Differences in effects when using virtual reality balance trainer or wobble board in terms of postural responses

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ABSTRACT

The aim of this study was is twofold: firsts to examine whether the choice of balance training device has any influence on overall therapeutic outcome and secondly whether it affects postural strategy in patients with low-back pain. Six patients used Gamma trainer with virtual reality games and five patients used a wobble board. Before and after the treatment the postural responses were tested. 5 out of 11 patients improved their postural responses in terms of latency and stability. Contribution of the balance training to the improvement of postural responses was not statistically significant (ANOVA, $p > 0.05$), but differences in functional reaching test were statistically significant ($p = 0.0215$) for each group ($p = 0.0419$), while differences between the groups were not found significant ($p = 0.1257$). In spite of small number of participating subjects, we may suggest that balance training improves postural responses and functional reaching in people with low back pain regardless of the choice of the balance training device.

1. INTRODUCTION

Chronic low-back pain is one of the most common causes of absence from work in the EU, U.S. and elsewhere in the world (Blasche et al, 2013). In subjects with acute and chronic low-back pain a change in the activation of certain muscle groups appear, in particular of the trunk muscles. A delay in the activation of trunk muscles can be considered as an impairment of the neuromotor control of spinal stabilization system. This actually leads to the changes in the behaviour of the trunk muscles. These muscles provide stability and control of the stiffness of the spine when compensating for internal and external forces generated by the movement of the entire body. Hodges (Hodges et al, 1998) has shown that the co-ordination of the trunk muscles correlated with the movement of the lower limbs in all subjects, those w/o low-back pain. The published results showed latencies in the electromyographic activity of certain abdominal muscles for movement of the lower limbs as a result of (un)expected perturbations in all directions in people with low-back pain.

Therefore rehabilitation is recommended not only in the chronic phase, but also in the sub-acute, when usually the healthcare professionals recommend resting. Particularly balance training that also activates trunk muscles is recommended. Indeed, balance training has proven to be more effective than individual muscles strengthening (Blasche et al, 2013). However, the exercises should be target based, repeatable and be conducted for two consecutive weeks.

In the study we were particularly interested in the implications of balance training on postural responses in persons with low-back pain as reported on latencies of responses in selected directions of perturbations. We also investigated whether the functional progress in rehabilitation depends on the method and device chosen for balance training.

2. METHODOLOGY

2.1 Balance training equipment

The Gamma trainer (PHU Technomex Sp., Gliwice, Poland) is a simple platform for evaluation and neuromuscular coordination training, weight transfer and balance training. It is designed as a pressure platform with two plates, each measuring the vertical component of the reaction force with four sensors and calculates the centre of the reaction force. These two measures enable calculus of the common centre of gravity (COG).

Besides COG a linear acceleration and speed of the COG can be also calculated. Games presented in a virtual environment to attract attention, enabling a variety of settings, thus promoting neuromuscular coordination, reflex movements, etc. The user interacts with the game through the COG tracking. For the case of loss of balance lateral handles were available, but to prevent a fall a physiotherapist who monitors the whole process, was also present (Fig 1a). The wobble board (diameter 41/9 cm, max tilt 22^{o}) is designed as a rehabilitation tool for balance training, muscle strengthening and concentration. The disc is designed as a movable surface, which requires rather good balance of the user. Due to the low-back pain or neuromuscular disorders or diseases such balancing required full time assistance of the physiotherapist (Fig. 1b).

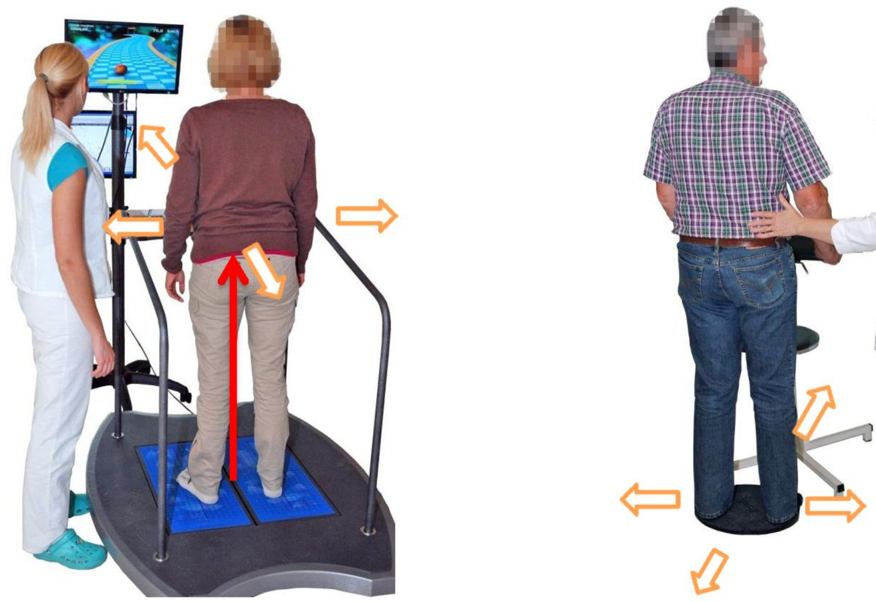

Figure 1. ***a)*** The *Gamma device consists of two pressure plates, which monitor the movement of the vertical component of the gravity force. The appropriate information is then displayed in the form of a moving object in a virtual environment.* ***b)*** *On the wobble board besides balance skills additional muscle strength is required. And in subjects with low-back pain or balance disorders also an assistance of a physiotherapist is mandatory.*

2.2 Subjects

In the study 13 outpatient volunteers participated (3 men, 8 women, mean height 167.82 ± 8.23 cm, mean age 56.81 ± 12.36 years, mean weight 72.73 ± 19.51 kg, right-handed) and 11 of them also completed the clinical and the assessment protocol. The inclusion criteria were: chronic low-back pain expanding into the lower limb with the possibility of malfunction thoracic spinal roots, which does not cause paresis of muscles of the lower limbs. Exclusion criteria were as follows: 1) a variety of joint injuries in the lower limbs (hip, knee, ankles), causing an additional pain and disruption of passive or active joint mobility, 2) various traumatic situation in the lower extremities, causing abnormalities in the lower limbs, 3) associated impairments or diseases of the central nervous system, 4) peripheral or central paresis of the lower limbs muscles. 6 patients out of 11 were randomly selected for balance training on Gamma device (group G), and the remaining 5 patients were set for the wobble board (group W) balance training.

2.3 Equipment for postural responses assessment

A modified device BalanceTrainer (Fig. 2) equipped with four electric motors was used to capture postural responses after the perturbation at the level of pelvis. The motors were computer controlled via an interface (National Instruments PCI - 6229, USA), instrumented with suitable electronic circuits and high-speed automatic thermal fuses, which ensure 100% safety, despite the low level voltage supply of 24V from batteries (Cikajlo and Matjačič, 2009) was used. Mechanical constraints of the device provide a safe standing frame tilt in all directions of the transverse plane (Fig. 2b) and prevent a fall of the person standing in the frame.

The computerized system generated an electrical pulse (duration 600 ms) after the operator (physiotherapist) pressed the button, which activated the electric motor and caused a sudden mechanical tweak of the standing frame in a randomly selected direction. The computer randomly selected one of the 4 main directions (forward -

FW right - RT , left - LT and back - BW) or a combinations of them (forward / right - FR , back / right - BR , forward / reverse - FL, back / left - BL). The onset of the mechanical tweak or perturbation was also randomly selected, within 1s after the activation in the user interface and the magnitude of displacement was approximately 10 cm. Thus we ensured the assessment environment where the subject could not predict the direction or the accurate onset of the perturbation. The participating subjects positioned in the standing frame stood on the force plate, which measured the changes in the COG (Cikajlo and Matjačić, 2009). Instead of the 6 degrees of freedom tensiometric force plate, we used a simple force plate with four pressure sensors measuring only the vertical component of the reaction force (Wii Balance Board, Nintendo, USA). We calculated a common vertical reaction force, COG using the data of four pressure sensors and compared the outcomes with the normative assessed in healthy subjects (Cikajlo and Matjačić, 2009). The complete measurement lasted 6s, thus the complete postural response was assessed as well as potential problems in the "recovery" after the response.

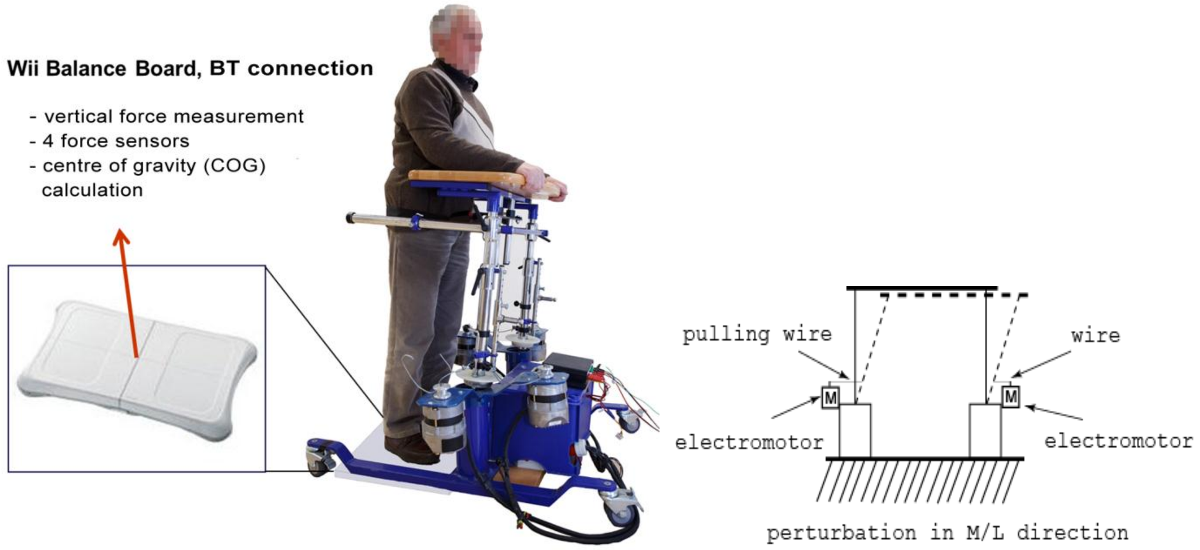

Figure 2. ***a)*** *Postural perturbation generation and response assessment device was based on the generation of mechanical tweak in the level of pelvis in 8 directions of transversal plane. Deviation of the COG was measured by simple force plate (Nintendo Wii Balance Board). A force plate was connected to the measurement system via bluetooth (BT) connection.* ***b)*** *The device forces a mechanical disturbance in the medio-lateral (M / L) direction at the level of pelvis. The person in the device responds to the disturbance of postural response to prevent a fall.*

2.4 Protocol of the study

Targeted therapy lasted 14 days (5 consecutive days / week) and comprised of hydrotherapy, individually guided exercises in relation to the pathology and treatment of the pain with functional electrical stimulation and balance training. The therapy was common to all subjects, while subjects performed balance training in two separate groups. Subjects assigned to balance training with the device Gamma (G) performed training in the following chronological order: 5 minutes of training, 5 minutes of passive rest and 5 minutes of training with the same task in a virtual environment.

Balance training with the Gamma device consisted of two tasks in a graphical computing environment, two games. The first task requested from subjects to sort the objects by shifting the weight and thus the centre of gravity to the left (right) or front (back). In the second task the user rolled the ball on a selected virtual path. The direction of the ball was determined by shifting the weight (COG) left-right and the speed was pre-set by the physiotherapist.

Subjects performing balance training on wobble board (W) followed the same daily schedule: 5 minutes of balance training on the board (weight transfer in the A/P and M/L direction), 5 minutes of passive rest and repeat the balance training for additional 5 minutes.

Prior to, and after the therapy postural response assessment and some clinical tests (functional reaching, standing on the left and right leg) were carried out. Functional reaching (FD) is an assessment test where the subject is trying to reach the maximal distance with hands during the statically stable stance (Duncan et al, 1990). We carried out 3 assessments for each directions of perturbation (FW, BW, LT, RT, BR, BL, FR, and FL).

2.5 Evaluation of postural responses and clinical tests

The postural responses were analysed with special postural response analysis tool (Cikajlo and Matjačić, 2006). The assessed COG postural responses were analyses for each direction of perturbation. Each response was compared with a normative data (Cikajlo and Matjačić, 2009, Winter, 2009) in terms of amplitude overshoot and latency. If the overshoot or latency was within 2 standard deviations of the normative, the response had been considered acceptable. Otherwise, each unacceptable response was carefully examined and major changes were highlighted. Slow reaction of the patient (large latency) or with a large overshoot (more than 2 standard deviations) implies a high degree of instability in the response.

Additionally we also statistically tested the outcomes of the clinical tests before and after therapy. Mean and standard deviation for each group of subjects (G, W) and Analysis of Variance was conducted to see whether the differences in performance measures for each study condition were statistically significant (Statistical Toolbox, ANOVA -2, Matlab, MathWorks Ltd., Natick, USA).

3. RESULTS

In 2 subjects from different groups (W, G) we did not find any deviations from the postural responses normative (Cikajlo and Matjačić, 2009) and/or minor deviations were limited to one direction and this remained unchanged after therapy. In three other subjects, we found minor problems (oscillation response, increased response amplitude in the wrong direction, delayed response) in postural responses to the perturbations in those directions in which responses from non-dominant limb were expected (directions of perturbation: FL, BL, LT and partly BW). In these three subjects there was minor progress after treatment (Fig. 3), especially the response in the AP direction became stable without a delay and matched the normative. The Fast Fourier Transform (FFT) peaks appear at lower frequencies in AP direction and vertical force, however, peak at higher frequencies in ML directions means more oscillations and a delayed response. However, the rest of the subjects (3 from G and 3 from W group) reduced the latencies of the responses for perturbation directions LT, BL and their postural responses amplitudes in AP direction for perturbation directions FL and BL became more compliant with the normative, but only for group G (Fig 4).

The clinical outcomes revealed improvement of subjects' functional capabilities; FD increased from 20.2 (SD 9.6) cm to 26.0 (SD 7.5) cm for W and from 30.5 (SD 4.4) cm at 32.0 (SD 4.6) inches for group G after the therapy (Table 1). The ability to stand on the left (non-dominant) leg increased from 18.8 (SD 23.7) s to 22.7 (SD 22.3) for group W and from 20.8 (SD 18.1) s to 21.7 (SD 20.5) s for group G. The ability to stand on the right (dominant) leg increased from 11.4 (SD 15.6) to 18.0 (SD 5.2) for group W and from 21.8 (SD 22.0) to 24.2 (SD 21.2) for group G. The 2 -way ANOVA found no differences between participant groups in standing on the single extremity were statistically insignificant ($p > 0.05$, Table 1) and also the balance training had no significant impact on standing on a single extremity. The differences between groups W and G in functional reaching were statistically significant ($p = 0.0419$) and this may confirm the effectiveness of the therapy ($p = 0.0215$). However, interaction between the two groups before and after treatment was not statistical significant ($p = 0.1257$).

Table 1. *Clinical outcomes (mean and standard deviation).*

	GROUP	ASSESSMENT				P group effect	P time effect	P interaction
		1	STD	2	STD			
FUNCTIONAL REACHING (cm)	W	20.2	9.6	26.0	7.5	**0.0419**	**0.0215**	0.1257
	G	30.5	4.4	32.0	4.6			
STANDING ON THE LEFT LEG (s)	W	18.8	23.7	22.7	22.3	0.9441	0.5697	0.976
	G	20.8	18.1	21.7	20.5			
STANDING ON THE RIGHT LEG (s)	W	11.4	15.6	18.0	5.2	0.9724	0.1013	0.721
	G	21.8	22.0	24.2	21.2			

P < 0,05

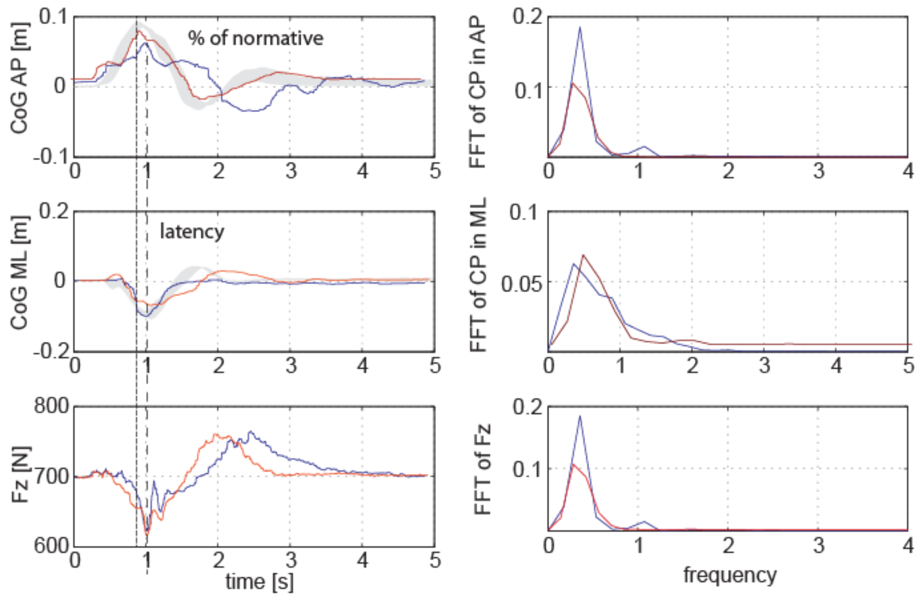

Figure 3. *Averaged postural responses (COG and vertical force F_z) in anterio-posterior (AP) and medio-lateral (ML) direction on perturbation in FL direction for the three subjects that demonstrated minor progress after the therapy (red, prior the therapy – blue, shadow area – normative). The response in AP direction became compliant with the normative. Two parameters were compared with the normative– latency and amplitude.*

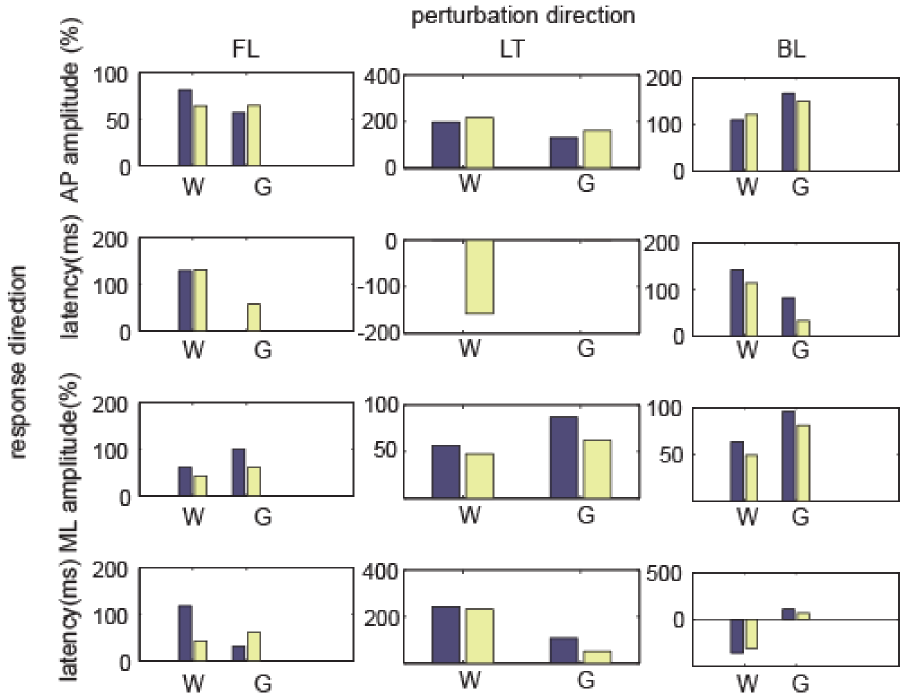

Figure 4. *Latencies and amplitude (in % of the normative) of the postural responses (COG) in anterio-posterior (AP) and medio-lateral (ML) direction on perturbation in FL, LT and BL directions for wobble group (W) and Gamma trainer group (G) before and after the therapy.*

4. DISCUSSION

Assessment and evaluation of postural responses has been considered important additional information to the clinical tests of balance, especially because it enables identification of functional problems with dynamic balance for each direction and thus presents important information in fall prediction (Cikajlo and Matjačić, 2009). The participating subjects with low back pain had minor problems with postural responses to the mechanical perturbations at the level of pelvis mainly due to the less reliable loading of the non-dominant extremity. Usually the cause of unreliability was a strong pain at the lumbar level of the spine when the non-dominant extremity was loaded. Some subjects demonstrated noticeable improvement after the therapy – the postural responses "returned" in the range of standard deviation of the normative for healthy, neurologically intact persons. Therefore we may confirm that subjects who did not experience balance disorders in spite of the low-back pain demonstrated similar postural activities than completely healthy persons (Davarian et al, 2012).

The clinical outcomes demonstrated improvement of functional capabilities in subjects with low-back pain after therapy that consisted of pain therapy with electrostimulation, hydrotherapy, individually guided exercises and balance training. Ability to stand on a single foot was shorter than in neuromuscular intact persons, which was due to the low-back pain. However, the study demonstrated improvement in quiet standing, especially in the group practicing balance with the Gamma trainer. There was no improvement in the group that practiced balance on the wobble board. Such training also had no effect on the improvement of other parameters, in particular, musculoskeletal pain after the therapy (Blasche et al, 2013). In contrast the FD test demonstrated significant improvement of functional reaching of the group W, which was also shown by the statistical test. The outcomes of the research on the effective improvement of balance ability of older people after 9 weeks (twice per week) of balance training on balance wobble board (Ogaya et al, 2011) can confirm that such balance training with the wobble board must have also contributed to the results of the FD test. Indeed the study was focused on elderly population, who were able to successfully control the movement of the COG in order to maintain the upright posture on the unstable base, such as wobble board. Similar results, demonstrating average improvement of all assessed clinical parameters, were obtained in the group that practiced balance with the Gamma device. Despite the higher FD score prior to the therapy, the subjects of the G group achieved better FD score after the therapy and balance training. The subjects were motivated and focused on a challenging racing game of the Gamma trainer, which aim was to keep the ball in the virtual path. Motivation and focusing on the task played an import role, similar as the visual feedback informing the subject about the activities within the task. The virtual environment itself cannot improve balance capabilities of the individual more or less than simple interactive tasks with visual feedback within the real environment, but can almost equally improve postural control (Lamoth et al, 2012) and has several advantages, e.g. flexibility and configurability of levels of complexity fast and without additional expenses.

5. CONCLUSIONS

Due to the small number of participating patients we may only suggest that the selected clinical outcomes and postural responses improved in patients with low back pain after the physiotherapy, which included balance training. We have demonstrated that there was no statistical difference between the balance training using the gamma device compared to balance exercises on wobble boards in terms of clinical results. Our findings are in line with expectations and the results of previous studies that found that it was difficult to distinguish which type of exercise balance would be more beneficial in rehabilitation after back pain (Desai and Marshall, 2010).

Our study found similar success of the rehabilitation outcomes with or without a system using target based therapeutic tasks in virtual reality. Such system provided extra motivation and much higher level of interest and fun (Fitzgerald et al, 2010). However, it is worth considering that wobble board training required permanent presence of the physiotherapist and thus its usefulness in patients with neurological impairment is very limited. Despite the small number of patients involved we may conclude that balance training is important for trunk muscles strengthening in people with low-back pain regardless of the choice of the balance training device. When selecting a device, the effort of the physiotherapists to ensure repeatability as well as the ability and motivation of the patients should be also considered.

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