A comparison of the effectiveness of three types of trunk orthoses on the balance performance of older people with osteoporotic hyperkyphosis: A cross-over study

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Abstract

Background: Orthotic immobilization is an early treatment for osteoporotic vertebral fracture at the hyperkyphotic thoracic spine.

Objective: This exploratory study compared the immediate impact of three types of trunk orthoses on the balance parameters of older people with osteoporosis hyperkyphosis.

Methods: Twenty older people (aged 60-65 years) with osteoporosis kyphosis and a history of falls participated in a pilot cross-over study. Four randomized comparisons were carried out, including either soft, semi-rigid, and rigid trunk orthoses worn on the participants compared to "no orthosis" as the control condition. Kyphosis angle, Forward Reach Test, Timed Up and Go test, and postural stability during standing on a force plate was recorded and compared between study conditions using one-way repeated measures analysis of variance test.

Results: All orthoses significantly reduced the kyphosis angle ($p<0.05$). More rigid designs were more effective in the reduction of kyphosis than less rigid orthoses. None of the orthoses has a significant change in the Timed Up and Go test ($p>0.05$). Rigid orthosis significantly reduced the forward reach compared to "no orthosis" (p=0.03, 95% CI: 1.08 to 6.3 cm) and soft orthosis (p=0.04, 95% CI: 0.05 to 6.1 cm) conditions. Rigid orthosis (p=0.04, 95% CI: 0.03 to 1.3 mm/s) and soft orthosis (p=0.03, 95% CI: 0.13 to 2.9 cm) induced significant increase in the velocity of postural sway in antroposterior direction compared to control condition.

Conclusion: These findings suggest that using rigid orthosis in older people with osteoporosis hyperkyphosis reduces the balance performance.

Keywords: spine, kyphosis, osteoporosis, balance, orthosis

Highlights:

- Trunk orthoses reduce the hyperkyphosis in older people with osteoporosis
- Semi-rigid orthoses cause less restriction of functional movements in the users
- Rigid orthoses induce balance impairment in older people with osteoporosis hyperkyphosis

INTRODUCTION

The excessive anterior curvature of the thoracic, known as hyperkyphosis, is the most common spinal deformity in older adults (Ailon et al., 2015; Katzman et al., 2010). Hyperkyphosis rate has been reported to be 20 to 40 percent in older people aged over 60 years (Kado et al., 2007). Hyperkyphosis restricts the mobility of the thoracic spine in the flexion, resulting in the reduced ability to react for postural adjustments in daily activities (de Groot et al., 2014). Previous literature has reported that hyperkyphosis is associated with reduced balance performance (Katzman et al., 2010; Roghani et al., 2017). Furthermore, the spine's alignment changes could lead to additional compressive stress on the ventral aspect of the vertebral bodies that could exacerbate the flexion deformity of the spine (Ailon et al., 2015). The increased compression force on the thoracic spine is a serious health condition for older people, particularly those with mechanically less robust vertebral bodies (Wei et al., 2017).

Osteoporosis is a metabolic bone disease commonly seen in the older population (Sözen et al., 2017). Spinal osteoporosis leads to increased flexion deformity of the thoracic spine and hyperkyphosis (Pollintine et al., 2009). Hyperkyphosis and spinal osteoporosis both can lead to a range of adverse symptoms, including pain, fatigue, weakness of back extensors, respiratory problems, depression, limited physical function, and reduced quality of life (Kado, 2009). In hyperkyphosis, the flexed misconfiguration of the thoracic spine shifts the body's center of mass

(CoM) forward, closer to their limits of stability (LoS) (Horak, 2006). This sagittal misalignment causes impaired postural control and predisposes a person to sudden falls (de Groot et al., 2014; Overstall et al., 1977). It warrants therapeutic management to straighten the flexed posturing spine in older people. In addition to medication and physical fitness, the provision of a spinal orthoses can be part of a rehabilitation program tailored to manage the misalignment and prevent its adverse consequences in older people with osteoporotic hyperkyphosis (Pfeifer et al., 2004b). While the adverse effect on motor function and balance control related to osteoporotic hyperkyphosis is not an easily reversible phenomenon (13), early balance adaptations after wearing various orthoses need further investigations.

Balance is a multidimensional concept and refers to the ability to restore CoM over the LoS during different positions; called "postural control" (Pollock et al., 2000). Adjustment of postural control involves coordinated movement strategies at the ankle, hip, and trunk and requires an integration of visual, vestibular, and proprioception feedback (Horak, 2006). A wide range of outcome measures have been studied to evaluate postural control and its association with the risk of falls (Mancini and Horak, 2010; Pardasaney et al., 2013). These outcomes mainly include clinical assessments such as Timed Up & Go and functional reach tests, as well as laboratory measurements such as a computerized force plate that records postural control more objectively (Mancini and Horak, 2010). There are some reports from previous studies that long-term use of spinal orthoses improves balance control in older people with hyperkyphosis (Kweh et al., 2020; Newman et al., 2016). However, there is a contrasting view that the early impact of some spinal orthoses could limit some movements which are required for balance control, and wearing an orthoses may be harmful to older people with balance problems. Orthoses cause limited trunk motion to realign the spinal column, and this could influence the movement strategies required for postural control. There are a variety of spinal orthoses with different possible effects on the balance parameters used for people with osteoporotic hyperkyphosis, including rigid, semi-rigid, and soft structures (Newman et al., 2016).

Orthotic immobilization is an early treatment for osteoporotic vertebral fracture (OVF) at the hyperkyphotic thoracic spine when neurological deficit and instability are excluded (Kato et al., 2019; Meccariello et al., 2017). A variety of orthotic designs has been suggested in previous research to find a balance between often conflicting requirements of biomechanical effectiveness and user compliance. On this basis, literature has shifted from the recommendation of rigid TLSO towards a dynamic or soft TLSO in more recent years (Kweh et al., 2020). Rigid TLSO can provide a more effective mechanical resistance, which is beneficial for thoracic flexion control to reduce hyperextension and protects injured segments in people with OVF (Murata et al., 2012), but has drawbacks of discomfort and atrophy of paraspinal muscles during prolonged use (Meccariello et al., 2017). Most of the previous research compares the long-term effects of rigid and soft TLSOs (Kweh et al., 2020). Less attention has been paid to compare the immediate impacts that wearing TLSOs might have on balance parameters. According to Global Spine Care Initiative, the conservative treatment of OVF should include early mobilization with spinal orthoses (Ameis et al., 2018). Still, no recommendation for selecting a safe orthosis or in-brace postural strategy has been provided.

It remains a major concern if trunk orthoses have any adverse effects on balance performance and how people with OVF cope with wearing the orthoses. Therefore as a precursor to trials in the patients, this exploratory study has been undertaken to investigate the possible benefits and risks of different spinal orthoses on people with osteoporosis hyperkyphosis related to the risk of falling within testing. The objective of this study was to compare the immediate impact of rigid, semi-rigid, and soft trunk orthoses on the balance performance of older people with osteoporosis hyperkyphosis. It has been hypothesized that using flexible spinal orthoses could allow postural adaptations and lead the higher balance control in older people with osteoporosis hyperkyphosis.

METHODS

Study design

This was a cross-over trial to compare the effects of rigid, semi-rigid, and soft spinal orthoses on the balance performance of older people with osteoporotic hyperkyphosis and a history of falling in a single session. Participants acted as their own control (no orthosis), and the order of control/interventions and testing conditions was randomized by drawing concealed envelopes from a bag. This study was approved by the Isfahan University of Medical Sciences (Isfahan, Iran) review board and ethics committee. Each participant provided written informed consent before testing.

Participants

Twenty ambulatory community-dwelling participants who had osteoporotic hyperkyphosis were recruited through convenience sampling methods in the outpatient healthcare centers. Inclusion criteria were people aged ≥60 years with a thoracic curve angle ≥45°, diagnosed with osteoporosis (clinical document or report of Dual-energy X-ray absorptiometry), who had at least two sudden falls within the last twelve months. The definition of fall was adopted from the World Health Organization. Fall was defined as an unintentional event of coming down of a person on the lower level surface. The reason for sudden fall did not include a violent blow, loss of consciousness, onset of paralysis, or epileptic event (Zecevic et al., 2006). Exclusion criteria were a new vertebral fracture, malignancies of the spine, or neurological diseases. The diagnosis of osteoporotic vertebral fracture was self-reported; however, participants were asked if they had any clinical record or X-ray for vertebral fracture. None of the participants had any experience with the orthotic devices used in the study.

Procedure

Data collection was carried out by an examiner who was a certified orthotist and had academic training in surface anatomy (to find spinal landmark by palpation) and biomechanical assessments of human balance performance. The examiner's task was explained, demonstrated, and exercised before data collection. After recording individuals' demographics, each participant was assessed under four conditions in random order: with 1) no orthosis (control), 2) rigid orthosis, 3) semi-rigid orthosis, and 4) soft orthosis.

Interventions

The spinal orthoses used in the study were thoracolumbosacral orthoses (TLSO) which spans the thoracic, lumbar, and sacral regions. The rigid TLSO (1200 gr weight) consisted of bivalve (anterior and posterior) thermoplastic sections. There was a subclavian supra-structure on the anterior section of the rigid TLSO to prevent the forward flexion of the thoracic spine. The rigid TLSO was fitted on the body with pairs of pelvic, waist, thoracic, and shoulder straps (Figure 1.A). The semi-rigid TLSO (900 gr weight; kypho-Support,Teknotan, Tehran, Iran) consisted of a supportive back panel with a flexible metal frame placed inside a dorsal pocket. The belts and paddings system fitted the orthosis on the trunk and around shoulders, thereby reminding users to keep themselves in a correct posture (Figure 1.B). The soft TLSO (800 gr weight) was a single-piece textile corset with an opening on the front. The soft TLSO had four thermoplastic bars to support the back alignment and placed between the soft dorsal layers. The soft TLSO was fitted on the body with bilateral and shoulder straps (Figure1.C). All orthoses in this study were custom-fitted and could be supplied upon participants' enrollment and after size measurements. The fitting of the orthoses was performed by a certified orthotist. Participants were given a few minutes interval to stand and walk around the lab and accommodate to their new spinal orthosis.

<u>Outcome measures</u>

The primary outcome measures were kyphosis angle, Timed Up and Go (TUG) test, Forward Reach Test (FRT), and the postural sway.

Kyphosis angle

Participants wore the back-expose gown for measurement of kyphosis angle. The C-7 and T-12 spinous processes were found according to a standard protocol previously reported (Ensrud et al., 1997). The C-7 spinous process was identified with the palpation of the first prominence at the lower end of the neck while the head was kept moderately down. The T12 was identified with the deep palpation of the inferior costal margin of the twelfth rib on the back and following its course with the fingers inward and upward until fingers reach the spinous process of the T12. After the spinous process were located, they were marked with a black dot made with a pen. Participants were asked to stand relaxed with their usual posture, and the examiner stood on the side of participants for kyphosis measurement. Measurement of thoracic kyphosis angle was carried out using a manual kyphometer (kyphometer, ghamatpoyan Co, Iran) with the same principle as DeBrunner kypometer (Protek AG, Bern, Swithzerland). This kyphometer consisted of a 1° scaled protractor connected to bilateral arms, and each arm ended to a block that was large enough to span two spinous processes., and the kypometer was placed on the spine, then the measurement was recorded (Figure 2). The two blocks of kyphometer were placed on the spine so that the upper trim of its upper block was directly over the C-7 spinous process and the lower trim of the lower block was directly over the T-12 spinous process. An oval window was cut out on the posterior wall of the spinal orthosis to put the distal block of the kypometer directly over the T-12 spinous process.

The measurement of kyphosis angle was repeated three times to reduce the impact of measurement error and ensure intra-tester reliability. If the difference (maximum-minimum) of recorded values was more than 5 degrees then the measurements were repeated until repeatable values were reached.

Timed Up and Go test

Dynamic balance during mobility was measured by the TUG. Participants are asked to sit on an armchair and stand up with a verbal signal of "go" then walk forward until they reach a marked line at 3 m distance from the chair and turn and walk back toward the chair, then sit down on the chair. The time to complete the test was recorded with a digital stopwatch. The TUG also has excellent intra-rater reliability (ICC=.99) (Podsiadlo and Richardson, 1991). Reported sensitivity is 87%, and specificity is 100%, with suggested cut-off values of 13 seconds for identifying fallers in the older population (Shumway-Cook et al., 2000).

Forward reach test

Standing balance during functional movements was measured with the FRT. In FRT, the distance each participant could reach while leaning forward with an outstretched arm was recorded with a yardstick kept at shoulder level. This test has good intra-rater reliability (intra-class correlation coefficient [ICC]=0.92) (Rockwood et al., 2000). The reported sensitivity of FRT is

62%9 and specificity is 92%, with a suggested cut-off point of 25 cm were identified with older people (Behrman et al., 2002).

Postural sway

Postural stability was recorded using a force platform (Advanced Medical Technologies Inc., Watertown, USA). Participants stood over a marked area on the force platform (heels were kept together, and forefoot slightly turned out) and was looking straight forward to a reference point on the wall, which was placed at their sight level. Participants were asked to maintain an upright standing position with arms relaxed at their sides. The recording time was set at 70s with a sampling rate of 100 Hz. The center of pressure (CoP) over the force platform was calculated as a variable of postural sway. The CoP signal was filtered using a second-degree curve with a 10 Hz cut-off threshold. The first and last 5s were trimmed (60s remaining) to obtain more reliable data. The recorded CoP had two components of anteroposterior (AP) and mediolateral (ML) for the time series. Mean velocity (MV) was calculated to present the quality of the CoP movement during a standing test for the AP or ML components.

All tests were completed in a single session that lasted 1.5 to 2 hours. The testing sessions were arranged about the morning time (ranged from 9 a.m to 2 p.m) to reduce the impact of disc dehydration on the measurements particularly, on kyphosis angle. All tests were explained and demonstrated to participants. The measurement of kyphosis and postural sway was carried out in the barefoot condition, and each participant used their own shoes to complete TUG and FRT. Each participant was given 2-3 minutes for acclimation with their orthoses and a practice run (without orthosis) to become familiar with the testing process. Each test was repeated three times, and mean values were calculated. Participants were allowed a 2 to 5min break between each trial to prevent fatigue. The participants could take a seat and drink water during their break time.

Statistical analyses

The Shapiro-Wilk test of normality and Leven's test of homogeneity of variance was performed before parametric tests. One-way repeated-measures analysis of variance (ANOVA) was used to compare outcomes measured in the four study conditions for participants. The Bonferroni post-hoc analyses were conducted to explore pairwise differences between study conditions. Cohen's d was calculated to investigate the effect size for pairwise comparisons. Cohen suggested that d=0.2 represents "small" effect size, 0.5 indicates "medium" effect size, and 0.8 a "large" effect size. The statistical analyses were carried out using SPSS software (V.18; IBM, Armonk, NY, USA). The adjusted p-value was used (instead of the traditional value of 0.05) to prevent the risk of inflation error type-1 in using separate one-way repeated measures ANOVAs:

$$\text{Adjusted p} - \text{value} = \frac{Traditional\, p - value}{Number\ of\ dependent\ variables} = \frac{0.05}{5} = 0.01$$

RESULTS

Twenty older people with osteoporotic hyperkyphosis participated in this study. All participants completed the testing. The demographic characteristics of the participants are outlined in Table 1. There were some reports of discomfort during acclimation with orthoses. The reasons for discomfort were mainly high pressure on the chest due to poor fitting of anterior supra-structure in rigid TLSO and tightness of shoulder straps in semi-rigid and soft TLSOs. All complaints were sorted out once orthotics were modified and fitted. There was no further report of discomfort during the testing and resting times.

One-way repeated measures ANOVA showed a significant difference between 2 out of 5 outcome measures (including Kyphosis angle and FRT) while using different TLSOs. TUG and mean velocity of CoP did not show significant differences between study conditions. The change in the study's outcome measures across the testing condition is reported in Table 2.

Post hoc pairwise comparisons indicated significant differences in the reduction of kyphosis angle using a soft orthosis (p<0.001, 95% CI: 1 to 2.5, Cohen's d=0.47), semi-rigid orthosis (p<0.001, 95% CI: 1.7 to 3.3, Cohen's d=0.65), and rigid orthosis (p<0.001, 95% CI: 2.5 to 4.5, Cohen's d=0.93) indicating medium to large clinical significance. There was a significant reduction in the kyphosis angle in comparing the effectiveness of rigid orthoses with soft orthoses (p<0.001, 95% CI: 0.9 to 2.6, Cohen's d=0.44) and semi-rigid orthoses (p=0.04, 95% CI: 0.03 to 1.9, Cohen's d=0.26) suggesting a moderate and small clinical significance, respectively. There was no significant difference between soft and semi-rigid orthoses in the reduction of kyphosis angle.

The forward reach was significantly reduced using a rigid orthosis (p=0.03, 95% CI: 1.08 to 6.3, Cohen's d=0.65) suggested a moderate clinical significance. Soft and semi-rigid orthoses did not show any significant change in the FRT compared to control condition. Post hoc pairwise comparisons also revealed that soft and rigid orthoses were significantly increased the AP component of the CoP mean velocity; (p=0.04, 95% CI: 0.03 to 1.27, Cohen's d= 0.59) and (p=0.03, 95% CI: 0.13 to 2.9, Cohen's d= 0.91) suggested moderate to large clinical significance, respectively. The results of post hoc pairwise comparisons are presented in Table 3.

DISCUSSION

This study showed that using a TLSO could decrease the kyphosis angle in older people with osteoporotic hyperkyphosis. The rigid TLSO was more effective than semi-rigid and soft orthoses in the realignment of the flexed thoracic curvature. Yet, this study gives preliminary evidence that rigid orthoses could affect the performance of the standing balance in the users, as it showed an immediate reduction of the forward lean and increase of the mean velocity of CoP displacement in the AP direction.

The spinal orthosis can interfere with movement control during standing sway in people with OVF wearing a TLSO. It has been explained that people use several movement strategies to maintain their postural stability during upright standing (Nashner, 2014). Firstly, the ankle strategy in which the body's line of gravity (LoG) is moved is mainly in AP direction, by rotating the body around the ankle joint. Second, the hip strategy in which people move the LoG with longer and faster movements at the level of the hip joint and trunk. If a large movement runs the LoG outside the limit of stability, then the person needs to use the stepping movement strategy to place the feet in a new position thereby bringing the LoG back within the limit of stability. The TLSO controls the gross spinal movements and as such, could have an impact on these movement strategies that are required for postural stability. Therefore, the selection of an appropriate spinal orthosis with the least risk of balance problems for people with OVF is necessary.

This study showed that all TLSO was effective in the reduction of the kyphosis angle, and more rigid designs were more effective than less rigid orthoses. The reduction of kyphosis angle was an expected outcome as reported in previous literature (Goodwin et al., 2016; Kweh et al., 2020; Newman et al., 2016), but to the authors knowledge, no study has reported the immediate change of kyphosis angle after wearing a spinal brace. Interestingly, one study considered the immediate effect of spinal taping on the reduction of hyperkyphosis (Liaw et al., 2009). This could suggest that the biofeedback provided by wearing less rigid orthoses may be an underlying mechanism to reduce hyperkyphosis in users (Pfeifer et al., 2004b). The average improvement in sagittal alignment was from 1.75° (soft TLSO) to 3.5° (rigid TLSO). Although these values seem small they can be clinically significant. It has been shown that a slight change in thoracic kyphosis has a substantial influence on the axial loading of the thoracic spine (Bruno et al., 2012). The reduction of hyperkyphosis in this study can be favorus for the balance parameters of people with osteoporotic kyphosis (Eum et al., 2013). This improvement in kyphosis angle can prevent the risk of new fractures in people with OVF (Jin and Lee, 2016). The realigning of the thoracic curvature could allow better respiratory inspiration which may decrease the risk of overall mortality in this population (Pfeifer et al., 2004a). Previous literature reported kyphosis angle using different techniques, including radioghraphs, inclinometer, flexible ruler, kyphometer, and photomorphometry (Barrett et al., 2014). We used kyphometer, which is a non-radiological, easy to use, and low-cost method (Greendale et al., 2011). This method is sensitive enough to show the change in sagittal curves of the spine. The Pearson's correlation coefficient of 0.76 was reported between measurements of kyphosis angle with kyphometer and Cobb methods (Greendale et al., 2011). Measurement of kyphosis angle with a kyphometer is a very high inter- and intra-reliability (both values are 0.98) (Barrett et al., 2014; Greendale et al., 2011).

TUG and FRT were measured in this study as the predictive parameters for functional mobility and falls (Thomas and Lane, 2005). The use of TLSOs did not lead to an improvement in TUG. This finding was in accordance with the previous literature that pointed out kyphosis realignment does not guarantee the improvement of mobility in orthotics users (Jin and Lee, 2016). It is also mentioned that functional mobility tests are less sensitive balance parameters than force plate measurements (de Groot et al., 2012). Another study reported each 12° increase of hyperkyphosis led to 0.2 seconds to complete TUG (Katzman et al., 2011). It has been reported that OVF-related pain is the primary determinant of functional mobility in older people with osteoporotic hyperkyphosis (Liu-Ambrose et al., 2002). In the current study, wearing TLSOs could not improve the mobility of participants during TUG. Rigid TLSO showed a greater reduction of forward lean than soft TLSO. This implied that rigid bracing might not be comfortable to wear during activities of daily living involving forward leaning (for example, picking up objects and cleaning). The restriction of forward bending also can explain the low compliance to rigid bracing reported in older people with OVF (Kweh et al., 2020; Murata et al., 2012). As a result, patients wearing rigid TLSO should receive proper instructions on wearing and ambulation with the orthosis and using substitute motions (such as bending hip and knee joints) to reach objects during activities of daily living.

If the level of statistical significance was set at 0.05, this study could show that wearing soft and rigid orthoses increased the velocity of CoP displacement in the AP direction. Semi-rigid orthosis had a dynamic panel placed on the back musculature and may have provided biofeedback to the dorsal musculature to facilitate postural adjustment after reduction of the kyphosis angle. Previous studies have reported that older people with osteoporosis (Lynn et al., 1997) and back pain (Nies and Sinnott, 1991) more frequently use the hip strategy than ankle strategy and displacement of CoP in ML than the AP direction. The lack of painful conditions in the participants of this study could explain why no significant CoP displacement in ML direction was recorded. It has been pointed out that kyphosis angle could influence the CoP displacement in the AP direction. We hypothesize that an immediate change of kyphosis angle after wearing orthoses could change the LoG and compromise the postural control in the AP direction. As the body sway is documented as a risk factor for balance disability and falls-related fracture (Lord et al., 2003), this increase of sway in the AP direction may be accompanied by a higher rate of falls in patients who start wearing a TLSO.

Limitations

This study had several limitations which should be taken into account. First, this was an exploratory clinical study on the immediate outcomes of a relatively small number of patients with lesser risk of falls than their peers with OVFs. Therefore results should be interpreted with caution. The longer-term effects with an optimal number of participants can be the subject of future research. Second, the examiner was not blinded to the orthoses type. The impact of assessor bias should be taken into account for study measurements particularly, kyphosis angle. Yet, the assessment bias might not be a concern in the automated measurement of postural sway. Third, the mean kyphosis angle was 51°, and participants did not have a fixed deformity. Patients with more severe deformities likely have different results. Fourth, we studied only thoracic curvature in one plane, and there may be a change in other spinal segments or curvatures, which may affect outcomes that we did not measure.

Conclusion

The finding of this study suggested that the dynamic construction of semi-rigid TLSO could provide a higher advantage of curve correction and safe mobility performance together, potentially because it allows the spine to compensate for the realignment of the thoracic curve with postural adjustments. The concern that rigid TLSO may present a challenge for balance and increase the risk of falls should be taken into account while managing older people with OVF.

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Figure and Table Legends:

Figure 1: The orthoses were used in the study. A: Rigid TLSO; B: Semi-rigid TLSO; C: Soft orthosis.

Figure 2: Measurment of thoracic kyphosis with a kyphometer

Table 1: Demographic characteristics of participants (n=15).

Table 2: Change in outcome measures across the study conditions.

Table 3: The results of pairwise comparisons between study conditions.

Figure 2: The orthoses were used in the study. A: Rigid TLSO; B: Semi-rigid TLSO; C: Soft orthosis.

Figure 2: Measurment of thoracic kyphosis with a kyphometer

Table 4: Demographic characteristics of participants (n=15).

Characteristics	Values*
Female, n (%)	13 (65)
Age, year	62±2 (60-65)
Height, cm	162±9 (146-175)
Weight, kg	72±10.6 (55-100)
BMI	27.6±4.4 (19-34.6)
Handgrip, Newton	313±84 (176-510)
* Values are Mean ± SD (minimum-maximum) unless another is indicated.	

Table 5: Change in outcome measures across the study conditions.

Outcome Measures	Study Conditions				1-way repeated measures ANOVA
	No orthosis	soft orthosis	Semi-rigid orthosis	Rigid orthosis	
Kyphosis angle (Degrees)	51.3±3.7 (45-59)	49.5±3.9 (42-57)	48.8±3.9 (43-55)	47.8±3.8 (40-55)	Wilk's Lambda=0.13, f=10.5, p<0.001*, η^2=0.87
Timed up & go (Seconds)	11.7±2.4 (7.5-15.8)	11.6±1.7 (8.3-15.6)	11.8±2.5 (8-17.1)	11.5±1.7 (7.3-14.3)	Wilk's Lambda=0.95, f=0.28, p=0.83, η2=0.05
Forward reach (cm)	17.6±5.4 (7.5-30.5)	16.9±5.2 (4.2-29.6)	18.8±6.7 (4.2-29.6)	13.9±6 (5.7-27)	Wilk's Lambda=0.49, f=5.53, p=0.008, η^2=0.49
MV of CoP (mm/s) AP	3.85±1 (11.7-38)	4.5±1.2 (2.9-7.8)	4.1±1.4 (2.4-8.6)	5.4±2.2 (2.9-12.8)	Wilk's Lambda=0.61, f=3.65, p=0.03, η^2=0.39
ML	8.6±2.2 (6-13)	9.9±3 (6.1-18.6)	9.1±2 (5.8-12)	9.7±2.1 (7-13.9)	Wilk's Lambda=0.76, f=1.8, p=0.19, η^2=0.24

ANOVA: analysis of variance; MV: mean velocity; CoP: center of pressure; AP: anteroposterior; ML: mediolateral; η^2: partial eta squared .Descriptive values for study conditions are presented as mean±SD (minimum-maximum).

* indicates a statistically significant difference between groups (p<.05).

Table 6: The results of pairwise comparisons between study conditions.

Pair-wise comparisons		Kyphosis angle (Degrees)	Timed up & go (Seconds)	Forward reach (cm)	MV of CoP (mm/s)	
					AP	ML
"No orthosis" Vs. "soft orthosis"	P (95% CI)	<0.001* (1 to 2.5)	1 (-1 to 1.12)	1 (-2.2 to 3.5)	0.04* (0.03 to 1.3)	0.22 (-2.3 to 0.3)
	MD (SE)	1.75 (0.26)	0.06 (0.36)	0.63 (0.99)	0.65 (0.2)	0.45 (0.2)
"No orthosis" Vs. "Semi-rigid orthosis"	P (95% CI)	<0.001* (1.7 to 3.3)	1 (-0.8 to 0.6)	0.1 (-0.36 to 5.9)	0.96 (-0.88 to 0.3)	1 (-1.1 to 0.8)
	MD (SE)	2.5 (0.27)	-0.12 (0.24)	2.76 (1.06)	0.3 (0.2)	0.16 (0.32)
"No orthosis" Vs. "Rigid orthosis"	P (95% CI)	<0.001* (2.5 to 4.5)	1 (-0.84 to 1.22)	0.003* (1.08 to 6.3)	0.03* (0.13 to 2.9)	0.54 (-2.2 to 0.55)
	MD (SE)	3.5 (0.35)	0.19 (0.35)	3.69 (0.89)	1.5 (0.47)	0.47 (0.03)
"soft orthosis" Vs. "Semi-rigid orthosis"	P (95% CI)	0.1 (-1 to 1.6)	1 (-1.1 to 0.7)	0.33 (-0.95 to 5.2)	1 (-0.5 to 1.1)	0.8 (-0.7 to 2.4)
	MD (SE)	0.78 (0.3)	0.18 (0.3)	1.04 (0.33)	0.36 (0.28)	0.85 (0.54)
"soft orthosis" Vs. "Rigid orthosis"	P (95% CI)	<0.001* (-0.9 to 2.6)	1 (-0.62 to 0.88)	0.04* (0.05 to 6.11)	0.14 (-0.16 to 1.9)	1 (-1.66 to 1.3)
	MD (SE)	1.75 (0.3)	-0.12 (0.26)	3.06 (1.04)	0.86 (0.35)	0.16 (0.51)
"Semi-rigid orthosis" Vs."Rigid orthosis"	P (95% CI)	0.04* (0.03 to 1.9)	1 (-0.67 to 1.07)	1 (-1.35 to 3.2)	0.07 (-0.75 to 2.5)	0.94 (-0.7 to 2.1)
	MD (SE)	0.98 (0.3)	0.31 (0.34)	0.93 (0.78)	1.22 (0.44)	0.69 (0.47)

MV: mean velocity; CoP, center of pressure; AP, anteroposterior; ML, mediolateral; P, Vs.: versus, p-value; CI, confidence intervals; M.D, mean differences; SE, standard error.

* indicates a statistically significant difference between groups (p<.05).