Balance and antecipatory postural adjustments in elderly fallers: effects of kinesiotherapy and virtual rehabilitation

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ABSTRACT

Aging causes a number of changes in motor control of the individual and consequently in postural adjustments. **Objective:** To evaluate the balance and anticipatory postural adjustments of the agonist muscles and the ankle joint antagonists and compare the effect of rehabilitation virtual and kinesiotherapy in the elderly. **Methods:** Twenty four elderly participated of this study divided into two groups. 12 participants and the kinesiotherapy group by 12 participants composed the virtual rehabilitation group, equally. The treatment protocol was conducted for six weeks. Virtual rehabilitation group used Xbox 360 with kinect and Your Shape Fitness Evolved game. In the kinesiotherapy group the same protocol exercises were performed. **Results:** The results indicated a statistically significant difference between pre and post intervention phases in Berg Balance Scale in both groups. There was decreased activation of tibialis anterior muscle in the right functional range of task after interventions, and increased lateral gastrocnemius muscle activation rights in the trunk flexion after training. No differences were observed in muscle activation between the two types of intervention. **Conclusion:** Protocols with therapeutic exercise and virtual rehabilitation were effective in improving balance and functional capacity of fallers, with no differences between the two types of intervention.

Keywords: Aged, Postural Balance, Physical Therapy Modalities, Virtual Reality Exposure Therapy

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Received on August 17, 2016.
Accepted on December 12, 2016.

DOI: 10.5935/0104-7795.20160036

INTRODUCTION

Motor responses promoted by posture disturbances are known as postural adjustments. These adjustments are controlled by the central nervous system (CNS) and depend on the information about the task performed and the environment. It can happen in two moments: before the disturbance, the anticipatory postural adjustment (APA), which is the muscular action that predicts and opposes the postural imbalance of a known movement before it occurs, usually between 0.2s before the beginning of the movement until 0,05s after the beginning of the movement, and after the disturbance, the compensatory postural adjustment (CPA), which is considered as the correction phase after the end of the movement with duration of 250 ms, in which the postural muscles aim to compensate the action of the focal muscles on the stabilization of the body.[1-4]

The use of virtual reality was introduced a few years ago as a new therapeutic approach in different areas of rehabilitation. This is due to the similarity of movements performed in this type of activity (*exergames*) with those used by physiotherapists in kinesiotherapy programs.

Virtual reality consists of an interaction of graphical images, in which there is a relation between the computational components and the motor sensory channels, which makes the simulation of a real environment.[5] Virtual rehabilitation has the advantage promoting multisensory experimentation through of visual and sound stimuli for enhancing attention, motor coordination, balance, strength and also for arousing interest in performing tasks with a greater number of repetitions due to its playfulness, and the restoration of physical and mental well-being.[6]

With aging, there is a decrease in the performance of postural control, and consequently, deficits in the ability to generate anticipatory responses to voluntary movements, making the elderly more vulnerable to falls. Therefore, among the rehabilitation protocols using virtual reality, some of them aim at balance training and motor coordination for the elderly in order to reduce their risk for falls.[5,6] However, there are still few studies comparing the effect of this type of therapeutic resource with traditional protocols used with the rehabilitation of these patients, such as kinesiotherapy, as well as its effects on postural control.

OBJECTIVE

To compare the effect of rehabilitation with virtual reality and kinesiotherapy on postural control of faller elderlies, specifically in balance and anticipatory postural adjustment of the agonist and antagonist ankle joint muscles.

METHODS

This was a quasi-experimental study without a control group. The study had a non-probabilistic sample of 24 individuals over 60 years of age (19 women and 5 men) conveniently recruited from a waiting list of the Clinic of Physiotherapy of *São Judas Tadeu* University, São Paulo, Brazil.

Subjects were randomly allocated into two groups (random numbers in sealed envelopes), and one group with 12 subjects was treated with virtual rehabilitation (69.2 ± 3.2 years, 151 ± 6 cm, 68 , 1 ± 10.2 kg), and a kinesiotherapy group, also with 12 subjects (67.6 ± 3.5 years, 153 ± 3 cm, 68.7 ± 11.7 kg).

The inclusion criteria were: individuals over 60 years of age with a history of at least one fall over the previous 12 months, and without sphincter alterations either urinary or fecal, renal insufficiency, neurological diseases, use of catheter, thrombosis, cardiac insufficiency, uncontrolled blood pressure, and medical contraindication to exercise. The exclusion criteria were: dyspnea on exercise, less than 80% and participation in another physical activity program.

This study was approved by the Ethics Research Committee of the São Judas Tadeu University, and received the registration number 7289. All participants voluntarily signed the informed consent term, in accordance with Resolution 466/12 of the Brazilian National Ethics Committee for Clinical Research.

In order to evaluate the balance, the Berg balance scale was used and for the evaluation of postural control the surface electromyography (EMG) of the right and left anterior tibialis muscles (AT), right and left lateral gastrocnemius muscles (LG) were used.

For the assessment of postural control, the Bigongari evaluation protocol,[7] in which two previously trained motor tasks (Figure 1) were analyzed: the 90 ° flexion of the shoulder (FLX) of the dominant limb with an additional load of 2kg, and the functional reach (RCH), in which the patient performs a 45º flexion of the trunk and a flexion of the shoulder of the dominant limb to touch a table in front of him.

In order to determine the beginning of the upper limb movement, an accelerometer was used and a footswitch was used to indicate the exact moment when the hand touched the table during the functional reach task.

The three instruments described were synchronized by the same signal conditioner that sends the digitized signals to a computer controlled by EMG Lab V 1.1 EMG System of Brazil, which in turn manages the data acquisition and storage.

The movements were self-initiated after a beep and performed at the maximum speed possible. The accelerometer was placed on the dorsal part of the distal radio-ulnar joint (wrist) during the execution of both tasks, the FLX and RCH. They were repeated 10 times, totaling of 20 movements with 30 seconds of interval between each one.

The analyzed variables were the time series of the EMG activity of the selected muscles. In the FLX task, the initial ($t_{initial}$) and final (t_{final}) times of the shoulder movement were indicated by the linear acceleration of the shoulder, obtained by the accelerometer. During the RCH task, the t_{final} was the moment the participant touched the footswitch on the table. From the EMG of each muscle, the Root Mean Square (RMS) value was calculated as the parameter of signal amplitude of the APA window [$t_{inicial}$-200, $t_{inicial}$+50] ms.

The raw EMG signals had their mean deleted, rectified and filtered with the 4th order Butterworth low pass filter of 200 Hz. The acceleration and footswitch signals were filtered with the 4th order Butterworth low pass filter of 20 Hz. Therefore, the EMG, the accelerometer and the footswitch signals were ready for the determination of the APA parameters and ranges.

Intervention

This research was carried out in the kinesiotherapy laboratories of the physiotherapy clinic of the university. The patients undertook two physical therapy sessions per week for six weeks, totaling 12 sessions of 50 minutes each. This fashion was applied for both virtual rehabilitation and kinesiotherapy interventions.

1- 90º shoulder flexion of the dominant limb with additional load of 2kg
2- Functional reach with a 45º trunk flexion and shoulder flexion of the dominant limb

Figure 1. Visual representation of the experimental conditions of the motor tasks

The interventions were performed with the following materials: 42" TV sets connected to the Kinect Xbox 360 consoles and the game *Your Shape Fitness Evolved*.

Virtual rehabilitation protocol

The researcher simultaneously applied the protocol on two participants in an interposed way, i.e. while one patient performed one type of exercise, the other rested and so on until the end of the protocol. Two game types were used. In the first type, the participant had to reach specific targets. These exercises were carried out in three sets of 1 minute with a break between each series of 1 minute, totaling 3 active minutes and 3 resting minutes for each exercise. In the end, each participant performed 9 minutes of activities and 9 minutes of rest. In the second game type, the participant had to perform a task proposed by a *virtual personal trainer* who provided feedbacks on how to correctly execute the movements and achieve the ideal results for each exercise.

A complete cycle of the game is composed of two sets of three exercises (Leg Curl, Step and Dodge) and has an average time of 5 minutes. There were three cycles, totaling 15 minutes of exercises and 15 minutes for resting for each participant.

At the end of the service, each participant performed 24 minutes of exercise with equal resting time. The following exercises were applied:

1. Virtual Smash: The participant had to break floating blocks as fast as possible by hitting the center of blocks. Movements performed for upper limb (UL): shoulder in adduction with flexion and internal rotation; elbow in flexion and extension; forearm pronated; neutral grip; and rotation of trunk. Movements performed for the Lower limb (LL): neutral ankle, hip abduction, and hip and knee half-flexion; and unipedal closed kinetic chain exercise.
2. Ligth Race: The participant had to step as fast as possible on the lights on the floor at a specific rhythm. Movements performed for UL: Alternate movements of adduction and abduction, hip flexion and extension, knee flexion and extension, dorsiflexion and plantar flexion.
3. Loop - a – Hoop: The participant had to make circular movements with the hip as fast as possible until all the balls are floating without letting the hula hoop fall. Movements performed: circular movements of the hip with abducted UL and closed kinetic chain exercises.
4. Leg Curl – Lower limb initial position: semi-flexion of hip and knee, slight dorsiflexion of ankle. Upper limb initial position: hands on the iliac crests. Movements: unipedal open kinetic chain exercise, knee flexion and hip extension with plantar flexion, followed by the inverse movement to return to the starting position.
5. Step – Initial position: Lower limb: abduction and adduction, flexion and extension of knee and hip with slight dorsiflexion. Upper limb - flexion and extension of shoulder with extension of elbow, neutral wrist, and fingers in extension. Movement: combined movement of UL and LL in open kinetic chain.
6. Dodge – Initial position: Upper limb: arms to the side of the body with flexed elbow, neutral wrist and flexed fingers. Lower limbs: neutral ankle, hip abduction and semi-flexion of hip and knee. Closed unipedal kinetic chain exercise. Movement: Plantar flexion, extension of knee, hip and internal rotation of hip. To return to initial position, dorsiflexion, external rotation and knee and hip flexion.

Kinesiotherapy protocol

In this protocol, the same exercises of the virtual rehabilitation protocol were performed, with the same activity and rest time for each exercise.

With verbal commands, one researcher directed the performance and correction of each exercise to replace the video game. The group was simultaneously trained, and while half of the group practiced the exercise, the other half was at rest.

At the end of the session, each participant performed 24 minutes of exercise with an equal resting time. The following exercises were applied:

1. Punch simulation, with crossed movements. Movements performed: Upper limbs: shoulder in adduction with flexion and internal rotation; elbow in flexion and extension; pronated forearm; neutral wrist; and rotation of trunk. Lower limbs: neutral ankle, hip abduction and hip and knee semi-flexion. Unipedal closed kinetic chain exercise.
2. Stepping on colored semicircle ribbons on to the floor, following a sequence of colors proposed by the therapist. Movements: Lower limbs: alternate movements of adduction and abduction, hip flexion and extension, knee flexion and extension, dorsiflexion and plantar flexion.
3. Circular movements with the hip. Movements performed: circular movements of the hip with abducted UL. Closed kinetic chain exercises.
4. Initial position: Lower limbs: semi-flexion of hip and knee, slight dorsiflexion of ankle. Upper limbs: hands on the iliac crests. During the movement: unipedal open kinetic chain exercise, knee flexion and hip extension with plantar flexion followed by the inverse movement to return to the starting position.

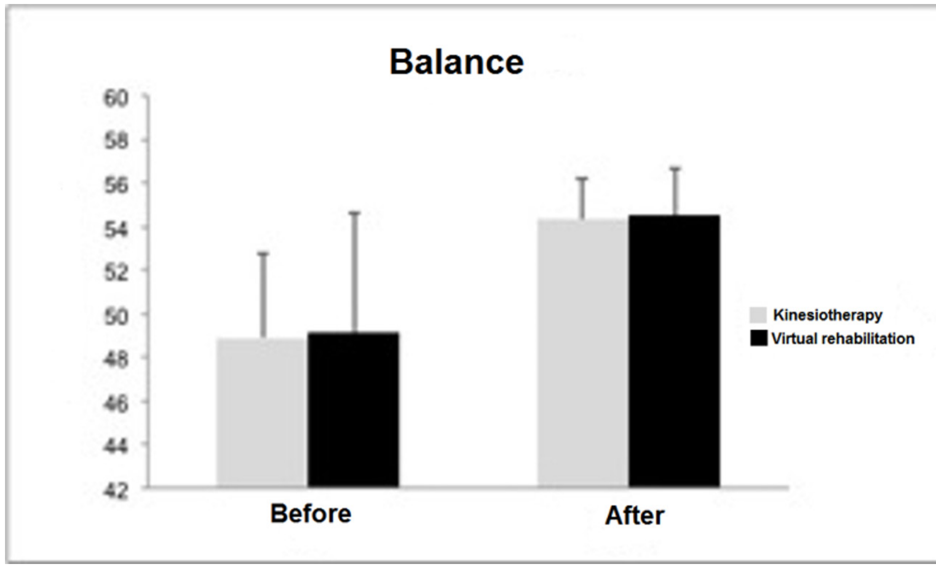
5. Initial position: Lower limbs: abduction and adduction, flexion and extension of knee and hip with slight dorsiflexion. Upper limbs: flexion and extension of shoulder with extension of elbow, neutral wrist, and extended fingers. Movement: combined movement of UL and LL in open kinetic chain.
6. Initial position: Upper limbs: arms to the side of the body with flexed elbow, neutral grip and flexed finger. Lower limbs: neutral ankle, hip abduction and hip and knee semi-flexion. Unipedal closed kinetic chain exercise. Movement: plantar flexion, extension of knee, hip and internal rotation of hip. To return to the initial position, dorsiflexion, external rotation and knee and hip flexion.

Statistical analysis

The data was reported as mean and standard deviation of the mean. The analysis of variance (ANOVA) of two factors (groups x phases) was used to analyze the Berg Balance Scale. Three-way ANOVA (task x group x phase) was used to analyze the electromyographic activity. The Tukey post hoc test was used to analyze the differences. Statistical analyzes were performed with the Statistical Package for Social Sciences (SPSS) version 17 for Windows. The level of significance was 5%.

RESULTS

Figure 2 shows the mean and standard deviation values of the Berg balance scale in the kinesiotherapy group before (48.9 ± 3.9) and after (54.3 ± 1.9), as well as in the virtual rehabilitation group before (49.1 ± 5.5) and after (54.5 ± 2.2). There was a significant difference between the two time points of both groups. The post-intervention evaluation had better results when compared to the pre-intervention phase for both groups. There was no significant difference in between the groups.



*p< 0.05

Figure 2. Mean and standard deviation of the Berg balance scale score for kinesiotherapy and virtual rehabilitation groups before and after the interventions

Electromyography

The effects of the tasks, intervention and evaluation over the Root Mean Square (RMS) on the activation of the tibialis anterior (right and left) and lateral gastrocnemius (right and left) muscles were evaluated by three-way ANOVA. The tasks affected the RMS value of the right anterior tibial muscle ($F_{1,23}$ = 6.7; p = 0.02). The interaction between task and intervention affected the RMS value of the right anterior tibial muscle ($F_{1,23}$ = 4.7; p = 0.04). The reach task showed greater activation (p <0.05). In the reach task, the RMS value decreased after the training (p <0.05). The data presented in table 1 demonstrate that the three factors did not affect the RMS value of the left anterior tibialis and left lateral gastrocnemius muscles.

The task, ($F_{1,23}$=4.6; p=0.02), and the evaluaton time point ($F_{1,23}$=6.1; p=0.02) affected the RMS value of the right lateral gastrocnemius muscle. The highest RMS value of the right lateral gastrocnemius muscle was observed in the shoulder flexion task (p<0.05) and after the training (p<0.05).

Therefore, it was observed that there was a decrease in the activation of the right anterior tibial muscle in the RCH task after the intervention, and an increase in the right lateral gastrocnemius muscle activation in the FLX task after the training. There were no differences in muscle activation between the two types of intervention (kinesiotherapy and virtual rehabilitation).

DISCUSSION

The objective of study was to compare the effect of rehabilitation with virtual reality and kinesiotherapy in balance and postural control in elderly fallers. The results suggest that both virtual reality and kinesiotherapy interventions were effective in improving the balance of the elderly participants. However, when comparing the degree of improvement obtained between the two types of intervention, there was no difference between the groups, indicating that virtual reality rehabilitation can be as effective as kinesiotherapy in improving the balance and motor performance of the elderlies. Also, from a public health perspective, these results shows the importance of physical activity to enhance muscle function and improve balance.

The Berg Balance Scale (BBS) was used to evaluate the balance, which provides a quantitative evaluation of functional balance, determines the risk factors for loss of independence and falls of elderlies, and also evaluates the effectiveness of interventions in clinical practice and in research.[8] After the intervention, there was a significant improvement in the balance of patients in both groups, kinesiotherapy and virtual reality. Similar findings[9] on the balance of elderly fallers a 12-week training protocol with virtual reality.

Since it is a scale that reproduces functional movements, the improvement of the BBS scores after the interventions suggests an improvement in activities of daily life, which may allow greater independence and affect decision making by the participants, since the fear of recurrent falls interferes with socialization.[10]

One of the main strategies used by elderly people to maintain stability in situations of imbalance is the co-activation of agonist and antagonist muscles, especially of the ankle joint.[11] As a result, the EMG was performed

Table 1. Mean and standard deviation of the RMS value of the anterior tibialis and lateral gastrocnemius (right and left) muscles in the tasks of functional reach and shoulder flexion before and after the kinesiotherapy and virtual rehabilitation during the anticipatory postural adjustment (APA)

Task	Evaluation	Intervention	Right anterior tibialis muscle	Left anterior tibialis muscle	Right lateral gastrocnemius	Left lateral gastrocnemius
Functional reach	Before	Kinesiotherapy	0.60±0.09	0.49±0.11	0.28±0.05	0.33±0.07
		VR	0.49±0.09	0.56±0.11	0.46±0.05	0.47±0.07
	After	Kinesiotherapy	0.68±0.19	0.24±0.21	0.47±0.10	0.51±0.13
		VR	0.56±0.11	0.48±0.12	0.44±0.05	0.35±0.08
Shoulder flexion	Before	Kinesiotherapy	0.44±0.09	0.47±0.11	0.39±0.05	0.47±0.07
		VR	0.56±0.09	0.53±0.11	0.49±0.05	0.53±0.07
	After	Kinesiotherapy	0.12±0.19	0.61±0.21	0.61±0.10	0.57±0.13
		VR	0.27±0.11	0.42±0.12	0.55±0.05	0.58±0.08

with the objective of evaluating the muscle recruitment type used by the elderlies to maintain stability and balance during two motor tasks that tend to cause postural imbalances: functional reach and shoulder flexion.

During the electromyography evaluation, the RMS served as an indicator for the degree of muscular activity. It was observed that there was no difference in muscle activation during APA between the patients of both groups, kinesiotherapy and virtual rehabilitation. The right tibialis and right lateral gastrocnemius muscles showed different activation in relation to the two tasks performed, functional reach and flexion of the shoulder. The right anterior tibialis muscle showed greater APA in the task of functional reach and the right lateral gastrocnemius muscle showed a greater APA in the task of shoulder flexion. The other muscles did not have different APA between both tasks. The right lateral gastrocnemius muscle increased APA after both interventions. The right anterior tibialis muscle decreased APA after the intervention in the task of functional reach of both the kinesiotherapy group and in the virtual rehabilitation.

These data demonstrate that after both treatment groups, kinesiotherapy and virtual rehabilitation, there was a reduction in the recruitment of the anterior tibialis muscle and an increase in recruitment of the lateral gastrocnemius muscle, both on the dominant side. This indicates a decrease in the co-activation of the ankle joint agonist and antagonist muscles. Modification of the right-side muscle activation pattern shows that dominance plays a key role in postural control, as well as in other motor skills. Postural control tasks with manual support showed that when the support was done with the dominant hand, it was more successful than compared to the contralateral hand.[12]

Elderly patients present greater muscle co-activation for maintaining static upright posture and functional reach when compared to younger subjects. This increase in muscle co-activation has negative effects on postural control and movement, as it reduces the degree of available freedom of the nervous system to perform the anticipatory and compensatory postural adjustments.

The excess of co-activation can be explained by the lack of supraspinal modulation of alpha and gamma motor neurons that modify the tension-length curve of the muscle and hinder the control of muscle activation characteristics. Lesions in the CNS as in children with cerebral palsy lead to increased tonus, decrease of the stretch reflex threshold, muscle weakness and consequently deficits in movement and posture control. In addition, co-activation is observed in healthy children of less than four years of age, suggesting CNS immaturity.[13] Subjects with Down syndrome use co-activation rather than reciprocal inhibition.[14] Therefore, for studying the CNS of the subjects of this study, we suggest the use a more conservative strategy, before the intervention, with the decrease of joint flexibility and consequently of the movements. Thus, both the kinesiotherapy protocol and virtual reality reduced the co-activation of the ankle joint muscles, what suggests an improvement in the postural control the elderlies.

The fact that the intervention with virtual reality has generated improvements in the balance of the elderlies similarly to that was observed with the kinesiotherapy protocol allows the use of this type of resource in the training of the elderlies both in physical therapy clinics and long term elderly treatment institutions or even in the elderlies' residence. This is of major importance especially for those who do not have access to a rehabilitation centers. In addition, training with virtual reality also presents a playful character, which may encourage the elderly to continue training.

CONCLUSION

The results of this study demonstrated that training with the kinesiotherapy and virtual rehabilitation protocols were effective in improving the balance of the elderlies, with no differences between the two types of intervention. The results also indicated that it is possible to affirm that the physiotherapist has one more available resource to provide an innovative therapy to their patients, without losing the initial objectives of the treatment of elderly fallers. Virtual reality, as a therapeutic tool, adds positive aspects to the acceptance of the therapy, due to the playfulness and various possibilities of tasks to be performed with the proposed games.

The efficacy of kinesiotherapy in this study reinforces the importance of biomechanical and functional understanding for improving balance and postural adjustments of elderly fallers. It also proves that such objectives can be achieved without costly resources, what allows the achievement of objectives to an immensely larger demand, regardless of social status and environment.

We suggest further studies with this population and proposition with the objective to analyze other variables.

Sugerimos que mais estudos com essa população e proposição sejam realizados objetivando análises de outras variáveis.

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