The Effect of Two Types of Thoracolumbosacral Braces on Electromyography Activity of Selected Muscles in Patients with Kyphosis during Walking

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Abstract

Introduction: The relationship between the use of braces and gait parameters in people with kyphosis has been not well understood. The aim of the present study was to evaluate the effect of two types of thoracolumbosacral braces on erector spinae, and gluteus medius muscles activities in individuals with kyphosis during walking. **Materials and Methods:** Fifteen males with kyphosis volunteered to participate in the present study. All participants were right footed. Each participant performed three walking trials in each of the three brace conditions including without brace, with alarm brace, and with simple brace. Muscle activities were recorded during walking at constant walk speed. Statistical analysis was performed using repeated measures ANOVA test at the significant level of 0.05. All analyses were performed using the SPSS version 22. **Results:** There is no significant difference in electromyography activities of the lower limb muscles at the loading response and mid-stance phases ($P>0.05$). Also, results showed a significant difference during push-off phase for gastrocnemius medialis muscle ($P<0.05$). **Conclusions**: The use of thoracolumbosacral braces reduced the electrical activity of the gastrocnemius medialis muscle during the push-off phase. These changes may lead to gait efficiency while using thoracolumbosacral braces.

Keywords: Brace; Electromyography; EMG; Kyphosis; Thoracolumbosacral

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Introduction

The angle between T4 and T12 is the usual definition of thoracic kyphosis. The classic definition of thoracic kyphosis using T4–T12 tends to underestimate the total amount of kyphosis (1). Changes in kyphosis distribution in the normative population suggest that, like lumbar lordosis, thoracic kyphosis is not a simple circle arc but rather closer to a sinusoidal shape. With low thoracic kyphosis, 2/3 of the kyphosis is located in the upper part of trunk and when thoracic kyphosis increases, the distribution of kyphosis will be symmetric around T7 (2). It is possible to predict the amount of kyphosis in the upper part of trunk using total kyphosis value. It could be used to estimate preoperative compensation and predict reciprocal change (3). The deformity may progress and lead to neurologic and orthopedic problems (4). Evidence showed that increased thoracic kyphosis is associated with a decline in physical performance, impaired balance, slower walking and stair climbing speeds, shorter functional reach (5), and decreased household activity performance (6, 7). The kyphosis angle is also correlated with back extension strength (8). The normal range of kyphosis is 20 to 40 degrees (9).

Bracing has been established as the most effective no operative treatment for adolescences with mild idiopathic scoliosis and kyphosis (10, 11). Previous studies have been showed promising short-term improvements in kyphosis among older women with a 6-month spinal bracing intervention (12). Also, it has been reported that spinal misalignments are associated with different pathologies including acute and chronic

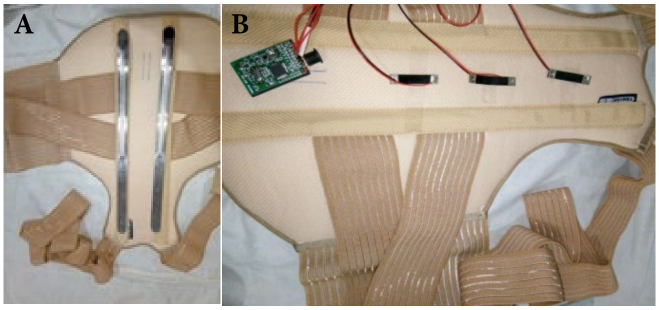

Figure 1. *A*) Thoracolumbosacral brace; *B*) Bending sensors and their location

characteristics of the spine (13), increased intradiscal pressure (14), viscoelastic deformation (15), and low back pain (16, 17). On the other hand, some studies have reported kyphosis with low back pain (18, 19).

Since the lumbosacral braces impacted muscle activity in the lumbar spine (19), there have been a few negative or even contradictory findings as well (20, 21). However, a few negative or even paradoxical findings were also reported (21, 22). However, the effect of lumbar braces on muscles activity while walking is still controversial. Therefore, the aim of this study was to evaluate the effect of two types of thoracolumbosacral braces on electromyography activities of tibialis anterior, gastrocnemius medialis, biceps femoris, semitendinosus, vastus lateralis, vastus medialis, erector spinae, and gluteus medius muscles in patients with kyphosis during walking.

Materials and Methods

Participants

Fifteen males with kyphosis (mean±SD; age 23.8±3.9 years, body mass 788.2±12.2 kg, height 1.78±7 m, and curvature of kyphosis 27.18±3.18 degrees) volunteered and gave their written informed consent to participate in the present study. Estimated kyphosis angle was calculated using Arc Tan=2h/L (23). Participants were male with more than 3 hours of physical activity per week for at least 2 years. None of the individuals previously had the brace model used in this study. A priori defined exclusion criteria comprised a history of musculoskeletal surgery at the trunk and/or lower limbs, and neuromuscular or orthopedic disorders (except of kyphosis). Ethical approval for research involving human participants was obtained from the Medical University of Ardabil (IR.ARUMS.REC.1399.255).

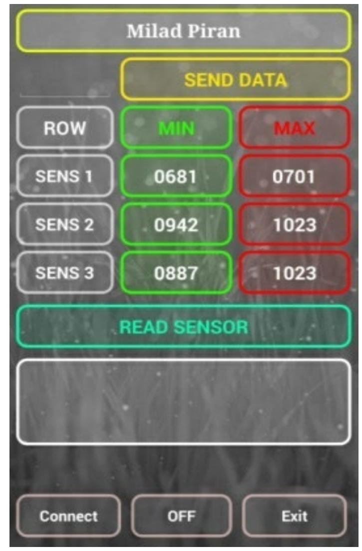

Figure 2. The Mobile Application Software (mobile App)

Brace

For designing a corrective and wireless brace, we made a thoracolumbosacral brace that is suitable for all ages (Figure 1A). It is triangular design that provides a good distribution of pressure on the shoulder, and adjustable hook and loop closure facilitates proper fastening (24).

The support structure of the brace is consisting of six straps to adjust, electronic enclosure, and two local stabilizers in which there is a bending sensor (Figure 1B).

The Mobile Application Software (mobile App) of designed brace is able to find out the bending angle and signal to the participant if the angle is more than the predefined angle by the vibration switch (Figure 2). To do this, the researcher must turn on the electronic circuit, then, software and mobile phones connect with Bluetooth. After that, the bending sensor data transform to researcher's mobile App and its shows the amount of bending on the mobile phone.

Experimental protocol

The thoracolumbosacral brace with vibration and mobile control capability was strapped around the lumbar using strips. All participants were asked to walk at a constant speed along an 18-m straight walkway (without slope) inside the biomechanics laboratory of University of Mohaghegh Ardabili. After a standardized warm-up program, each participant performed three walking trials in each of the three brace conditions including without brace, with alarm brace, and with simple brace in a randomized order. The support structure of the simple brace includes six adjustable straps and two local stabilizers to maintain proper alignment of the

Table1. Muscle activity three condition during Loading Phase

Variables	EMG			*P*-value		
Loading response	**Nonsupport (1)**	**Support simple model (2)**	**Support sensory model (3)**	**1&2**	**1&3**	**2&3**
TA(HZ)	111.51±19.62	106.61±13.18	107.84±15.69	0.657	1.000	1.000
Gas-med (HZ)	136.69±29.23	145.52±39.61	156.84±40.53	1.000	0.335	1.000
VL (HZ)	121.40±50.61	116.15±49.5	113.53±40.41	1.000	1.000	1.000
VM (HZ)	127.50±58.01	139.92±56.11	136.41±42.36	1.000	1.000	1.000
BF (HZ)	103.91±24.8	103.50±30.58	113.69±30.96	1.000	1.000	0.862
ST (HZ)	133.61±25.72	132.46±39.81	157.81±48.51	1.000	0.461	0.305
Glut-med (HZ)	114.43±45.90	128.72±42.01	140.05±48.11	1.000	0.715	1.000
Erector spinal (HZ)	110.50±37.71	90.15±40.43	113.52±74.01	0.264	1.000	0.735

TA, tibialis anterior; Gas-M, gastrocnemius medialis; VM, vastus medialis; VL, vastus lateralis; BF, biceps femoris; ST, semitendinosus; Glut-M, gluteus medius; SD, standard deviation, 1&2: compare Nonsupport and Support simple model, 1&3: compare Nonsupport and Support sensory model, 2&3: compare Support simple model and Support sensory model

person's posture. The start and finish lines of the walking trials were recorded using timing gates. The dominant leg was determined as the participant's preferred leg to kick the ball. Participants were only instructed to walk on the force platform embedded within the floor during their first step of the dominant leg. Participants were also given rest periods of 90 seconds between trials to avoid fatigue.

The electromyographic activity (EMG Pre-Amplifier, Biometrics Ltd., Nine Mile Point Ind. Est., Newport, United Kingdom) with eight pairs of bipolar Ag/AgCl surface electrodes (25 mm center-to-center distance; input impedance of 100 MO; and common-mode rejection ratio of>110 dB) were recorded for tibialis anterior (TA), gastrocnemius medialis (Gas-M), biceps femoris (BF), semitendinosus (ST), vastus lateralis (VL), vastus medialis (VM), erector spinal (ES), and gluteus medius (Glut-M) muscles of the right leg (25). A die-cut medical-grade double-sidedadhesive tape (T350, Biometrics Ltd., Nine Mile Point Ind. Est., Newport, United Kingdom) was used to attach the electrodes to the muscle bellies. The raw EMG signals were digitized at 1000 Hz and streamed via Bluetooth to a computer for further analysis. According to the European recommendations for surface EMG (SENIAM), the skin surface was shaved and cleaned with an alcohol (70% Ethanol–C_2H_5OH) over the selected muscles (25). Thereafter, the skin was gently abraded before electrode placement (25). The ground reaction force and EMG data were synchronized using Nexus software (Oxford Metrics, Oxford, United Kingdom). For EMG analyses, the gait cycle was divided into the following phases: loading phase (0–20% of the gait cycle), mid-stance (20–47% of the gait cycle), and push off (47–70% of the gait cycle) (26). Using a handheld dynamometer, maximum voluntary isometric contraction (MVIC) was calculated for each recorded muscle to normalize EMG during walking to MVIC. All normalization procedures were realized in accordance with recommendations from (27). For example, the participants were encouraged to perform the tests at their maximal effort (28). Three test trials were conducted with 1–2 min rest periods between them (28). For measuring MVIC, an isometric belt (where the joint is locked) was utilized (set for zero velocity) (28). This instrument is important to control testing factors that can influence the output and facilitate the production of maximal contraction. The maximum value of the MVIC test was considered for normalization purposes (27, 28).

Statistical analysis

The prior calculation of the sample size indicated that at least 15 subjects were required for the present study. For calculation, the software G*Power 3.1.2.9 was used with a statistical power of 0.80 at an effect size of 0.80 with an alpha level of 0.05 and the respective statistical test based on a related previous study that examined walking mechanics (29, 30).

The Shapiro-Wilk test was used to confirm the normal distribution of data. Repeated measure test along with Bonferroni post hoc test were used for statistical analysis. Additionally, effect sizes were determined by partial eta-squared (η_{2p}). All analyses were performed using the SPSS version 26.0 with significance level of $P<0.05$.

Results

During the loading response and mid-stance phases, there was no significant difference at the activity of selected muscles during walking with and without the brace (Tables 1 and 2).

Table 2. Muscle activity three condition during mid-stance phase

Variables	EMG			*p*-value		
Mid-stance	**Nonsupport (1)**	**Support simple model (2)**	**Support sensory model (3)**	**1&2**	**1&3**	**2&3**
TA(HZ)	104.20±23.47	102.70±17.50	108.42±18.51	1.000	1.000	0.947
Gas-med (HZ)	119.92±36.72	125.38±34.01	120.73±28.01	1.000	1.000	1.000
VL (HZ)	92±34.22.05	88.15±17.81	88.61±18.34	1.000	1.000	1.000
VM (HZ)	106.21±40.20	100.23±26.60	104.41±32.50	1.000	1.000	1.000
BF (HZ)	115.07±33.30	112.90±24.61	108.02±22.86	1.000	1.000	1.000
ST (HZ)	122.22±34.02	118.60±21.19	127.06±45.52	1.000	1.000	1.000
Glut-med (HZ)	122.22±73.81	114.15±38.81	131.41±48.46	1.000	1.000	0.737
Erector spinal (HZ)	*86.31±32.07*	*89.84±24.15*	*81.15±16.58*	*1.000*	*1.000*	*1.000*

TA, tibialis anterior; Gas-M, gastrocnemius medialis; VM, vastus medialis; VL, vastus lateralis; BF, biceps femoris; ST, semitendinosus; Glut-M, gluteus medius; SD, standard deviation, 1&2: compare Nonsupport and Support simple model, 1&3: compare Nonsupport and Support sensory model, 2&3: compare Support simple model and Support sensory model

Table 3. Muscle activity three condition during push off phase

Variables	EMG			*p*-value		
Posh-off	**Nonsupport (1)**	**Support simple model (2)**	**Support sensory model (3)**	**1&2**	**1&3**	**2&3**
TA(HZ)	112.61±12.06	108.82±18.41	107.62±22.18	1.000	1.000	1.000
Gas-med (HZ)	119.42±23.45	101.51±18.03	116.92±21.81	**0.002***	1.000	**0.009***
VL (HZ)	95.15±30.63	90.03±30.73	99.10±34.16	1.000	1.000	1.000
VM (HZ)	107.07±37.60	107.02±43.27	119.6±43.54	1.00	1.00	0.522
BF (HZ)	116.61±28.74	104.80±37.31	103.52±35.21	0.697	0.827	1.000
ST (HZ)	123.30±38.61	123.30±39.80	142.51±49.70	1.000	0.568	0.142
Glut-med (HZ)	101.60±23.23	99.06±26.10	114.40±28.52	1.000	0.659	0.310
Erector spinal (HZ)	87.09±24.62	84.90±22.61	85.41±25.50	1.000	1.000	1.000

TA, tibialis anterior; Gas-M, gastrocnemius medialis; VM, vastus medialis; VL, vastus lateralis; BF, biceps femoris; ST, semitendinosus; Glut-M, gluteus medius; SD, standard deviation, 1&2: compare Nonsupport and Support simple model, 1&3: compare Nonsupport and Support sensory model, 2&3: compare Support simple model and Support sensory model

The results at the push-off phase showed that gastrocnemius medialis activity during walking without brace was significantly greater than that walking with the simple brace (P=0.002 d=0.863). Moreover, the gastrocnemius medialis amplitude was significantly greater during walking with sensory brace than that walking with the simple brace (P=0.009 d=0.773) (Table 3).

Discussion

The present study aimed to evaluate the effect of three thoracolumbosacral braces on EMG activities of muscles in individuals with kyphosis during walking. The main findings of this study can be summarized as follows. The analyses revealed that gastrocnemius medialis activity during walking without brace was significantly greater than that walking with the simple brace. Moreover, the gastrocnemius medialis amplitude was significantly greater during walking with the sensory brace than that walking with the simple brace.

The activity of the gastrocnemius medialis muscle was reduced using the simple and sensory braces compared to without brace conditions. In this regard, the results of a study by Barton *et al.* (31) showed that heel lifts altered muscle activity reactively around heel strike (*i.e.* greater activity after heel strike) immediately after immediate use of brace. In order to better establish this issue, assessment of fully neuromuscular adaptation during walking with the three thoracolumbosacral braces would be necessary. In order to obtain these upper bound estimates experimentally, full neuromuscular adaptation to the three Thoracolumbosacral braces would be necessary. It is likely that complete adaptation did not occur in this current study. Furthermore, Jorgensen and Marra showed that wearing an abdominal belt did not affect EMG data recorded from the electrodes placed underneath the belt (34). It has been reported that lumbar braces can reduce compressive force on the spine, help the low back muscles in generating trunk extensor moment, or support the back (35). However, a thorough review of the literature indicates that there are no differences in trunk muscle electromyograms (EMG) or spine compression force when various activities are performed with and without lumbar supports and the kinematics of the tasks are well controlled (35). Therefore, the results of these studies are inconsistent with our finding, so that in our study, thoracolumbosacral braces affected the activity of muscle electromyograms in the push-off phase during walking. The use of thoracolumbosacral braces reduced the electrical activities of the gastrocnemius medialis muscle during the push-off phase. This frequency reduction is probably related to the inactive support of the brace. On the other hand, lower electrical activity of this muscle when using this brace probably reduces the time to fatigue.

The limitations of the present study were the small number of sample size, the lack of long-term e of the effects of braces, and lack of practice. It is suggested to investigate the effects of this type of brace in people with back pain patients as well.

Conclusion

The use of thoracolumbosacral braces reduced the electrical activity of the gastrocnemius medialis muscle during the push-off phase in individuals with kyphosis. These changes may lead to gait efficiency while using thoracolumbosacral braces.

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Conflict of interest

None.

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None.

Authors' contributions

Mr. Milad piran hamlabadi: He did the initial design of study, writing and paper revision. Mr. Amir Ali Jafarnezhadgero: He did the initial design of study, writing and paper revision. Ms. Sevda Abdullahigoliki: She did the initial design of study, data analysis and writing and laboratory work. Mr. Ebrahim Piri: He did the initial design of study, data analysis and writing and laboratory work.

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