 kg, height 1.63 ± 0.09 m, BMI 24.15 ± 0.50 kg/m², 6 males and 10 females) from Chulalongkorn University were recruited (Table 1). In this study, overweight was defined as a person with a body mass index (BMI) between 23.0 and 24.9 kg/m², according to the Asian BMI cut-off points¹⁴. Prior to participation in this study, all the study procedures were explained by the researcher. Written informed consent was obtained from the subjects using forms approved by the institutional ethics committee. A questionnaire was used to obtain demographic data and screening for the inclusion and exclusion criteria. The inclusion criteria were: 1) BMI between 23.0 and 24.9 kg/m²; 2) normal visual field and acuity (the subjects able to wear eye glasses); 3) normal hearing; 4) the ability to stand in a bipedal position with the eyes closed and without help for 1 minute or more; and 5) the ability to stand on one leg for 30 seconds or more. The exclusion criteria were: 1) a history of musculoskeletal disorders; 2) a history of neurological disorders; 3) a history of back or lower limb surgery; or 4) the presence of any joint diseases, such as osteoarthritis, gout, or rheumatoid arthritis. All of the study procedures were approved by the Ethics Review Committee for Research Involving Human Research Subjects, Health Science Group, Chulalongkorn University (Project #: 032.2/55).

The subjects exercised on a Wii balance board for 30 minutes per day, twice a week, for 8 weeks. The exercise program included 6 yoga exercises (i.e., warrior pose, tree pose, standing knee pose, palm tree pose, chair pose, and dance pose) and 5 strength exercises (i.e., single-leg extension, lunge, rowing squat, single-leg twist, and sideways leg lift). The subjects were asked to write in exercise dairies if they performed any other exercise during the 8 weeks of this study. The exercise dairies were collected weekly. No subject performed other exercise of more than 20 minutes/session/week during this study.

A NeuroCom Balance Master (NeuroCom, OR, USA) was used to assess static and dynamic postural stability. This equipment consists of a double force plate that is connected to a computer and is controlled by the Balance Master Program. The static and dynamic postural stability were measured using the unilateral stance test and a limit of stability test, respectively. In each assessment, the subjects were allowed to practice before recording the results. All of the tests were performed in the Neurological Treatment Room, Health Sciences Service Unit, Faculty of Allied Health Sciences, Chulalongkorn University.

The limit of stability (LOS) is the dynamic standing balance test that measures the maximum distance a subject can lean without losing balance in 8 directions (i.e., forward, forward-right, right, backward-right, backward, backward-left, left and forward-left). The tested parameters were the reaction time (the time between the start-to-move signal

Table 1. Characteristics of the participants ($n = 16$)

Characteristics	Mean \pm SD	Range
Age (years)	21.87 \pm 1.23	20–24
Weight (kg)	64.03 \pm 7.79	54.90–78.70
Height (m)	1.63 \pm 0.09	1.52–1.79
BMI (kg/m ²)	24.15 \pm 0.50	23.02–24.85
Male : Female	6 : 10	

and the initiation of the center of gravity (COG) movement), the COG movement velocity (the average speed of COG movement), the endpoint excursion (the distance of the COG movement toward the target in the first attempt) and the maximum excursion (the maximum distance of COG movement from the center point during the trial).

The unilateral stance test is a static balance test that measures COG sway velocity while standing on one leg on the force plate for 10 sec under 4 conditions (i.e., standing on the left leg with eyes open, standing on the left leg with eyes closed, standing on the right leg with eyes open and standing on the right leg with eyes closed). Each test was repeated 3 times; therefore, a total of 12 tests were performed.

A hand-held dynamometer (the Lafayette Manual muscle test system model 01163; Lafayette Instrument, USA) was used to assess the lower limb muscle strength pre- and post-training. The tested muscle groups were the hip flexor, hip extensor, hip abductor, hip adductor, knee extensor, knee flexor, ankle dorsiflexor and ankle plantarflexor. We used the starting positions and location of the dynamometer as described in a previous study¹⁵) (Table 2). To avoid frequent changes of position, the testing sequence was begun in sitting and progressed to supine lying, side lying and prone lying. In order to familiarize the subjects with the test, they were allowed to practice before data acquisition trials. The maximum muscle strength was assessed in 2 trials with 120 seconds rest between trials. The muscle strength of each muscle group was then averaged.

Statistical analyses were conducted using GraphPad Prism version 6.0 (GraphPad Software, CA, USA). A descriptive analysis was used to illustrate demographical data. The paired t-test was used to compare pre- and post- training results. All results are shown as mean \pm SD. Statistical significance accepted for values of $p < 0.05$.

RESULTS

To assess the static balance ability, the LOS test was performed on the Balance Master. Table 3 shows the results of pre- and post- training of four LOS parameters: the reaction time, the COG movement velocity, the endpoint excursion and the maximum excursion. There was a significant decrease in the reaction time in the forward right ($p = 0.0383$) and backward left directions ($p = 0.0224$); a significant increase of the average speed of COG movement (COG movement velocity) in the backward direction ($p = 0.0147$); a significant increase in the endpoint excursion and the measurement of the distance of COG movement toward the target in the first attempt in forward ($p = 0.0320$) and

Table 2. Positions of the lower limb muscle strength assessment using a hand-held dynamometer⁽⁵⁾

Muscle groups	Subject positions	Extremity and joint positions	Location of dynamometer application
Hip flexor	Supine lying	Hip and knee flexed 90°, contralateral hip neutral	Just proximal to femoral condyles
Hip extensor	Prone lying	Hips neutral, knees extended	Just proximal to femoral condyles
Hip abductor	Side lying, measured side is upper	Hips and knees extended	Just proximal to lateral joint line of knee
Hip adductor	Side lying on measured side	Hip and knee extended, contralateral hip and knee flexed with foot placed on bed anteriorly to measured side	Just proximal to medial joint line of knee
Knee extensor	Sitting with straight back	Hips and knees flexed 90°	Just proximal to malleoli
Knee flexor	Prone lying, feet out of bed	Hips and knees extended	Just proximal to malleoli
Ankle dorsiflexor	Supine lying	Hips and knees fully extended, ankles perpendicular to legs	Just proximal to metatarsophalangeal joint line
Ankle plantarflexor	Prone lying, feet out of bed	Hips and knees extended, ankles perpendicular to legs	Just proximal to metatarsophalangeal joint line

Table 3. Mean \pm SD of reaction time, COG movement velocity, end point excursion and maximum excursion in each direction

Directions	Reaction time (second)		COG movement velocity (degree/sec)		End point excursion (percent of LOS)		Maximum excursion (percent of LOS)	
	Pre-training	Post-training	Pre-training	Post-training	Pre-training	Post-training	Pre-training	Post-training
Forward	0.87 \pm 0.36	0.75 \pm 0.34	4.76 \pm 2.14	4.79 \pm 1.99	83.8 \pm 22.7	91.6 \pm 18.1*	97.2 \pm 11.5	104.0 \pm 9.69*
Forward right	0.78 \pm 0.40	0.56 \pm 0.17*	3.60 \pm 4.70	4.60 \pm 6.60	98.4 \pm 15.4	110.0 \pm 10.6*	103.0 \pm 12.9	112.0 \pm 8.92*
Right	0.62 \pm 0.17	0.62 \pm 0.23	2.70 \pm 4.75	3.80 \pm 6.40	86.9 \pm 10.5	86.6 \pm 12.4	98.8 \pm 8.64	98.2 \pm 7.29
Backward right	0.73 \pm 0.40	0.60 \pm 0.23	5.09 \pm 1.81	4.71 \pm 1.42	78.0 \pm 17.7	72.8 \pm 22.5	86.2 \pm 14.2	86.1 \pm 15.7
Backward	0.67 \pm 0.33	0.65 \pm 0.20	3.10 \pm 1.35	4.09 \pm 1.53*	58.3 \pm 12.8	56.4 \pm 11.7	73.6 \pm 12.2	79.0 \pm 15.3
Backward left	0.80 \pm 0.31	0.63 \pm 0.26*	6.20 \pm 2.08	6.34 \pm 1.07	85.1 \pm 18.6	90.2 \pm 25.7	90.1 \pm 19.0	100.0 \pm 18.9*
Left	0.69 \pm 0.28	0.63 \pm 0.24	7.09 \pm 2.13	8.01 \pm 2.80	93.3 \pm 9.71	97.2 \pm 10.1	98.0 \pm 6.6	103.0 \pm 6.4*
Forward left	0.74 \pm 0.25	0.63 \pm 0.25	6.87 \pm 2.89	7.81 \pm 2.89	99.8 \pm 14.8	105.0 \pm 15.4	105.0 \pm 11.6	110.0 \pm 10.6

COG, center of gravity; LOS, limit of stability; * significant difference, $p < 0.05$, compared to pre-training

Table 4. Mean \pm SD of COG sway velocity during the unilateral stance test

	COG sway velocity during unilateral stance with eye closed (EC) (degree/sec)		COG sway velocity during unilateral stance with eye open (EO) (degree/sec)	
	Pre-training	Post-training	Pre-training	Post-training
Right leg	1.60 \pm 0.90	1.40 \pm 0.59	0.57 \pm 0.13	0.61 \pm 0.16
Left leg	1.79 \pm 0.66	1.55 \pm 0.52	0.73 \pm 0.20	0.81 \pm 0.33

COG, center of gravity; No significant differences were found, $p > 0.05$, compared to pre-training

Table 5. Mean \pm SD of lower limb muscle strengths between pre- and post-training

	Right leg muscle strength (kg)		Left leg muscle strength (kg)	
	Pre-training	Post-training	Pre-training	Post-training
Hip extensor	28.70 \pm 8.07	29.90 \pm 6.90	27.50 \pm 6.69	30.10 \pm 7.00
Hip flexor	15.30 \pm 4.50	17.60 \pm 4.36 *	15.20 \pm 4.83	17.70 \pm 4.39 *
Hip abductor	26.50 \pm 7.47	26.10 \pm 6.18	26.40 \pm 6.89	26.10 \pm 5.98
Hip Adductor	19.20 \pm 5.05	21.20 \pm 5.03	19.60 \pm 5.03	20.40 \pm 5.28
Knee extensor	27.30 \pm 5.93	25.60 \pm 5.25	25.30 \pm 6.77	24.90 \pm 5.01
Knee flexor	12.60 \pm 3.55	14.70 \pm 2.70 *	13.10 \pm 3.15	14.80 \pm 2.98 *
Ankle dorsiflexor	19.00 \pm 4.48	23.80 \pm 4.28 *	18.10 \pm 5.13	23.80 \pm 4.40 *
Ankle plantarflexor	28.70 \pm 4.33	33.80 \pm 5.46 *	28.10 \pm 3.50	34.90 \pm 5.92 *

* Significance at $p < 0.05$ compared to pre-training

forward right ($p = 0.0213$); and a significant increase in the maximum excursion, the measurement of the maximum distance of the COG movement from the center point during the trial, in the forward ($p = 0.0154$), forward right ($p = 0.0279$), backward left ($p = 0.0361$), and left direction ($p = 0.0100$).

The unilateral stance test was used to quantify postural sway velocity during quiet standing on one foot on the force plate with eyes closed (EC) and eyes open (EO). There were no significant differences between pre- and post-training in any condition (Table 4).

The subjects' lower-limb muscle strength of 8 muscle groups (hip extensor, hip flexor, hip abductor, hip adductor, knee flexor, knee extensor, ankle dorsiflexor, and ankle plantarflexor) was measured in kilograms (kg) by the same researcher with a handheld dynamometer, pre- and post-training. The comparisons of lower-limb muscle strength between pre- and post-training are shown in Table 5. Four groups, the hip flexor (left leg, $p = 0.0013$; right leg $p = 0.0005$), knee flexor (left leg, $p = 0.0105$; right leg, $p = 0.0033$), ankle dorsiflexor (left leg, $p = 0.0005$; right leg, $p = 0.0001$) and ankle plantarflexor (left leg, $p = 0.0015$; right leg, $p = 0.0103$), showed significant improvement.

DISCUSSION

The post-test results, after the subjects had exercised on a Wii balance board, showed significantly better LOS than the pre-test results. The reaction time of the post-test subjects was significantly faster in the forward right and backward left directions. Reaction time represents the time lag between the prompt to move and the start of movement¹⁶. This result means the subjects were able to respond to

prompts faster and spend less time processing information than in the pretest. These results may be explained by an increased level of concentration which would have allowed the subjects to keep their body in the correct or best position. Such awareness would have affected subjects' motor systems, nervous systems and proprioceptive systems by enabling them to learn how to respond to the prompt¹⁷). A previous study found that exercises with the Nintendo Wii Fit™ improved muscle strength and the speed of the cognitive timed up and go test¹⁸), because Nintendo Wii Fit™ training involves considerable single-limb balance requirements and body-weight resistance workouts that intuitively produce these results.

The movement velocity is the average speed of the center of gravity (COG) movement that occurred between 5% and 95% of the endpoint of the excursion¹⁶). The results show a significant increase in movement velocity in the backward direction. In other words, the subjects were able to more rapidly move their COG. This may be a result of practice and repetition because the subjects learned the self-perceived cognitive response in order to implement a safer strategy (i.e., when they moved their COG, they did not experience the fear of falling) and achieve higher biomechanical efficiency¹⁹).

The maximum excursion is a feedback movement control that helps subjects to correct the direction of movement, while the endpoint excursion is the ability to pre-plan (feed forward control) the magnitude of the movement¹⁶). The maximum excursion showed significant increases in forward, forward right, backward left and left direction, and the endpoint excursion showed similar increases in the forward and forward right directions. A possible explanation for these results is that the Wii balance board detects the

COG of the subject and displays feedback on the monitor, which may promote the motor learning of the subject²⁰. Another possible explanation is that the subjects learned how to shift their body weights and how to coordinate their bodies in order to maintain balance, execute smooth movement, and reach different target positions through practice²¹.

A previous study found that postural stability decreased while weight-bearing asymmetry increased²², which means that subjects require greater postural control in a single-leg stance than in a double-leg stance²³. The pre- and post-training results of the present study were not significantly different in the unilateral stance test. However, the findings of the current study are not supported by previous research²⁴. These differences can be explained in part by the difference in the amount of exercise (2×30 min/week for 10 weeks in the previous study vs. 2×30 min/week for 8 weeks in the present study) and the type of Wii balance board exercises (yoga, balance, aerobic and strength activities in the previous study vs. yoga and strength in the present study).

The results of a recent study, which researched the effects of playing on a Nintendo Wii balance board on lower-limb muscle strength, showed that it could significantly strengthen the muscles of the lower limbs¹². In the video games, players have to follow fixed-movement patterns during the game. All of the movement patterns or positions would challenge players' muscles to contract as they would during exercise. Our results show that lower-limb muscle strength can be improved by Wii balance board exercise. However, only four muscle groups were significantly improved in this study (hip flexor, knee flexor, ankle dorsiflexor and ankle plantarflexor). In a previous study, the hip and knee extensor muscles of young adults²⁴, high body weight subjects and healthy subjects²⁵ were shown to have high strength without exercise, compared to the hip and knee flexors, which have low strength. Even people of different ethnicities show the same results²⁶. This outcome may be because activities in daily life often affect the hip and knee extensor muscles more often than the hip and knee flexor muscles. A previous study established that stepping significantly improves the strengths of only the hip abductor and knee extensor muscles²⁷. The results also showed that the knee extensor muscles were already strong through performing the activities that people often do on a daily basis. In addition, exercise to strengthen the lower-limb muscles elicited more improvement in the hip and knee flexor muscles than in the hip and knee extensor muscles²⁷. This result indicates that low-strength muscles may be more challenged and show more improvement than high-strength muscles. There were 11 positions in our present study's exercise program. From our analysis of muscle contraction, the hip and knee flexors were mostly used together with the hip and knee extensors in the same contraction. The results of the present study show that muscle strength was significantly improved in the hip and knee flexors but not in the hip and knee extensors by the same intervention, as a previous study indicated. The hip abductor muscles were used the same in all positions of the exercise program, but they showed no significant improvement, possibly because the exercise program's posi-

tions only challenged them a little. The ankle dorsiflexor and ankle plantarflexor muscles were heavily challenged to support the whole body weight to achieve the goal in almost all positions. A previous study concluded that the ankle plantarflexor and ankle dorsiflexor muscles are directly associated with the ability to control posture²⁸. The present study required the subjects to heavily contract their ankle plantarflexor and ankle dorsiflexor in order to participate in the Wii Fit exercise program.

A recent study demonstrated that decreased muscle power was associated with an increasing risk of falls⁵. In another study, Mayson et al. showed that greater lower-limb muscle strength was associated with better balance²⁹. It is possible that Wii balance board exercise not only improves muscle strength while promoting enjoyment through the game, as our results indicate, but it may also improve balance at the same time. When balance improves, the risk of falls may be reduced.

In conclusion, Wii balance board exercise can improve the balance ability and lower-limb muscle strength of overweight young adults. In addition, the Nintendo Wii balance board enhanced physical activity of the overweight subjects, which may have improved their quality of life. The findings of this study are subject to at least three limitations. First, these findings are limited by the use of a within-subject repeated measures design. Further study including a control group is needed. Second, this study only examined the effect of exercise on balance. Thus, further study is needed to investigate the effect of other factors such as muscle mass and fat mass. Finally, the subjects of this study were young adults, and the findings might not be transferable to other populations.

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