Research Article

Motor Control Changes in Trunk Muscles after Using Anatomical Posture Control Orthosis in the Elderly Hyperkyphotic Subjects

Masoumeh Veiskarami[1*], Mehrdad Gholami[1,2], Atefeh Aboutorabi[3], Monireh Ahmadi Bani[3], Ebrahim Khamesi[4]

1. *Department of Physiotherapy, Faculty of Paramedical Sciences, Lorestan University of Medical Sciences, Khorramabad, Iran.*
2. *Department of Radiology Technology, Faculty of Paramedical Sciences, Lorestan Univercity of Medical Sciences.Khorramabad, Iran.*
3. *Department of Orthotics and Prosthetics, Faculty of Rehabilitation University of Social Welfare and Rehabilitation Sciences, Tehran, Iran.*
4. *Department of Neurosurgery, Faculty of Medicine, Lorestan University of Medical Sciences, Khorramabad, Iran.*

Use your device to scan and read the article online

Citation Veiskarami M, Gholami M, Aboutorabi A, Ahmadi Bani M, Khamesi E. Motor Control Changes in Trunk Muscles after Using Anatomical Posture Control Orthosis in the Elderly Hyperkyphotic Subjects. Journal of Modern Rehabilitation. 2022; 16(4):347-354. https://doi.org/10.18502/jmr.v16i4.10762

https://doi.org/10.18502/jmr.v16i4.10762

Article info:
Received: 27 Jul 2021
Accepted: 17 Oct 2021
Available Online: 01 Oct 2022

Keywords:
Hyperkyphosis; Orthosis; Electromyography; Motor control

ABSTRACT

Introduction: Hyperkyphosis is known to interfere with the normal function of the trunk musculature in the elderly. Although the effectiveness of orthoses in improving posture and balance in hyperkyphotic elderly people has received much attention, the effect of an orthosis on motor control of muscles remains unknown. This study aimed to evaluate changes in motor control strategies of trunk muscles during walking in elderly hyperkyphotic subjects after using an anatomical posture control (APC) orthosis.

Materials and Methods: A total of 19 elderlies (11 women and 8 men) with thoracic hyperkyphosis of more than 45 degrees were enrolled in the study. Surface electromyography (EMG) signals were recorded from 6 trunk muscles bilaterally with and without orthosis. The voluntary response index (VRI) was calculated from quantitative analysis of surface electromyography (sEMG) data during level walking in those with and without orthosis. The outcome variables of VRI included the similarity index (SI) and electromyographic magnitude (MAG) of muscle groups. The effects of APC orthosis on trunk motor control were tested using a Wilcoxon non-parametric test. Cohen’s d effect sizes were also calculated.

Results: A significant improvement was observed ($P<0.05$) in MAG and response vector (RV) of five muscles from the right and left sides and the VRI increased significantly after using this posture control orthosis ($P<0.05$; effect size [ES]: 0.27).

Conclusion: Improving trunk motor control after using orthosis, with relatively medium effect sizes, was observed in the elderly with hyperkyphosis during walking.

*** Corresponding Author:**
Masoumeh Veiskarami, PhD.
Address: *Department of Physiotherapy, Faculty of Paramedical Sciences, Lorestan University of Medical Sciences, Khorramabad, Iran.*
Tel: *+98 (33) 409972*
E-mail: *veiskarami.ma@lums.ac.ir, m_vayskaramy@yahoo.com*

1. Introduction

Hyperkyphosis is an abnormal forward curvature of the spine and is a common progressive deformity related to aging [1]. It is often linked with muscle weakness, especially in spinal extensor muscle, and changes the extensor muscles' line of action and alters their role in supporting anterior shear forces [2]. A flexed posture shifts forward the center of mass of the entire body causing gait instability [3]. Therefore, in elderly people, greater muscle co-contraction is induced during gait [4] as a compensatory mechanism to increase joint stiffness to increase stability during walking [5].

Correction of skeletal alignment following orthotic intervention by maintaining the center of gravity within the base of support [6-8] and indirectly through modification of trunk muscle activity pattern [8, 9] are possible mechanisms suggested in the previous studies to improve balance performance.

Reducing the kyphotic angle and the biomechanical changes caused by using orthosis can increase the ability of the muscles to support the spine. It seems that following the reduction in the kyphotic angle and the improvement of spinal alignment (appropriate position), the stretching and straining of the muscles and tendons are reduced and the muscle functions and force generation are improved.

Anatomical posture control (APC) orthosis is a newly designed posture control orthosis that can be used for the orthotic management of hyperkyphosis in the elderly. Our previous study demonstrated that APC orthosis can decrease the eerector spinae (ES) muscle activity during static standing and improve static and dynamic balance in hyperkyphotic individuals [10]. Since evaluating the effect of therapeutic intervention on motor control helps chooses the suitable treatment option, the Voluntary Response Index (VRI) is proposed for quantitative analysis of the muscle activity pattern and motor control [2, 3]. This index contains two numeric values, including Similarity Index (SI) and measurement of the magnitude (MAG) of muscle group activities. In this protocol, the MAG and the similarity of activities of all muscles involved in a task are studied in a work pattern [11].

Although Ambulation is an important output of a complex neural system, the analysis of the surface electromyography (sEMG) data recorded during walking in elderly people is a useful motor task to assess. Accordingly, the present study was designed to assess the effect of APC orthosis on the VRI strategies of trunk muscles during walking in the elderly hyperkyphosis.

2. Materials and Methods

Participants

A total of 19 elderly individuals, including11 women, and 8 men suffering from hyperkyphosis, participated in the current study (Table 1). All the participants completed and signed an informed consent form after receiving information about the research procedure. The Ethics Committee at Lorestan University of Medical Sciences (IR.LUMS.REC.1397.002) approved the study.

The criteria in selecting the participants included healthy elderly with the thoracic kyphotic angles greater than 45 degrees. Also, the exclusion criteria included prior surgery on the vertebral column and lower limb in the previous year, recent lower limb joint injury or pain, recent fracture or localized back pain, congenital hyperkyphosis, other spinal deformities including scoliosis and kyphoscoliosis, use of medications during the previous year that could affect the muscle performance or balance control, and cognitive impairments [8].

Intervention

Figure 1 shows the customized patient-specific orthosis and its features described in the authors' previous work [10]. The orthoses were fabricated by a skilled orthotist and he instructed the patient to use the orthosis properly. The patients were guided to place the orthosis over the spine and adjust the straps.

Study protocol

First, the thoracic kyphosis was measured using a Dualer electric inclinometer (North American Fork, Utah). An experienced investigator was assigned to manage the intervention according to the guidelines [12]. The height and weight of all the participants were also recorded before determining the baseline measurements. The participants were informed about the test procedure and were given enough time to learn the evaluation procedure. Data were collected before and after using orthosis. Before starting the experiment, the participant was asked to lie on the bed in a prone position, and skin of the back was cleaned and exces-

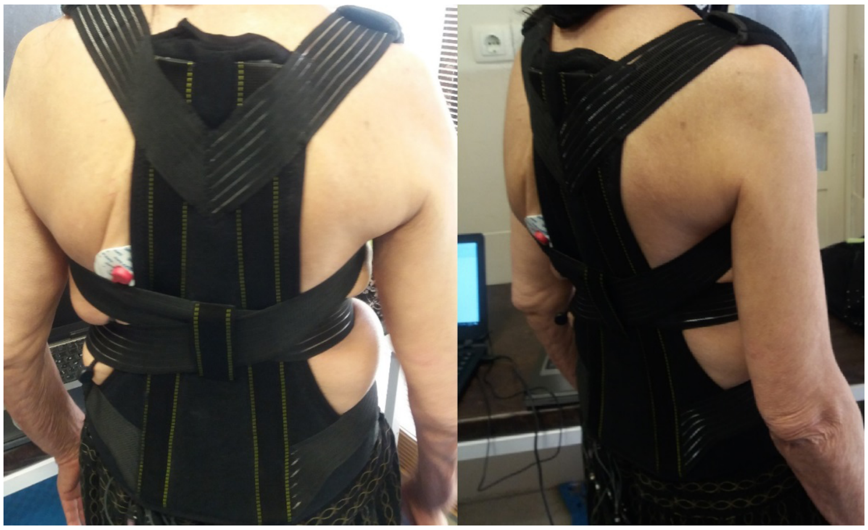

Figure 1. Posterior and lateral view of the orthosis

JMR

sive hair was shaved if needed to prepare him/her for the electromyography (EMG) tests.

The EMG signals were collected using a portable electromyogram (ME3000P, Mega Electronics Ltd., Finland) with a sampling rate of 1000 Hz and a band-pass filter of 10–500 Hz. Muscles were all assessed bilaterally, including lumbar erector spinae, thoracic erector spinae, and lumbar multifidus muscles. The surface electrodes (10 mm diameter, and 20 mm inter-electrode distance) were applied. For thoracic erector-spinae was placed 5 cm lateral to the T9 spinous process, the lumbar erector spinae muscles were placed 3 cm lateral to the L4 spinous process, and the surface electrodes of lumbar multifidus muscles were placed at the level of the L5 spinous process (i.e., about 2-3 cm from the midline). The reference electrode was placed on the right 10^{th} rib (Figure 2). The electrode positions of each muscle were selected based on the surface EMG for non-invasive assessment of muscles (SENIAM) instructions [13].

First of all, before asking the participant to wear the orthosis, the muscle EMG was recorded during 1 minute of level walking and at a self-selected normal walking speed with his/her head held high and looking forward. Then, after a short break for 2-3 minutes, the patient puts on the orthosis and after 10 minutes, the tests were repeated. Each test was repeated 3 times in the test session at 30-s intervals.

Data processing

VRI was used to quantitatively analyze motor control before and after using orthosis. The total activity of the muscles under the study is defined as a vector in VRI. MAG and similarity index (SI) are the two values produced in the VRI calculation. First, the root means square (RMS) of each muscle was calculated as the muscle response (R1, R2, R3, R4, R5, and R6). Then, the normalized response was measured by the ratio between each response (R1, ...R6) to the vector of baseline correction of each muscle to RMS of rest-activity (RA) [1]. The MAG parameter, which is the amount of combined sEMG activity for six muscles during 1 minute of level walking before using orthosis, was calculated as the length of the response vector (RV) and, prototype response vector (PRV), which represents the MAG of all the muscles when using orthosis during the gait was calculated by placing the response vectors of six muscles into Equation 1. The SI shows the similarity between the RV of the elderly before using orthosis and the PRV obtained when using orthosis during the gait (Equation 2). The SI value was computed for each task as a cosine of the angle between the RV and PRV, ranging between 0 and 1.0, where 1.0 means the best match for compared vectors. The VRI was calculated from multiply of MAG by SI (RV×SI) before and after using an orthosis [11].

The response vector was obtained as follows (Equation 1):

$$1.\ R_{norm} = \frac{R_1\, R_2\, R_3 \ldots R_n}{\sqrt{\sum_i R_i^2}}$$

Ri = Response vector (RMS) of each muscle

Table 1. Demographic characteristics of the study subjects

Subject's Characteristics	Mean±SD
Height (cm)	161.5±5.9
Weight (kg)	70.6±7.68
Age (y)	65.9±2.96
Kyphosis (deg)	52.46±4.92
BMI (kg/m²)	27.09±1.57

BMI, Body Mass Index.

JMR

Equation 2: SI is calculated as the scale of the overlap between two vectors RV and PRV (Equation 2):

$$2.\ SI = \frac{\sum i\,(RV_i\,PRV_i)}{|RV|PRV}$$

Data analysis

To analyze the data, SPSS software, version 25, was used. The Kolmogorov-Smirnov test was used to check for the normality of the data and, the Wilcoxon test was used to examine the relationship between the variables. The significance level was set at P<0.05 for all the analyses. Finally, to evaluate the effect of clinical treatment, the effect size was calculated using Cohen's D for statistically significant variables [14].

3. Results

Table 2 presents the Mean±SD of the VRI, MAG, and RV of six muscles with and without orthosis. The Mean±SD of SI was found to be 0.3±0.23. The VRI was increased significantly by using the spinal orthosis (P<0.05; ES: 0.27). The mean of the MAG was significantly different before and after using APC orthosis during gait. Comparing VRI variable before and after using this posture control orthosis indicated an increase in RV indices of right thoracic erector spinae (RTES) (P=0.003), left thoracic erector spinae (LTES) (P=0.008), right lumbar erector spinae (RLES) (P=0.001), left lumbar erector spinae (LLES) (P=0.005), Left Multifidus (LMF) (P=0.05), and right multifidus (RMF) (P=0.06) (Figure 3).

Table 2. Mean±SD and effect sizes of variables

Variables	Test Condition		P	Effect Sizes (95% CI)
	Mean±SD			
	Without Orthosis	With Orthosis		
MAG (µV)	28.62±12.91	74.28±24.22	0.001	2.353 (1.451-3.254)
VRI	14.24±8.99	13.73±12.87	0.002	0.277 (-0.419-0.974)
RTES (µV)	11.72±6.81	23.51±12.35	0.003	1.182 (0.12-2.244)
LTES (µV)	8.70±3.49	19.78±18.07	0.008	0.851 (-0.172-1.875)
RLES (µV)	13.29±8.27	32.48±18.45	0.001	1.342 (0.258-2.427)
LLES (µV)	12.90±8.44	34.39±24.98	0.005	1.153 (0.094-2.211)
RMF (µV)	10.74±8.33	22.97±22.77	0.05	-
LMF (µV)	10.56±8.33	24.35±22.43	0.06	0.652 (0.27-1.57)

JMR

MAG: Magnitude; RTES: Right Thoracic Erector Spinae; LTES: Left Thoracic Erector Spinae; RLES: Right Lumbar Erector Spinae; LLES: Left Lumbar Erector Spinae; RMF: Right Multifidus; LMF: Left Multifidus.

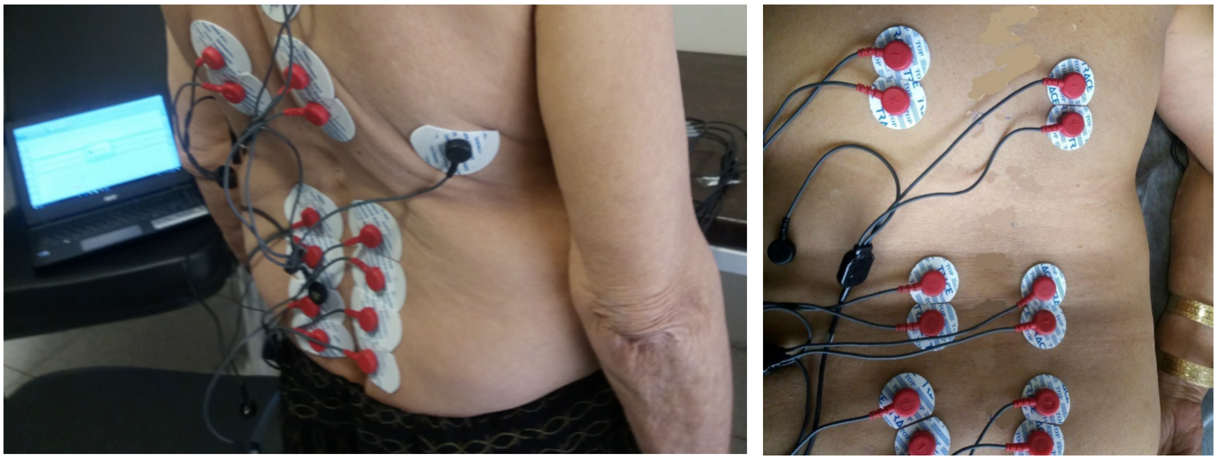

Figure 2. Example of electrode placements for Electromyography (EMG) recording

JMR

4. Discussion

In the current study, motor control was investigated using back muscle activation patterns and the VRI analysis. VRI is used to evaluate changes in the central nervous system (CNS) motor output that occurs following intervention [11]. It is based on the MAG of the RV, which is an expression of the total activity during the movement, and the SI resulting from the comparison between sEMG patterns recorded during walking with orthosis and an average prototype pattern acquired from walking without the orthosis. The main finding of our study was the improvement of motor control after using orthosis with a relatively medium effect size.

The increased MAG after using orthosis suggested the effectiveness of this intervention. Clinically, the increased MAG after using orthosis increased synergistic muscle coactivation due to changes in CNS motor output [15]. Therefore, using orthosis induced CNS changes and reflected in the control of motor actions and muscle activation patterns. To date, the evidence base for this topic is very limited and this is the first study to investigate the effect of a spinal orthosis on motor control and VRI in the elderly population.

A previous study demonstrated that using lumbar support in able-bodied young men improves the coordination in the activities of trunk agonist and antagonist muscles while lifting the loads [16].

However, in elderly hyperkyphotic individuals, most studies evaluated the effect of a spinal orthosis on muscle strength [9, 12, 17-21]. Valentin et al. reported that wearing spinomed orthosis after a 3-month was associated with a 50% increase in back extensor strength (P=0.01) [21]; another study showed 73% improvement in back extensor strength during 6 months of using spinomed orthosis [9]. These results were obtained probably due to the improvement in spinal posture and muscle activation in functional activities, which is consistent with our findings because improvement in motor control along with time can result in strengthening the muscles.

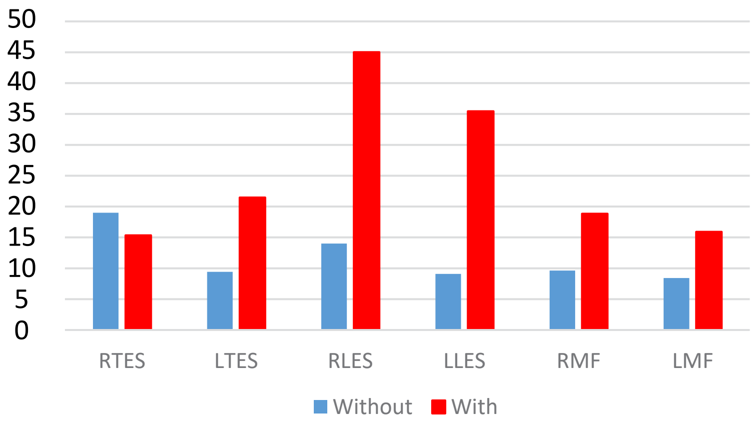

Figure 3. The mean of the Response Vector (RV) of muscles with and without orthosis

JMR

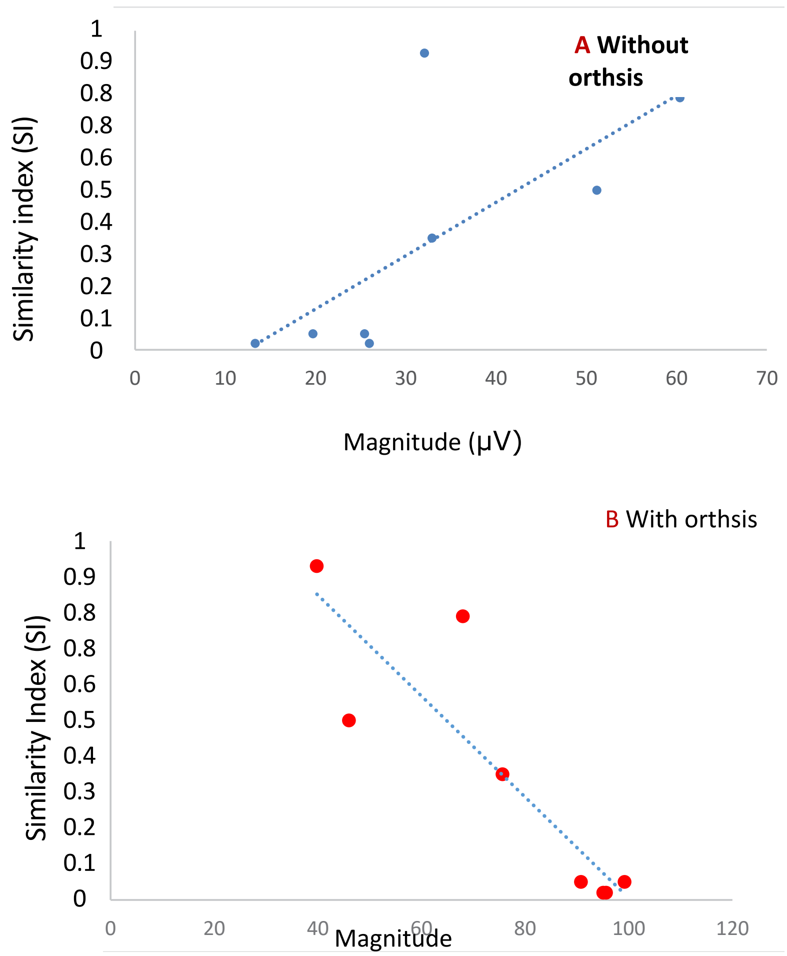

Figure 4. The similarity indices-Magnitude (MAG) plot during walking
A) without an orthosis; B) with orthosis

JMR

The previous studies investigating the effect of spinal orthoses on the activity of the erector spinae muscles have reported a decrease in the electrical activity of these muscles while standing and walking [10, 22, 23] which is not comparable to the results obtained in the present study because, in our study, RV is an indicator of the activity of each muscle relative to the rest of overall muscles, called the response vector, and differs from the raw electrical activity of the muscles.

Before using the orthosis, the RV value for each muscle was lower than when the elderly wore the orthosis because before using orthosis, muscles have a co-contraction, and therefore the vector summation of the response of each muscle is less when the orthosis is used (muscles activities neutralize each other).

In fact, after using the orthosis, co-contraction of erector spinae muscle becomes co-activation. In other words, before using orthoses in the elderly, we have an increase of activity for all muscles and the summations of this electrical activity create a contraction in which the response vector of each muscle individually becomes smaller. While wearing orthosis, this contraction of all muscles is reduced; however, the proportion of the individual response vector of each muscle increases numerically.

The VRI is computed by a combination of SI and EMG magnitude (SI, EMG magnitude) and expressed by plotted graph. Figure 4 shows the altered patterns of muscle activation during walking after using orthosis.

Various hypotheses exist about the improvement in motor control as a result of using the APC orthosis. Improvement in motor control may be due to the reduction in the kyphotic angle and the biomechanical changes caused by using orthosis, which increases the ability of the muscles to support the spine. It seems that after reducing the kyphotic angle and improving spinal alignment, the stretching and strain on the muscles and tendons are reduced and the muscle functions and force generation are improved. Being in the wrong position changes the orientations of the force vector and the lengths of the moment arm of the paraspinal muscles [24]. The muscular force and flexibility of the body can be affected by hyperkyphosis. This orthosis may help the back muscles in improving trunk extensor moment. Another hypothesis is that the device improves postural control and gait efficiency by keeping the body's center of mass at the base of support during gait [10, 25].

Consequently, body awareness would be more efficient and more functional, followed by enhanced proprioceptive inputs. In elderly people, impaired proprioception can alter paraspinal muscle spindle afferents or flawed central processing of the sensory input. Such a proprioceptive impairment could also explain delayed muscle reflex response to sudden trunk loading and poorer motor control [26].

The parts of orthosis increase proprioceptive input and improve the joint position sense of the spine. Increasing the somatosensory feedback induced by the orthoses facilitates postural control; it may help elderly individuals with hyperkyphotic compensate for the loss of motor control and function [27]. The improved proprioception may result from increased stimulation of skin afferents and the compression of the soft tissues around the receptors by orthosis elements [28, 29]. Integration of multiple sources of sensory information, including joint, muscle, and cutaneous receptors may play a vital role in joint position sense and motion [30]. Although effect sizes (Cohen's d) were medium, the present study found that APC orthosis might play a crucial role in the rehabilitation of elderly people.

5. Conclusion

Our study showed that the APC orthosis may have a significant effect on trunk muscle function and coordination in older people with hyperkyphosis during walking. Further research is needed to clarify the effect of this intervention on trunk flexor and lower limb muscles during functional movement in this population.

Our study has some limitations that should be considered before generalizing the findings. First, the current study lacks a control group. Second, we evaluated the immediate effect of the orthosis. Also, our study examined only trunk extensor muscles and thus provides no information on antagonist muscle activity. Finally, our data did not measure changes in lower extremity motor control during gait.

Ethical Considerations

Compliance with ethical guidelines

The study procedure was approved by the Ethics Committee of the Lorestan University of Medical Sciences (IR.LUMS.REC.1397.002).

Funding

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

Authors' contributions

Conceptualization, Data collection, and Data analysis: Masoumeh Veiskarami and Mehrdad Gholami; Methodology and Writing-original draft: Masoumeh Veiskarami, Atefeh Aboutorabi, and Monireh Ahmadi Bani; Writing-review & editing: Atefeh Aboutorabi. and Monireh Ahmadi Bani; Funding acquisition and Resources and Supervision: Ebrahim Khamesi.

Conflict of interest

The authors declared no conflict of interest.

References

[1] Fernandes VL, Ribeiro DM, Fernandes LC, Menezes RL. Postural changes versus balance control and falls in community-living older adults: A systematic review. Fisioterapia em Movimento. 2018; 31:1-15. [DOI:10.1590/1980-5918.031.AO25]

[2] McGill SM, Hughson RL, Parks K. Changes in lumbar lordosis modify the role of the extensor muscles. Clinical Biomechanics. 2000; 15(10):777-80. [DOI:10.1016/S0268-0033(00)00037-1]

[3] Arnold CM, Busch AJ, Schachter CL, Harrison L, Olszynski W. The relationship of intrinsic fall risk factors to a recent history of falling in older women with osteoporosis. Journal of Orthopaedic & Sports Physical Therapy. 2005; 35(7):452-60. [DOI:10.2519/jospt.2005.35.7.452] [PMID]

[4] Darainy M, Ostry DJ. Muscle cocontraction following dynamics learning. Experimental Brain Research. 2008; 190(2):153-63. [DOI:10.1007/s00221-008-1457-y] [PMID]

[5] Hortobágyi T, Solnik S, Gruber A, Rider P, Steinweg K, Helseth J, et al. Interaction between age and gait velocity in the amplitude and timing of antagonist muscle coactivation. Gait & Posture. 2009; 29(4):558-64. [DOI:10.1016/j.gaitpost.2008.12.007] [PMID]

[6] Raeissadat SA, Sedighipour L, Pournajaf S, Vahab Kashani R, Sadeghi S. Effect of posture training with weighted kypho-orthosis (WKO) on improving balance in women with osteoporosis. Journal of Aging Research. 2014; 2014:427903. [DOI:10.1155/2014/427903] [PMID] [PMCID]

[7] Hosseinabadi M, Kamyab M, Azadinia F, Sarrafzadeh J. Effect of a spinomed orthosis on balance performance, spinal alignment, joint position sense and back muscle endurance in elderly people with hyperkyphotic posture: A randomized controlled trial. Prosthetics and Orthotics International. 2020; 44(4):234-44. [DOI:10.1177/0309364620923816] [PMID]

[8] Sinaki M, Lynn SG. Reducing the risk of falls through proprioceptive dynamic posture training in osteoporotic women with kyphotic posturing: A randomized pilot study. American Journal of Physical Medicine & Rehabilitation. 2002; 81(4):241-6. [DOI:10.1097/00002060-200204000-00001] [PMID]

[9] Pfeifer M, Begerow B, Minne HW. Effects of a new spinal orthosis on posture, trunk strength, and quality of life in women with postmenopausal osteoporosis: A randomized trial. American Journal of Physical Medicine & Rehabilitation. 2004; 83(3):177-86. [DOI:10.1097/01.PHM.0000113403.16617.93] [PMID]

[10] Veiskarami M, Aminian G, Bahramizadeh M, Ebrahimzadeh F, Arazpour M, Abdollahi I, et al. Design, implementation and preliminary testing of a novel orthosis for reducing erector spinae muscle activity, and improving balance control for hyperkyphotic elderly subjects. Journal of Biomedical Physics & Engineering. 2020; 10(1):75-82. [DOI:10.31661/jbpe.v0i0.1200] [PMID] [PMCID]

[11] Lee DC, Lim HK, McKay WB, Priebe MM, Holmes SA, Sherwood AM. Toward an objective interpretation of surface EMG patterns: A voluntary response index (VRI). Journal of Electromyography and Kinesiology. 2004; 14(3):379-88. [DOI:10.1016/j.jelekin.2003.10.006] [PMID]

[12] Greig AM, Bennell KL, Briggs AM, Hodges PW. Postural taping decreases thoracic kyphosis but does not influence trunk muscle electromyographic activity or balance in women with osteoporosis. Manual Therapy. 2008; 13(3):249-57. [DOI:10.1016/j.math.2007.01.011] [PMID]

[13] Hermens HJ, Freriks B, Disselhorst-Klug C, Rau G. Development of recommendations for SEMG sensors and sensor placement procedures. Journal of Electromyography and Kinesiology. 2000; 10(5):361-74. [DOI:10.1016/S1050-6411(00)00027-4]

[14] Sullivan GM, Feinn R. Using effect size-or why the P value is not enough. Journal of Graduate Medical Education. 2012; 4(3):279-82. [DOI:10.4300/jgme-d-12-00156.1] [PMID] [PMCID]

[15] Hajouj E, Hadian MR, Mir SM, Talebian S, Ghazi S. Motor control changes after innovative aquatic proprioceptive training in athletes with anterior cruciate ligament reconstruction: Voluntary response index analysis. Archives of Neuroscience. 2021; 8(2):e112185. [DOI:10.5812/ans.112185]

[16] Ghofrani M, Olyaei GR, Talebian S, Bagheri H. [Effect of lumbopelvic belt on motor control strategy of trunk muscles during lifting and lowering of different loads symmetrically (Persian)]. Journal of Modern Rehabiliation. 2012; 6(1):56-61. [Link]

[17] Alin CK, Uzunel E, Kronhed AC, Alinaghizadeh H, Salminen H. Effect of treatment on back pain and back extensor strength with a spinal orthosis in older women with osteoporosis: A randomized controlled trial. Archives of Osteoporosis. 2019; 14(1):5. [DOI:10.1007/s11657-018-0555-0] [PMID] [PMCID]

[18] Dionyssiotis Y. Management of osteoporotic vertebral fractures. International Journal of General Medicine. 2010; 3:167-71. [DOI:10.2147/IJGM.S11751] [PMID] [PMCID]

[19] Hosseinabadi M, Kamyab M, Azadinia F, Sarrafzadeh J. [The effect of spinal orthosis on trunk muscle force control in hyperkyphotic elderly (Persian)]. Tehran University of Medical Journal. 2019; 77(3):179-85. [Link]

[20] Pfeifer M, Kohlwey L, Begerow B, Pyrmont B. Effects of two newly developed spinal orthoses on trunk muscle strength, posture, and quality-of-life in women with postmenopausal osteoporosis: A randomized trial. American Journal of Physical Medicine & Rehabilitation. 2011; 90(10):805-15. [DOI:10.1097/PHM.0b013e31821f6df3] [PMID]

[21] Valentin GH, Pedersen LN, Maribo T. Wearing an active spinal orthosis improves back extensor strength in women with osteoporotic vertebral fractures. Prosthetics and Orthotics International. 2014; 38(3):232-8. [DOI:10.1177/0309364613497393] [PMID]

[22] Ishida H, Watanabe S, Yanagawa H, Kawasaki M, Kobayashi Y, Amano Y. Immediate effects of a rucksack type orthosis on the elderly with decreased lumbar lordosis during standing and walking. Electromyography and Clinical Neurophysiology. 2008; 48(1):53-61. [PMID]

[23] Cholewicki J, Reeves NP, Everding VQ, Morrisette DC. Lumbosacral orthoses reduce trunk muscle activity in a postural control task. Journal of Biomechanics. 2007; 40(8):1731-6. [DOI:10.1016/j.jbiomech.2006.08.005] [PMID]

[24] Khalkhali M, Kalantari KK. [A comparative study of the effect of local and general fatigue on sense (Persian)]. The Scientific Journal of Rehabilitation Medicine. 2012; 1(3):22-8. [DOI:10.22037/JRM.2012.1100066]

[25] Namdar N, Arazpour M, Ahmadi Bani M. Comparison of the immediate efficacy of the Spinomed® back orthosis and posture training support on walking ability in elderly people with thoracic kyphosis. Disability and Rehabilitation: Assistive Technology. 2019; 14(3):217-20. [DOI:10.1080/17483107.2017.1419295] [PMID]

[26] Ribeiro F, Oliveira J. Aging effects on joint proprioception: The role of physical activity in proprioception preservation. European Review of Aging and Physical Activity. 2007; 4(2):71-6. [DOI:10.1007/s11556-007-0026-x]

[27] Dupuy EG, Leconte P, Vlamynck E, Sultan A, Chesneau C. Ehlers-Danlos syndrome, hypermobility type: Impact of somatosensory orthoses on postural control (a pilot study). Frontiers in Human Neuroscience. 2017; 11:283. [DOI:10.3389/fnhum.2017.00283] [PMID] [PMCID]

[28] Moberg E. The role of cutaneous afferents in position sense, kinaesthesia, and motor function of the hand. Brain. 1983; 106(1):1-19. [DOI:10.1093/brain/106.1.1] [PMID]

[29] Gandevia SC, Refshauge KM, Collins DF. Proprioception: Peripheral inputs and perceptual interactions. Sensorimotor Control of Movement and Posture. 2002; 508:61-8. [DOI:10.1007/978-1-4615-0713-0_8] [PMID]

[30] Gandevia SC, McCloskey DI, Burke D. Kinaesthetic signals and muscle contraction. Trends in Neurosciences. 1992; 15(2):62-5. [DOI:10.1016/0166-2236(92)90028-7] [PMID]