



Original Article

Effect of Wiihabilitation on strength ratio of ankle muscles in adults

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Abstract. [Purpose] This study was conducted to investigate the effect of Wiihabilitation on the ankle dorsiflexion/plantar flexion strength ratio in adults. [Subjects and Methods] Thirty-two healthy male volunteers were randomly assigned to two equal groups (experimental and control). Participants in the experimental group received a Wiihabilitation training program for six weeks. Data were collected using a Biodex system 3 Isokinetic dynamometer. Peak torques of the dorsiflexors and plantar flexors were measured at an angular velocity of 60°/sec which in turn were used to derive the ankle dorsiflexion/plantar flexion strength ratio. [Results] The mean values of the ankle dorsiflexion/plantar flexion strength ratio decreased significantly between before and after the training in the experimental group, meanwhile there was no significant difference between before and after the training period in the control group. [Conclusion] Wiihabilitation has an impact on the ankle dorsiflexion/plantar flexion strength ratio, so it can be considered an effective training tool in terms of the ankle strength ratio. Thus, it could be recommended for both prevention and rehabilitation of ankle instability patients.

Key words: Wiihabilitation, Strength ratio, Ankle instability

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INTRODUCTION

Wiihabilitation is a new idea that came about after introduction of Nintendo Wii Fit (Wii) for rehabilitation¹⁾. The Nintendo Wii is a low-cost commercial gaming system that provides an attractive means of facilitating exercise^{2, 3)}. Nintendo Wii Fit games encourage lower extremity movement, challenge balance, and require the player to remain in a standing position during play. These activities have the potential to address rehabilitation goals during patient recovery⁴⁾. The Wii has been used across a variety of clinical specialties and may potentially be a useful in the rehabilitation of a wide variety of conditions. Virtual reality-based training is a feasible and suitable therapeutic intervention for dynamic balance in older adults^{5, 6)}. The Nintendo Wii has been used as a tool that provides a novel way to interact with games in order to promote physical activities. It directs the user's motor response to be either specific or global to train motor abilities such as the range of motion of different limbs and whole body balance training⁷⁾. Addition of the Wii balance training program to conventional exercise programs has been recommended to improve ankle muscle strength in patients with functional ankle instability at a low cost⁸⁾. It has also been reported that virtual reality programs improve the static balance and dynamic balance of subjects with functional ankle instability and can be used safely and efficiently by patients⁹⁾.

The foot and ankle make up complex anatomical structures that contribute significantly to the function of the whole lower limb¹⁰⁾. Ankle joint stability involves co-contractions of surrounding muscles, recognized as agonist/antagonist activity, to facilitate reciprocal planar motion and protects and ensures efficient function of the joint¹¹⁾. Exercises should be planned to maintain a balance between agonists and antagonists. Muscle imbalance results in stresses on the underlying joints and ligaments¹²⁾. The strength ratios between antagonistic muscle groups have received considerable attention from clinicians

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during examinations and in monitoring of rehabilitation progress¹³). Also, they are thought to be clinically relevant because co-activation of opposing muscles across a joint may be important in maintaining dynamic joint stability¹⁴). The agonist/antagonist ratio was advocated to answer the dilemma regarding a means of more objectively evaluating and comparing the muscle balance (or imbalance) around a joint. Ratios for various muscle groups in both the upper and lower extremities have been developed and have become an improved gold standard for evaluation¹⁵).

Impaired foot function can give rise to many problems, such as strains on ligaments, poor co-ordination, and impairment of the function of the muscles¹²). Injuries to the ankle account for a large portion of the injuries to the lower extremity. Sprained ankle is the most common injury. It has been reported that approximately 80% of ankle sprains lead to injury recurrence and instability¹⁶). Ankle injury programs for prevention and treatment have disadvantages relating to time and cost. Repeated episodes of ankle sprain often occur despite introduction of many rehabilitation programs. Further research clearly is needed in this area in terms of both treatment and suggestions to reduce the rate of ankle sprains¹⁷).

To the knowledge of the authors, there are no previous studies investigating the effectiveness of Nintendo Wii Fit training on muscle strength ratios of ankle muscles. Additionally, many studies have investigated the inversion/eversion ratio, but patients still suffer from ankle instability. Furthermore, it has been reported that the concentric dorsiflexion/plantar flexion strength ratio was affected in chronic ankle instability (CAI) patients. Therefore, this study was conducted to investigate the effect of Nintendo Wii Fit training on the dorsiflexion/plantar flexion strength ratio as a new concept in the field of prevention and rehabilitation of ankle injuries.

SUBJECTS AND METHODS

Thirty- two healthy male college students from the Faculty of Physical Therapy, Cairo University, participated in the study. They were randomly assigned, using simple blind randomization by using procedures such as coin tossing into two equal groups: an experimental group (group I) and control group (group II) (Table 1). Participants in group I performed the Nintendo Wii Fit training program. Participants in group II were instructed to avoid participation in any strength training programs until after the post-training testing.

Participants were included in the study if they had good ankle muscle strength (grade four), normal flexibility of the ankle muscles, and a normal foot posture index. Participants were excluded if they had a history of previous ankle surgery or ankle injury, had a history of vestibular disorder, had previously participated in a strengthening or athletic training program, or had pronated or supinated foot postures. The foot posture index total score reference values were as follows: normal = 0 to +5, pronated = +6 to +9, highly pronated 10+, supinated = -1 to -4, and highly supinated -5 to -12.

The Ethical Committee of the Faculty of Physical Therapy, Cairo University, approved this study. All participants signed an informed consent form assuring that their participation was voluntary. A brief orientation session about the protocol of the study, its aims, and the tests to be performed was provided to each participant. The study complied with the ethical standards of the Declaration of Helsinki. The experimental procedures were conducted in the biomechanics laboratory of the faculty.

Nintendo Wii Fit includes over 40 games covering strength training, yoga, aerobics, and balance. The Wii training program in this study included an initial balance game (Table Tilt game) for 2/3 of session's total duration followed by a muscle strength game (Standing Rowing Squat game) for 1/3 of the session's duration. The sessions lasted up to 30 minutes and were performed 3 times per week for 6 weeks. The selected games target agonist-antagonist muscle contraction specifically dorsiflexion and plantar flexion.

The Table Tilt game was designed as a multidirectional balance game. In this game the participant tries to move a ball into a hole in a tilting platform. The platform tilted according to weight redistribution on pressure sensors in a Wii balance board (WBB). This game allowed motion in anteroposterior and mediolateral directions around the ankle joint. Furthermore, it trained the participant to control the position of the center of gravity (COG) during rapid changes of body movement.

The Standing Rowing Squat game is a muscle conditioning game that requires the player to perform squats by flexing the knees from a standing position until the flexed knee reach the required level. The required level was determined by COG movement displayed on the screen as a red dot that must be kept in a blue area in the final position of each squats. Performance of rowing squats correctly was scored and indicated with audible feedback. Squats are a form of closed chain exercise. They increase joint compressive forces leading to increased joint stability, increased muscle co-activation, and decreased joint shear forces¹⁸). They also dynamically recruit most of the lower-body musculature, including the quadriceps femoris, hip extensors, hip adductors, hip abductors, and triceps surae¹⁹).

A Biodex[®] system 3 Isokinetic dynamometer (Biodex Medical Systems, Shirley, NY, USA) was used for measuring the

Table 1. General characteristics of the participants in the experimental and control groups

	Experimental group (N=16)	Control group (N=16)
Age (years)	19.6 ± 1.3	19.6 ± 1.6
Weight (kg)	76.9 ± 5.6	72.9 ± 6.8
Height (cm)	173.2 ± 5.5	171.8 ± 5.7

peak torques/body weight (Nm/kg) of the ankle dorsiflexors and plantar flexors to calculate the dorsiflexion/plantar flexion strength ratio. The test procedure was performed according to manufacturer guidelines. Each participant was instructed to perform 5 sets of ankle plantar flexion and dorsiflexion through a 60° range of motion (ROM) (from 40° plantar flexion to 20° dorsiflexion) at an angular velocity of 60°/sec. This is the best angular velocity for measuring muscle strength because it is easy, safe, and a large number of motor units are recruited at low angular velocities²⁰. The test procedures were performed twice, once before and once after the Wii training program in the experimental group and at the beginning of the study and then after 6 weeks in the control group.

Statistical analysis was performed with IBM SPSS Statistics for Windows version 20 (IBM Corp., Armonk, NY, USA). 2 × 2 mixed design analysis of variance (ANOVA) was conducted to compare the isokinetic ankle dorsiflexion/plantar flexion strength ratio between the experimental and control groups before and after the training. Initially and prior to final analysis, data were screened for normality assumption using Shapiro-Wilks normality test. The alpha level of significance was set at 0.05.

RESULTS

The mean values of the ankle dorsiflexion/plantar flexion strength ratio decreased significantly ($F=7.41$, $p=0.01$) between before and after the training. The mean values of the ankle dorsiflexion/plantar flexion strength ratio were significantly decreased in the experimental group after the training when compared with before the training. However, there was no significant difference between before and after the training period in the control group (Table 2).

DISCUSSION

Nintendo Wii Fit was released just over six years ago as a mean of improving basic fitness and overall well-being. It has been adopted by a number of practitioners to assist in the treatment of various impairments. However, much work remained to be done to identify which type of participants would benefit from it, which system features are critical, and what types of training routine levels would work best. In addition, there have been few studies with randomized controlled designs that have investigated its effect on agonist/antagonistic muscle ratios and how this kind of training should be carried out.

The results of the current study revealed a significant decrease in the ankle dorsiflexion/plantar flexion strength ratio after the training compared with before the training in the experimental group. Meanwhile, there was no significant difference between before and after the training period in the control group. This might indicate an effect caused by the Wii training program as the control group did not receive training.

In the present study, the decreased strength ratio can be attributed more to the increased peak torque of the plantar flexors than the dorsiflexors, as the mean \pm SD values for the peak torque of the plantar flexors increased from 54.1 ± 22.85 Nm/kg before the training to 96.1 ± 30.83 Nm/kg after the training, an improvement of 42%. On the other hand, the mean \pm SD values for peak torque of the dorsi flexors increased from 38.46 ± 11.9 Nm/kg before the training to 55.73 ± 15.37 Nm/kg after the training, an improvement of 17.27%.

The abovementioned improvement was achieved through Wii training. This may be explained by Wii training acting as a form of neuromuscular training with feedback. Neuromuscular training is defined as a multi-intervention program with a combination of balance and strength training^{21, 22}. It improves mechanical leg muscle strength due to training-induced gains in neuromuscular function including strength gains^{23, 24}.

The interaction of balance and strength interaction is essential to lower limb function. Previous literature reported that lower extremity functional retraining depends not only on lower-limb mobility and bilateral coordination, but also requires other motor skills, such as balance control²¹. Also, adequate strength is necessary for normal movement patterns²⁵. Therefore, better controlled movement of joint results from increased muscle strength⁴. For this reason, combined strength and balance training should be incorporated into lower limb rehabilitation to augment the potential outcomes of training and rapid recovery. Wii training provides this in the same session.

Moreover, the squat is considered one of the best exercises for improving quality of life because of its ability to recruit multiple muscle groups in a single maneuver²⁶. It is estimated that over 200 muscles are activated during squat performance²⁷. The squat has biomechanical and neuromuscular similarities to a wide range of athletic movements and thus is included as a core exercise in many sports routines which designed to enhance athletic performance²⁸.

Table 2. Comparison of the mean changes in the ankle dorsiflexion/plantar flexion strength ratio between the experimental and control groups

	Experimental group		Control group	
	Before	After	Before	After
Ankle dorsiflexion/plantarflexion strength ratio (%)	78.8 \pm 31.7	57 \pm 18.2*	66.1 \pm 31.7	58.5 \pm 28.6

*Significant difference within group ($p<0.05$)

The feedback provided in Wii training is very important for user motivation and positive reinforcement²⁾. This feedback in the form of either knowledge concerning performance or knowledge concerning results, has been found to enhance motor skill learning²⁹⁾. It also improves reeducation of patient motor control³⁰⁾.

Motion about the ankle joint is controlled by combined actions of at least one pair of opposing muscles (the tibialis anterior and gastrocnemius). Therefore, the calf muscles are important in maintaining an erect posture and have a major role in controlling the ankle joint, which is often one of the first joints to help the body restore its equilibrium after perturbation³¹⁾.

Pronator weakness, evertor weakness, and calf dysfunction are all terms used to describe the cause of chronic ankle instability CAI¹⁵⁾. CAI patients have higher ankle dorsiflexion/plantar flexion strength ratio) resulting from lower plantar flexors strength³²⁾. In the same context, findings of the current study showed a decreased ankle dorsiflexion/plantar flexion strength ratio. For this reason, CAI patients may benefit from the Wii training principles, as the training program combines the benefits of balance training, closed kinetic chain exercise, and feedback effects.

Neuromuscular training programs are implemented with the aim of optimizing performance, preventing injury, or providing rehabilitation in functional ankle instability patients³³⁾. McGuine and Keene³⁴⁾ showed the effectiveness of neuromuscular training in reducing sport-related injury risk. It has also been shown to enhance functional performance after sports injury³⁵⁾. Any neuromuscular training program should incorporate a variety of physical activities that supports increasing strength and balance³⁶⁾.

This study was limited to healthy male adults who had no ankle deficits, and it only lasted for six weeks. The selected games for the training protocol were (Rowing Squats and Table Tilt) activities from Nintendo Wii Fit.

Based on the findings of the current study, Wiihabilitation is recommended as a preventive measure and treatment modality for ankle instability in sedentary individuals and athletes. Thus, the field of physical therapy may improve the rehabilitation protocol for ankle injuries by introducing Wiihabilitation as a novel method for rehabilitation.

Further studies should be carried with wider age categories, as this would be valuable for determining the responses of different age categories to Wii training. Patients with chronic ankle instability should be evaluated in future research. It is recommended to explore the correlation between the effect of Wii training and the results of functional performance tests. Additionally, extending the training period beyond two months may be advisable to elicit more significant effects. Also, choosing different games may add new results.

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