FALL PREVENTION AMONG OLDER ADULTS: CASE REPORTS EXEMPLIFYING THE VALUE OF INCORPORATING LUMBAR STABILIZATION TRAINING DURING BALANCE EXERCISES

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ABSTRACT: Background: *Older adults are at risk of falling each year. Fall injuries results in many health care expenses and disabilities, yet non-western countries lack the infra-structure and resources for prevention programs. Balance exercises have been found to be a cost effective evidence-based intervention in treating and preventing falls among older adults in western countries.*

Purpose: *The aim of this report was to show that lumbar stabilization exercises are not only a beneficial addition to a balance program for the prevention and treatment of falls in older adults, but to demonstrate that these exercise can more rapidly improve the functional status of older adults, limiting healthcare costs.*

Case description: *Two high functional older adults with a history of falls presented with poor balance and fear of falling. Both patients received the same balance exercise regime however lumbar stabilization exercises were added to one of the patient's exercise programs. Gait speed, lower extremity strength and balance were assessed with the Balance Evaluation systems test (BESTest), figure-of-eight, four-step-square (FSST), five-time-sit-to-stand tests (5TSTS) after two weeks and four weeks of treatment.*

Outcomes. *All the outcome measures showed statistically significant improvements. Greater improvements in vertical stability limits (14%), gait speed (9%), stability during gait (20%) and five-time-sit-to-stand test were seen with the addition of lumbar stabilization exercises.*

Discussion. *The addition of lumbar stabilization exercises during balance training is of value to improve gait speed, balance testing scores in stability in gait and vertical stability limits.*

KEY WORDS: *BALANCE EXERCISES, CORE STABILIZATION, FALL PREVENTION, LUMBAR STABILIZATION EXERCISES, OLDER ADULTS, PERTURBATION.*

BACKGROUND

One third of United States' older adult population has a risk of falling each year with the highest rate among 75 year olds. Healthcare cost escalated above $19 billion during 2000 according to the Center of Disease Control and Prevention. In non-western societies like South Africa 18% of the older adult population were counted as disabled in 2001. Three out of five of these older adults were hospitalized with fall risks due to frailty (Statistics South Africa 2001). Fall prevention and care however is neglected due to South African legislature which only allows 2% of the older population access to state-supported institutional facilities (Czerniewicz et al 2004).

Balance training is a cost effective fall prevention intervention in western societies (Madureira et al 2007). Balance challenged in three ways: reducing base of support, moving center of gravity and controlling body position are the most effective form of evidence-based interventions. Standing exercises with reduced upper limb support have also been found to improve static and dynamic balance and decrease the risk of falling (Sherrington et al 2008). Additional lower extremity exercises improved center of pressure velocity, sensory interaction during balance, directional control, lower extremity strength and stability limits (Burke et al 2010). Evidence-based alternative balance training like Tai chi improves functional balance, directional control and walking velocity during gait, and

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postural stability (Li et al 2010). Postural stabilization training is also listed in the Guide to Physical Therapy Practice's Pattern 5A, as an evidence-based fall prevention intervention. Postural stability especially plays an important role in controlling and improving changes in spinal load transfer patterns during perturbation (Muthukrishnan et al 2009).

Postural control exercises help to develop more efficient postural control strategies (Nagai et al 2012). Muscle weakness, a major fall risk factor, causes postural instability (Orr 2010). Dynamic lumbar stabilization training improves weight bearing distribution, gait and quality of life (Kaya et al 2012). Lumbar strengthening in functional positions are similar to regular balance exercises except that the transverse abdominus is constantly activated with the use of implicit motor learning techniques such as a biofeedback device and manual muscle activation (O'Sullivan 2000). The aim of this study was to demonstrate the value of additional lumbar stabilization exercises during fall prevention balance training to lower fall risk.

CASE DESCRIPTION

Medical history

Two physically independent patients age 71 years (Patient A) and 74 years (Patient B) presented with a history of falling, fear of falling and instability during environmental fluctuation and pivot movements. Both patients suffered with osteoarthritis and hypertension. Patient A was medicated with Ziac 10mg/day, Fedaloc SR 30mg/day and Patient B with Lomanor 50mg/day. Patient A and B inconsistently reported muscle spasm 2/10 based on the analogue pain scale in the thoracic and lumbar area.

Systems review

Thorough evaluations are recommended according to the American and British geriatric society clinical practice guidelines 2011 for prevention of falls among older adults. This includes physical examinations of gait, balance and lower extremity muscle strength levels and neurological assessments which evaluate cognitive function, lower extremity peripheral nerves, proprioception and reflexes. Examination of the feet for deformities and pain is recommended due to its association with impaired balance and fall risk. The International Classification of Functioning, Disability, and Health (ICF) model was applied with the assessment of the cardiovascular status due to hypertension's' effect on fall risks.

Both patients' exhibited sway-back postures and pain free full lumbar spine range of motion. Upper and lower extremity muscle strength and range of motion were within normal limits as measured by the Kendall's manual muscle test, "back-scratch" and "chair-sit-and-reach" tests. The neurological screening of sensation, upper- and lower extremity myotomes and reflexes presented normal while the active-straight-leg-raise test in both patients revealed weakness of transverse abdominus. The integumentary and foot screening showed bruised big toes of Patient A, varicose veins of Patient B and bilateral feet hammer toe formation of both patients. Vital signs were tested before and after the functional assessment tests (Table 1).

FUNCTIONAL ASSESMENT TESTS

The Balance Evaluation systems test (BESTest) was used due to its' high validity and reliability in differentiating between biomechanical constraints, stability limits, anticipatory postural adjustments, postural responses, sensory orientation and gait stability. The BESTest and gait speed have high sensitivity and validity in identifying fallers (Leddy et al 2011, Brach et al 2008). Greater step length and stance time variability are associated with poorer health and physical functional status (Brach et al 2008). In addition gait speed, figure-of-eight and four-square-step-tests proved to be of high reliability in measuring functional outcomes (Peters et al 2012, Whitney et al 2007). The four-square-step-test is also a very effective balance assessment tool in identifying multidirectional movement performance deficits (Whitney et al 2007). The Figure-of-8-Walk-Test correlates with step width variability and fear of falling (Hess et al 2010). The five-time-sit-to-stand-test (5TSTS) correlates with lower extremity strength, gait and balance (Whitney et al 2005, Brown et al 1995). The baseline measured outcome values (Table 2) determined the patients' functional status according to normative values (Hess et al 2010, Guccione et al).

DIAGNOSES AND PROGNOSIS

The author classified these patients according to the Guide of Physical Therapy Practice's Pattern 5A. The history of falls, medical history of osteoarthritis and hypertension, foot deformities, poor outcome values on the five-time-sit-to-stand, four-square-step and BESTest tests all confirmed that these patients were at high risk of falling. The patients had a good prognosis to achieve better balance outcomes, improve gait speed with the figure-of-eight and four-square-step tests, and to maintain high functional independence living status with lower risk of repetitive falling episodes. The goal of physical therapy was to decrease the patients' risks of falling by improving their objective balance properties.

Table 1: Cardiovascular screening and vital signs assessment before and after the Balance evaluation systems test (BESTest).

Vital signs	Patient A		Patient B	
	Rest	After BESTest	Rest	After BESTest
Heart rate	80	99	66	71
Blood pressure	140/72	127/77	141/67	112/71
SpO2	99	99	94	98

Table 2: Functional tests and outcomes compared to normative values.

Tests	Outcomes		Normative values
	Patient A	Patient B	
Gait speed	1.15 m/s	1.15 m/s	Physical Independant
Figure of 8 test	8.12 sec	10.37 sec	Normal
5TSTS test	15.31 sec	11.47 sec	Frail > 15sec (Hess et al 2010)
Four square step test	19.59 sec	20.00 sec	Frail
BESTtest	62%	67%	No normative values
• Biomechanical constrains	53%	53%	Poor
• Stability limits/vertically	86%	85%	Good
• Anticipatory postural adjustments	50%	50%	Poor
• Postural responses	67%	78%	Fair
• Sensory orientation	60%	80%	A: Fair, B: Poor
• Stability in gait	48%	52%	Poor

INTERVENTION

Exercise prescription

Patients A and B target exercise heart rate was monitored to maintain 60% of their maximum HR. Patient A's reduced exercise tolerance and heart rate secondary to the beta blockers was assessed with the use of the rate-of-perceived-exertion (RPE) scale at 13-15/20. The one repetition maximum weight for the Theraband® was calculated at 70% and progressed by 5% with good muscle tolerance at twelve repetitions. The patients received therapy three times a week for 30 to 45 minutes. The exercise programs were conducted in twelve treatments over a four week period according to the Guide to Physical Therapy Practice.

Exercise progression

Both patients were instructed in transverse abdominus muscle activation at initial treatment and received the same biomechanical postural correction education, static (figure 1), and dynamic (figure 2) balance exercise regime during therapy. They performed their exercises in front of a mirror for optimal corticospinal activation (Funasa et al, 2007). Patient B received balance training, with additional lumbar stabilization training which reinforced the external focus motor learning principle with the use of a biofeedback device (Schmith et al 2011) (Appendix 1). The biofeedback device was inflated to 40. Co-contraction of the transverse abdominus muscle was facilitated with inflation to 50 while doing extremity movements in standing position. The static and dynamic balance exercises were performed at random practice on a variety of different standing surfaces to incorporate environmental fluctuation and to optimize attention, executive function and retention (Schmith et al 2011). The patients' balance positions varied constantly by changing movement direction; progressing from forward lunges to side lunges and adding bilateral (D1) upper extremity proprioceptive neuromuscular facilitation (PNF) Theraband® pattern exercises. Static tandem stance position was progressed to tandem walking and forward lunges to side lunges after two weeks.

RESULTS

The patients were re-assessed after two and four weeks (Table 3). The statistical significance within each patient's outcome values in Table 4 were calculated with the use of the student-t test (Table 4). The paired t-test was used to calculate the 95% confidence intervals, mean and standard deviation and the two tailed p-value difference between the two patients. The single p-value statistical difference between the patients was calculated with the Friedman test and Chi square approximation.

Both patients showed statistically significant improvements in all the outcome values except in vertical stability limits (Table 4). Patient A, who performed isolated balance training exercises, showed no improvement in vertical stability outcome values which emphasizes the value of additional lumbar stabilization exercises during balance training. Patient B with the additional lumbar stabilization exercises showed greater improvements in gait speed (9%) and stability in gait (20%). Patient B also improved at a faster rate after two weeks of treatment with the 5TSTS test's scores.

Statistical significance equal improvements were found in Patient A and Bs' figure-of-eight test, four-square-step tests, biomechanical constraints, anticipatory postural adjustments, postural responses and sensory orientation.

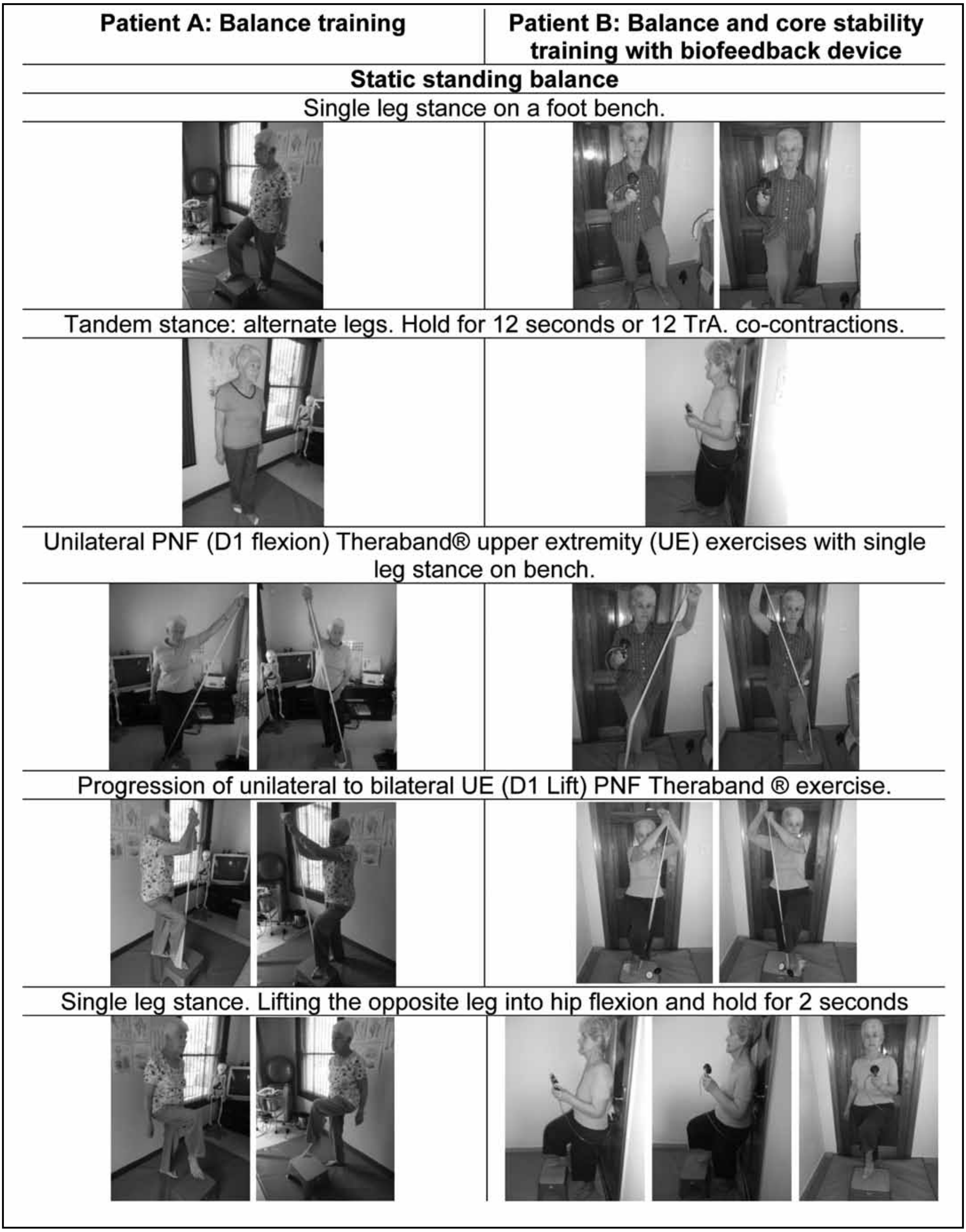

Figure 1: Static balance exercises of Patient A and balance exercise incorporated with lumbar stabilization with a biofeedback device of Patient B

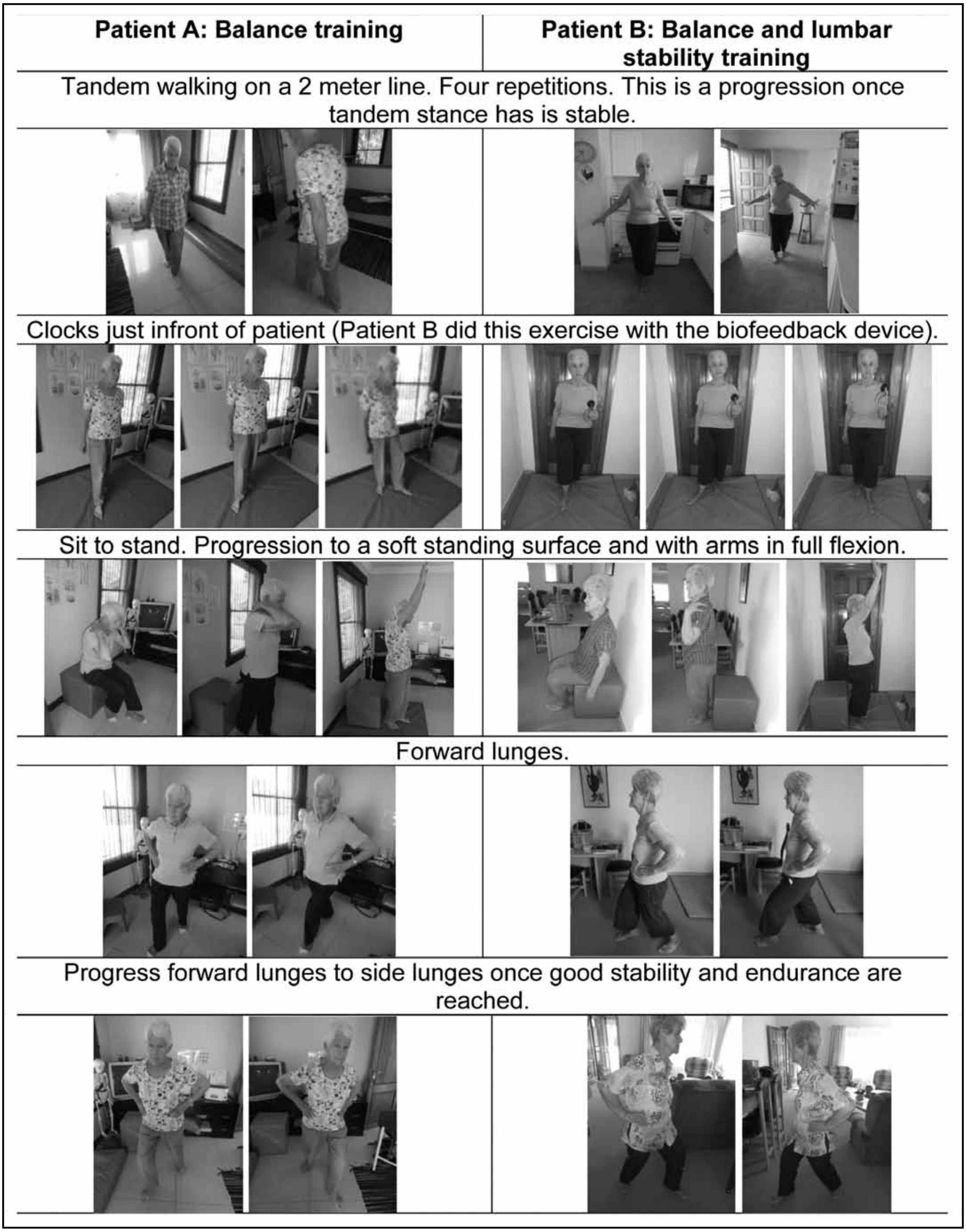

Figure 2: Dynamic functional balance exercises

The anticipatory postural adjustments and sensory orientation outcome values showed a ceiling effect after two weeks.

DISCUSSION

Statistically significant improvements in the functional assessment tests' results showed the evidence-based effect of balance exercises. The equal improvement of figure-of-eight and four-square-step tests, biomechanical constrains, anticipatory postural adjustments, postural responses and sensory orientation correlated with other high quality evidence based studies (Madureira et al 2007, Burke et al 2010). Balance exercises rather than additional lumbar stabilization significantly improved the patients' anticipatory postural adjustments ability. Balance training also can improve patients' ability to change position in multiple directions without any activation of the lumbar stabilizers (Nagai et al 2012). Anticipatory postural adjustments are considered the major "line of defence" against self-inflicted postural perturbations. Postural stability, body protection and focal movement performance during anticipatory postural adjustments are maintained by the central nervous system (Yiou et al 2012). The equal improvements in the biomechanical constraints, figure-eight and four-step-square tests results in this study correlated with the anticipatory postural adjustments' ability to adapt to various constraints like biomechanical constraints, postural stability, task superimposition, physiological fatigue, temporal time pressure and psychological fear of falling (Yiou et al 2012).

Table 3: Results of functional assessments of Patient A and Patient B at baseline, after two weeks- and after four weeks of treatment.

Outcome measures	Baseline		Two weeks		Four weeks	
Patient	A	B	A	B	A	B
Gait speed	1.15 m/s	1.15 m/s	1.16 m/s	1.24 m/s	1.19 m/s	1.29 m/s
Figure of 8 test	8.12 sec	10.37 sec	7.66 sec	7.75 sec	6.69 sec	6.86 sec
5TSTS test	15.31 sec	11.47 sec	11.34 sec	7.22 sec	10.35 sec	7.20 sec
Four square step test	19.59 sec	20.00 sec	13.66 sec	10.54 sec	12.81 sec	9.28 sec
BESTest	62%	67%	75%	83%	80%	91%
Biomechanical constrains	53%	53%	53%	53%	67%	67%
Stability limits/vertically	86%	85%	86%	100%	86%	100%
Anticipatory postural adjustments	50%	50%	67%	67%	67%	72%
Postural responses	67%	78%	72%	87%	87%	100%
Sensory orientation	60%	80%	93%	100%	93%	100%
Stability in gait	48%	52%	71%	86%	76%	100%

Table 4: Statistical outcome measures

Patient	**Patient A**	**Patient B**	**Difference between Patient A and Patient B**			
Outcome measures	**p-value**		**95% CI**	**Mean**	**SD**	**p-value**
Gait speed	0.0001	0.0011	-0.191 to 0.071	-0.060	0.053	0.1573
Figure of 8 test	0.0032	0.0156	-3.879 to 2.205	-0.837	1.225	0.0833
5TSTS test	0.0148	0.0260	2.263 to 4.943	3.703	0.499	0.0833
Four square step test	0.0148	0.0260	-3.301 to 7.461	2.080	2.166	0.5637
BESTtest	0.0055	0.0076	-20.5 to 7.8	-6.3	5.7	0.1573
Stability limits/vertically	-	0.0028	-30.5 to 12.5	-9.0	8.7	0.5637
Anticipatory postural adjustments	0.0084	0.0110	-8.8 to 5.5	-1.7	2.9	0.3173
Postural responses	0.0063	0.0052	-18.0 to -8.0	-13.0	2.0	0.0833
Sensory orientation	0.0175	0.0051	-34.3 to 3.0	-15.7	7.5	0.0833
Stability in gait	0.0171	0.0308	-39 to 10.5	-14.3	10.0	0.0833

Lumbar stabilization exercises.
Similar to other lumbar stabilization exercise studies, there were significant improvements in the vertical stability limits and gait speed with intervention aimed at stabilizing the lumbar spine through the contraction of the transverse abdominus muscles (Freeman et al 2012). The improvement of gait speed and stability correlated with Hodges et al 1997 conclusion that transverse abdominus activates prior to the initiation of all extremity movements. The timing between trunk and pelvic rotations and erector spinae activity varies systematically with walking velocity and any alteration is reflected in spinal stabilization during unexpected perturbations (Lamoth et al 2007). Lumbar stabilization exercises causes significant improvements in disability scores and ground reaction forces, due to improved changes in load transfer patterns during perturbation (Muthukrishnan et al 2010). Phasic superficial paraspinal activity is associated with foot strike which controls trunk motion in the frontal and sagittal planes during locomotion. The tonic activation of the transverse abdominus muscle throughout the gait cycle provides constant intersegmental stiffness and is the first line of defence against the cyclic internal and external lumbo-pelvic forces associated with gait (Saunders 2007).

Balance is also controlled through the temporal relationship between trunk and lower extremity strength (Yen et al 2011). The improved five-times-sit-to-stand test results showed that the additional lumbar stabilization exercises had an impact on lower extremity strength. The significant relationship which exists between knee extension force and gait speed correlate with this study's results (Brown et al 1995). Afferent input from the hip joints' load receptors play a crucial role in the generation of locomotion activity in the human spinal cord during loading phase (Dietz et al 2002). The use of body weight and control is especially important to facilitate the activity and load input in the extensor muscles (MacKay-Lyons 2002). It is hypothesized that the lumbar stabilizers might play a role in facilitating activity of the lower extremity extensor muscles due to prior activation and feed forward of the transverse abdominus muscle during gait initiation. The additional lumbar stabilization exercises during balance exercises showed that it may potentially add value to the patient's functional outcome. Future randomized control trials are recommended with a larger sample size of frail older adult population.

CONCLUSION
The additional lumbar stability training during balance training has the potential to improve vertical stability, gait speed and gait stability at an earlier stage of treatment than just plain balance training alone. The improved five-time-sit-to-stand test values also showed that higher physical independence levels can be reach sooner.

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APPENDIXES

APPENDIX 1: Biofeedback (Stabilizer) device behind patient's back. 12 repetition TrA contractions