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BALANCE AND POSTURE IN THE ELDERLY: AN ANALYSIS OF A SENSORIMOTOR REHABILITATION PROTOCOL

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Regular training programs are a concrete means to prevent and/or reduce functional decline due to aging. A multisensory training approach seems to obtain better results in the elderly with regard to both balance and quality of life. Forty subjects (age 65±10 years, height 165±4 cm, weight 73.0±4.6 kg) were randomized into two groups (GrHu and GrCl). Participants in the GrHu group received 3 months of balance and postural training, 3 sessions per week, with the use of a multisensory training approach. Those in the GrCl group received 3 months of training with a classical rehabilitation protocol that included isotonic training for the lower limbs and spine. With regard to walking, there was an improvement in step symmetry for participants in the GrHu group compared to baseline (0.93±0.09 vs. 0.84±0.1; $p<0.05$). Further, all subjects in the GrHu group showed a significant reduction in the energy used during a 4-min walk. Analysis of stabilometry data also showed a significant improvement in balance for those in the GrHu group, which was independent of age or gender. The multisensory training approach yields an improvement of balance in the elderly, which reduces the risk of falls. The observed improvement is significantly greater than that seen with the classical training program.

Human life expectancy at the beginning of the 20th century was substantially higher than that at the beginning of the 19th century (82 years for women and 76 years for men versus 43 years) (1). This has led to a deep change in societal structure throughout the world and an increase in the percentage of people over 65 years old. Aging is often associated with fragility characterized by a gradual degradation of the subject's postural and homeostatic capacities and by a reduction in strength and muscle resistance, leading to an imbalanced body and deterioration of the posture (2,3,4). The prevalence of mobility disability varies between 2.0% and 12.1% depending on sex and age (5). A decrease in autonomy represents the final result of a complex chain of events and precedes to a global imbalanced body. The resultant impaired posture leads to a loss of movement and a deterioration in the ability to adequately respond to external and internal stimuli.

During aging, a substantial modification of body composition is observed such that fat mass within the abdominal region increases and there is a decrease in both lean mass and bone density (6). These changes are progressive and insidious and correlate with a decrease in physical activity and changes of caloric intake (7). Elderly subjects are more susceptible to disease, less able to move on their own, and without specific therapies, they acquire a wrong compensatory gifts (6, 8, 9). In the last several decades, studies have shown that age-related physiological decay can be delayed by physical exercise training programs, with a consequent improvement in the quality of life of elderly subjects (10). Positive results have been obtained using various training methods, including muscle strengthening, aerobic, and postural exercises. In the last few years a multisensory approach has been proposed, whereby audio-visual stimuli provide the patient with feedback regarding body sensation and position, and has yielded excellent results (11, 12).

The objective of the present study was to compare a "classical" rehabilitation protocol with the recently developed Huber protocol. The classical protocol consists of isotonic muscle exercise in conjunction with proprioceptive training to strengthen muscles associated with the rachis and lower limbs. The Huber protocol provides sensorimotor training and is theorized to promote vestibular and motor development.

MATERIALS AND METHODS

Study Population

The study population consisted of 40 sedentary subjects

Keywords: Sensorimotor rehabilitation, Posturography, Elderly, Balance control.

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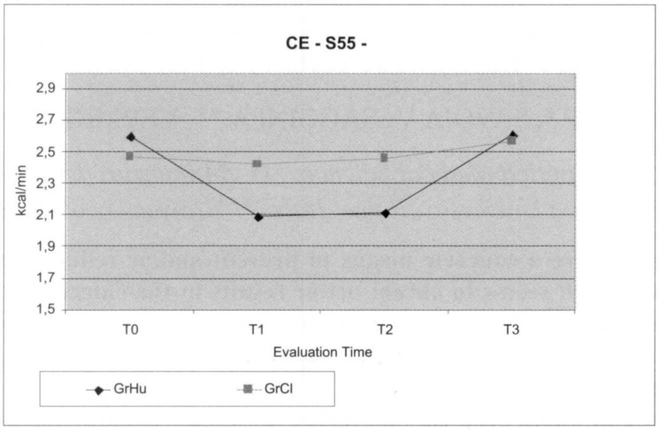

Fig. 1. *CE measured for both groups during a 4-minutes walking test. Improvement was observed in GrHu (T0 vs. T1* $p<0.05$*), this improvement continued to T2 (*$p<0.05$*). At T3, the values returned to baseline. No significant modification was observed in the GrCl group.*

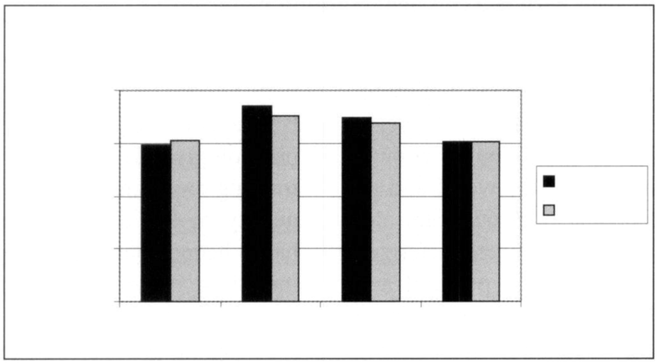

Fig. 2. *Results of TEF in* S^{55} *subjects. Significant improvement was observed at T1 in both the GrHu (*$p<0.01$*) and the GrCl group (*$p<0.05$*).*

(age 65.05±6.2 years, height 165±4 cm, weight 73±4.6 kg) who responded to a letter from the G. d'Annunzio University Rehabilitation Medical Center requesting the participation of elderly individuals from the province of Chieti (Italy) in this study. At the time of enrollment, none of the participants was engaged in any kind of physical activity. All participants were non-smokers, had no history of cardiovascular or pulmonary disease, and had normal ECG readings and blood pressure at rest.

Subjects were randomly divided into two groups of 20 subjects, one of which received training using the Huber protocol (GrHu) and the other received training using the classical protocol (GrCl). In each group there were 10 subjects aged between 55 to 65 years old (S^{55}) (5 men and 5 women) and 10 aged 65 to 75 years old (S^{65}) (5 men and 5 women).

The Ethical Committee of the School of Medicine, Chieti-Pescara University, approved the study. After having received a full explanation of the protocol, the subjects gave their written informed consent to participate.

Treatments

Subjects were assigned a specific training program according to their group. The GrHu group received 3 months of sensorimotor training (36 rehabilitative sessions, 3 times per week) with Huber® instrumentation according to manufacturer-specific protocols (LPG Systems, Valence, France). The subjects performed isometric postural exercises on an oval-shaped motorized platform with oscillating rotatory movements. The rotary movements operate in different ranges and at different speeds and act to throw the user off balance, requiring them to make postural adjustments to regain balance. There is also a system of handles equipped with sensors that measure the amount of energy used during exercise. Visual and audio feedback was provided for different tasks and served to point out good or bad exercise performance. Each training session lasted at least 30 minutes and at the end of each month the training intensity was individually adjusted, based on the subject's performance.

Subjects in the GrCl group received 3 months of training with a classical rehabilitation protocol (36 rehabilitative sessions, 3 times per week). Panatta isotonic machines (Panatta sport, Apiro, MC, Italy), which utilize a computerized proprioceptive platform, provided isotonic training for muscles in the lower limbs and rachis. Each training session in this group consisted of 6 series of 10 repetitions at 65% 1RM leg extension and exercise using a lower back machine followed by 20 minutes of exercise on a proprioceptive platform. Each month the training load was increased. At the end of the 3-month study all subjects were asked to return to their normal activities, and no subject continued any kind of training.

Evaluations

At the beginning of the study, a medical check-up was performed for each subject, during which anthropometric data, medical aptitude data, and a medical history were obtained. All subjects were assessed before training (T0), after 3 months of training (T1), and 6 and 12 months after the end of training (T2 and T3) in order to evaluate the short- and long-term impact of training. These assessments included:

- A video analysis of subjects in an orthostatic state (TCin) using the Elite System (BTS, Garbagnate Milanese, MI, Italy);

- An analysis of each subject's walk at normal speed (WA) and a stabilometric test (StT) of displacement of the center of balance (SB) were recorded for 52 seconds with open eyes (EO) and then with closed eyes (EC) using the Dynamic Foot System (ESSEDUE, Italy);

- An isokinetic analysis of the extension-flexion of the trunk (TEF), particularly with regard to muscular work (W) produced during 100 movements in a range of 60 and 120 rad/second, using the Cybex TEF System (CYBEX, Medway, MA, USA);

- A measurement of the energy cost (CE), oxygen volume (V_{02}), and heart rate (HR) during a 4 min walking test using the K4 device (COSMED, Roma, Italy). Walking was performed on a treadmill (Panatta, Italy), the walking velocity was set to 60 $m \cdot min^{-1}$, the grade of the treadmill was 0%.

To reduce confounding factors on experimental measurements, room temperature, humidity, and subjects' food intake were controlled for the duration of the study.

Data and Statistical Analysis

Data were analyzed in a blind fashion, with those in charge of evaluations unaware of the type of training program that each subject followed. The Wilcoxon signed-rank test was used to compare results. The level of statistical significance was established at $p<0.05$.

RESULTS

Data regarding CE showed that it was significantly reduced during a 4 minute walking test in the S^{55} subjects of the GrHu group. This reduction remained significant at T2 but disappeared at T3 (Fig. 1). GrCl showed no significant changes at any evaluation time. No modifications were observed for either group with regard to V_{02} or HR.

Video analysis of walking demonstrated age-independent improvements in spatial-temporal parameters in the GrHu group at T1 compared to baseline, particularly with regard to step symmetry (S^{55}: 0.84±0.1 vs. 0.93±0.09, $p<0.05$; and S^{65}: 0.73±0.2 vs. 0.9±0.27, $p<0.05$). At T2, improvement in the GrHu group compared to baseline remained significant (0.84±0.1 vs. 0.94±0.13, $p<0.05$ and 0.73±0.2 vs. 0.9±0.68, $p<0.05$, respectively). At T3, however, the values in the GrHu group had returned to baseline. The GrCl group showed no statistically significant improvement at any evaluation.

The TEF results are reported in Figures 2 and 3. In both groups the S^{55} subjects showed significant improvement at T1 (GrHu: $p<0.01$ and GrCl: $p<0.05$). The increase in trunk work capacity persisted at T2. In contrast, only S^{65} subjects from the GrHu group showed a significant improvement, and the improvement was seen at both T1 and T2 ($p<0.05$).

Evaluation of StT showed that there was improvement in SB at T1 in the S^{55} subjects ($p<0.01$); this persisted at T2 (men: $p<0.01$ and women: $p<0.05$) but disappeared at T3 (Table 4). The same results were observed in the test performed with EC (men: $p<0.01$ and women: $p<0.05$).just in GrHu

Similar results were observed in the GrHu S^{65} subjects. Men showed a significant improvement in the test performed both with EO and EC ($p<0.05$ and $p<0.01$, respectively), as did women ($p<0.05$ and $p<0.01$, respectively). The observed improvements persisted at T2 but disappeared at T3 (Table 5). The GrCl did not show significant modifications in SB for either S^{55} or S^{65} (Tables 6 and 7).

Tables 8 and 9 show comparisons of the GrHu and GrCl groups without sex differentiation. In this case, an improvement was observed in SB for both groups but it reached statistical significance only for GrHu (T0 vs. T1, $p<0.01$); the improvement persisted at T2 for both S^{55} and S^{65} subjects (T0 vs. T2, $p<0.05$), but disappeared at T3 (Fig. 4).

DISCUSSION

A regular training program is an effective way to prevent and/or reduce functional decline due to aging (13,14). Adaptive responses of aging subjects to physical exercise that is specific for resistance or strength, and the role of exercise in the improvement of quality of life in the elderly have been extensively documented (15, 10, 16). Most physiological changes associated with aging, such as a decrease in aerobic capacity (17, 18), and a loss of muscular strength (19, 20), muscular mass (19), and bone density (21), are modified with physical training (14, 22).

Contraindications for exercise are the same for the elderly as they are for young and healthy adults (23). Recent studies investigating the effect of postural training programs on aging subjects have shown that balance capacity is significantly improved after at least 8 weeks of training (23, 24, 25, 11, 26, 12). In the present study, similar results were observed after 3 months of training (3 sessions/week) on GrHu, with a significant improvement observed for StT of 38.7% and 37.5% in S^{55} and S^{65} subjects respectively ($p<0.01$). This improvement was maintained at 6 months, even though the training program

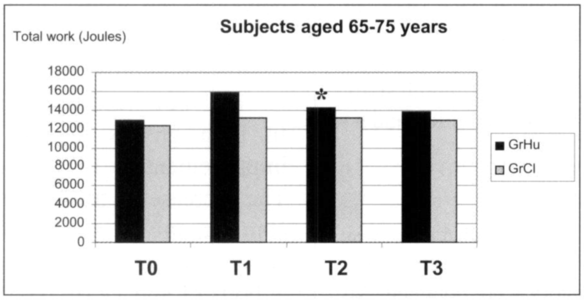

Fig. 3. *Results of TEF in S^{65} subjects. The improvement of W was significant at T1 and T2 only for GrHu (*$p<0.05$).*

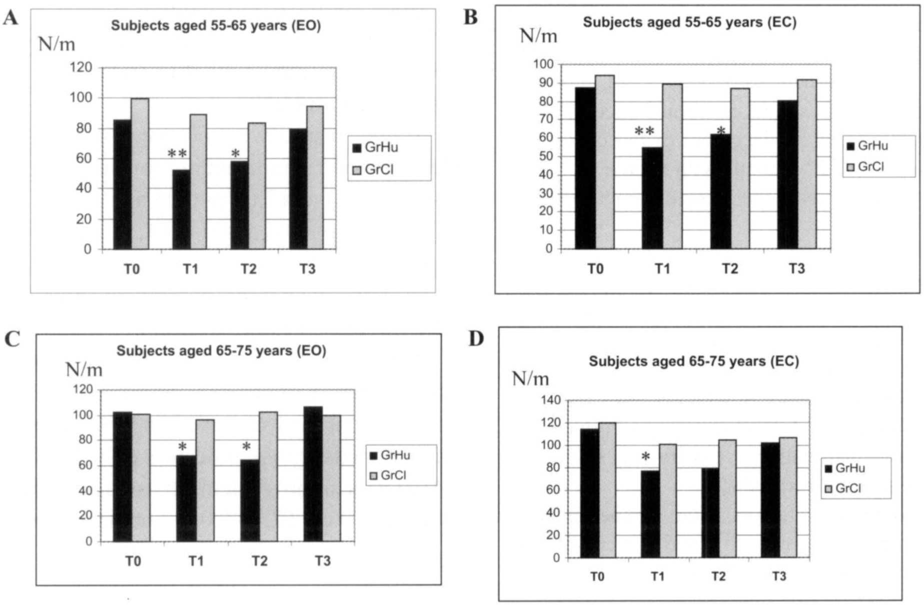

Fig. 4. *Results of stabilometry analysis of the two groups depending on age and measurement conditions (EO and EC): a) S^{55} EO at T1 (**$p<0.01$), at T2 (*$p<0.05$), at T3 (p=n.s.) b) S^{55} EC at T1 ($p<0.01$), at T2 ($p<0.05$), at T3 (p=n.s.) c) S^{65} EO at T1 ($p<0.05$), at T2 ($p<0.05$), at T3 (p=n.s.) d) S^{65} EC at T1 ($p<0.05$), at T2 ($p<0.05$), at T3 (p=n.s.).*

had ceased 3 months earlier. In previous work using isotonic and/or proprioceptive protocols, this persistent effect was observed only with continuous training with tai chi (27). In our study, all observed improvements were lost by 12 months after the end of the training, suggesting a need for continuous training to maintain improved function.

In the GrCl group, there was a trend towards improvement in SB, but the results were not significant. Recently, Lajoie (2004) observed an improvement in reaction capacity following 8 weeks of postural training with computerized feedback, but observed no modification in SB. The multisensory approach of Lajoie (2004) was similar to the one proposed by Hue (2004) and promotes improved balance in aging subjects (25, 28, 29).

Numerous studies have investigated HR, V_{O2} consumption (15,30), and CE and their relation to age (31, 32) and posture (33). Our data confirm what has been shown in the literature, that there is a decline of V_{O2} consumption in aging subjects (about 10% per decade) and training programs do not change this (e.g. Hawkins s 2003) (34).

Our results further show that exercise-related SB improvement also benefits dynamic balance while walking, walk alignment, and reduces energy expenditure during physical activity. The improvement in walk symmetry in the GrHu group was significant for all subjects irrespective of age (S^{55}: $p<0.05$ and S^{65}: $p<0.01$). Another important finding of our study is that the training program corrected walking problems in 70% of the subjects, which was verified by gait analysis carried out during a 4 min walking exercise. The data further showed that a decrease in CE at T1 was associated with improved walk performance in the GrHu group ($p<0.05$). An improvement of orthostatic

S^{55}

	T0		T1		T2		T3	
	GrHu	GrCl	GrHu	GrCl	GrHu	GrCl	GrHu	GrCl
VO_2 ml/min/kg	17.3±6.4	16.8±7.24	14.02±2.71	17.2±1.1	15.3±3.6	16.7±7.1	16.7±4.4	16.3±7.24
FC bpm	93±54	93±7	90±8	93±4	91±14	94±2	93±32	93±54
CE kcal/min	2.60±0.66	2.47±0.12	2.09±0.61	2.40±0.64	2.12±0.87	2.46±0.47	2.61±0.86	2.57±0.62
R	0.84±0.22	0.84±0.4	0.81±0.14	0.82±0.44	0.82±0.12	0.82±0.24	0.86±0.52	0.82±0.3

S^{65}

	T0		T1		T2		T3	
	GrHu	GrCl	GrHu	GrCl	GrHu	GrCl	GrHu	GrCl
VO2 ml/min/kg	16.7±6.2	16.6±4.1	15.4±4.5	16.1±22	16.1±5.3	17.2±2.1	16.1±5.2	16.9±4.1
FC bpm	98±24	99±33	97±34	97±57	98±24	99±17	98±58	97±37
CE kcal/min	3.11±0.72	3.10±0.21	2.97±0.52	3.01±0.49	2.84±0.22	3.11±0.32	2.98±0.59	3.09±0.24
R	0.92±0.52	0.91±0.61	0.90±0.42	0.89±0.63	0.92±0.22	0.90±0.61	0.87±0.62	0.91±0.43

Table I. *At T1 GrHu showed a decrease in CE during a 400m walk (T0 vs. T1 $p<0.05$) in S^{55}, which persisted at T2 (T0 vs. T2 $p<0.05$), but disappeared at T3.*

T.E.F. Cybex S^{55} GrHu vs. GrCl

Total Work (Joules)				
	T0	T1	T2	T3
GrHu	14790±367	18500±457	17400±834	15150±461
GrCl	15230±463	17520±739	16890±492	15060±272
Average work /repetition 90 rad.(Joules)				
	T0	T1	T2	T3
GrHu	219±29	305±38	293±13	226±21
GrCl	225±24	292±21	287±18	220±37

Table II. *Data regarding W of TEF. S^{55} subjects in the GrHu group showed a significant improvement at T1 as did those in the GrCl group ($p<0.05$). Both groups showed persistent improvement at T2.*

posture and ambulatory alignment allows a lower energy dispersion and thus a more effective walk (35). In contrast to the multisensory training protocol, the classical protocol did not affect these endpoints. Interestingly, by T3 all values had returned to baseline for both groups, further supporting the need for continued training to maintain the therapeutic improvement.

We additionally observed that these training programs improved W produced during TEF, such that for S^{55} subjects there was an increase of 25% from baseline at T1 for Ga ($p<0.01$) and 15% for Gb ($p<0.05$). For S^{65} subjects, there was an increase in W of 37% at T1 in the GrHu group ($p<0.01$) and 7% in the GrCl group (p=n.s.). These data agree with previous reports documenting increased muscular strength and hypertrophy in elderly subjects engaged in exercise programs (36).

The results of our study indicate that a traditional protocol utilizing isotonic devices is less efficient in subjects under 65 years old. Further, isometric training is more appropriate for elderly individuals to correct muscular deterioration due to aging, as it allows a global rehabilitation of musculature involved in posture as well as improved adaptive capacity.

CONCLUSIONS

The present study shows that sensorimotor training is a superior means of treating age-related fragility compared to the traditional isometric training approach. This rehabilitation protocol exercises and strengthens both the deep muscles of the spine and those of the lower limbs, and is associated with improved motor-vestibular rehabilitation. The sensorimotor training protocol resulted in a greatly improved capacity for locomotion, which can

T.E.F. Cybex S^{65} GrHu vs GrCl				
Total Work (Joules)				
	T0	T1	T2	T3
GrHu	12910±810	15790±672	14300±340	13874±403
GrCl	12370±620	13120±731	13227±583	12893±752
Average work /repetition 90 rad.(Joules)				
	T0	T1	T2	T3
GrHu	168.98±35	232±34	215±38	193±37
GrCl	160.45±26	172±76	174±61	168±67

Table III. *Data regarding W of TEF. S^{65} subjects showed an improvement at T1 but it was significant only for GrHu ($p<0.05$). Both groups showed persistent improvement at T2.*

S^{55} GrHu				
Sway area (EO)				
	T0	T1	T2	T3
Men	89.96±25.23	50.68±31.14	58.67±8.16	79.78±5.79
Women	80.20±10.35	51.52±7.85	57.09±7.16	78.60±8.62
Sway area (EO)				
	T0	T1	T2	T3
Men	90.22±19.12	53.31±26.37	60.48±7.56	80.27±9.47
Women	86.90±13.51	59.01±9.63	63.23±2.01	80.87±9.46

Table IV. *In the GrHu group training improved orthostatic balance capacity in both men (T0 vs. T1, $p<0.01$) and women (T0 vs. T1, $p<0.01$). Improvement was also observed in tests with EC: men (T0 vs. T1, $p<0.01$), women (T0 vs. T1, $p<0.05$).*

S^{65} GrHu				
Sway area (EO)				
	T0	T1	T2	T3
Men	107.86±53.98	62.91±32.59	65.55±15.33	111.03±40.29
Women	96.98±30.79	72.57±11.77	62.16±11.44	101.36±26.75
Sway area (EO)				
	T0	T1	T2	T3
Men	126.68±46.65	76.82±46.42	79.55±10.43	107.12±32.41
Women	101.08±19.33	77.09±11.83	79.37±9.84	97.12±18.33

Table V. *A significant improvement in StT was observed at T1 with both EO or EC, respectively men ($p<0.05$, $p<0.05$) and women ($p<0.05$, $p<0.01$).*

S^{55} GrCl				
Sway area (EO)				
	T0	T1	T2	T3
Men	104.45±07.27	105.45±24.57	98.45±18.34	98.49±12.61
Women	96.39±10.63	98.45±07.39	93.45±14.92	100.49±21.72
Sway area (EO)				
	T0	T1	T2	T3
Men	118.98±35.04	99.55±26.75	89.45±12.56	106.45±16.37
Women	120.45±26.21	110.34±19.76	112.56±23.81	107.18±16.47

Table VI. *StT in GrCl. No significant modifications were observed at T1. An improvement was observed at T2, but it was not significant.*

S^{65} GrCl				
Sway area (EO)				
	T0	T1	T2	T3
Men	101.34±19.33	89.69±11.83	88.61±09.84	95.56±18.33
Women	98.00±07.85	76.78±26.37	89.45±13.51	93.45±19.33
Sway area (EC)				
	T0	T1	T2	T3
Men	94.34±32.59	96.45±18.33	91.32±10.43	90.35±28.39
Women	93.45±11.77	77.23±02.01	91.93±07.56	93.45±09.30

Table VII. *StT in GrCl. An improvement of orthostatic balance for S^{65} was observed at T1 but it was not significant.*

S^{55}, GrHu vs GrCl				
Sway area (EO)				
	T0	T1	T2	T3
GrHu	85.08±10.2	52.09±21.38	57.88±07.16	79.19±11.92
GrCl	99.67±09.28	88.95±16.73	83.23±20.76	94.50±05.17
Sway area (EC)				
	T0	T1	T2	T3
GrHu	87.56±07.88	54.65±15.62	61.85±11.83	80.57±08.52
GrCl	93.89±02.28	89.45±06.27	86.84±08.68	91.90±11.39

Table. VIII. *Comparison of the StT results obtained from both groups of training.*

S^{65}, GrHu vs GrCl				
Sway area (EO)				
	T0	T1	T2	T3
GrHu	102.42±32.27	67.74± 34.53	63.85±27.82	106.19±16.72
GrCl	100.42±14.38	95.95±08.39	101.95±21.43	99.49±15.32
Sway area (EO)				
	T0	T1	T2	T3
GrHu	113.88±29.67	76.95±18.49	79.46±13.59	102.12±15.72
GrCl	119.71±14.51	101.01±21.84	104.94±11.65	106.78±15.63

Table IX. *Comparison of the StT results obtained from both groups of training.*

significantly improve quality of life in the elderly.

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