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Electromyographic responses of erector spinae and lower limb's muscles to dynamic postural perturbations in patients with adolescent idiopathic scoliosis

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ABSTRACT

The aim of this study was to evaluate electromyographic (EMG) responses of erector spinae (ES) and lower limbs' muscles to dynamic forward postural perturbation (FPP) and backward postural perturbation (BPP) in patients with adolescent idiopathic scoliosis (AIS) and in a healthy control group. Ten right thoracic AIS patients (Cobb = 21.6 ± 4.4°) and 10 control adolescents were studied. Using bipolar surface electrodes, EMG activities of ES muscle at T10 (ES_{T10}) and L3 (ES_{L3}) levels, biceps femoris (BF), gastrocnemius lateralis (G) and rectus femoris (RF) muscles in the right and the left sides during FPP and BPP were evaluated. Muscle responses were measured over a 1s time window after the onset of perturbation. In FPP test, the EMG responses of right ES_{T10}, ES_{L3} and BF muscles in the scoliosis group were respectively about 1.40 ($p = 0.035$), 1.43 ($p = 0.07$) and 1.45 ($p = 0.01$) times greater than those in control group. Also, in BPP test, at right ES_{L3} muscle of the scoliosis group the EMG activity was 1.64 times higher than that in the control group ($p = 0.01$). The scoliosis group during FPP displayed asymmetrical muscle responses in ES_{T10} and BF muscles. This asymmetrical muscle activity in response to FPP is hypothesized to be a possible compensatory strategy rather than an inherent characteristic of scoliosis.

1. Introduction

Adolescent idiopathic scoliosis (AIS) is a complex three dimensional deformity of the spine and thorax (Stokes, 1989; Stokes and Laible, 1990). Spinal muscles adapt to the scoliotic condition that varies according to the type (Hopf et al., 1998), severity (Chan et al., 1999; Tsai et al., 2010; Zetterberg et al., 1984) and progression (Cheung et al., 2005) of the curvature. In scoliotic patients muscle fiber type composition is altered. Type I (tonic-postural) fibers are predominant on the convex side and there are more type II fibers on the concave side (Zetterberg et al., 1983). In addition, muscle volume in AIS patients is mostly larger on the concave side (Zoabli et al., 2007). Due to the larger portion of type I (tonic) fibers together with the smaller muscle volume on the convex side of the scoliotic curvature, a higher muscle response is expected in this side.

Previous investigations showed that in fast progressive idiopathic scoliosis, muscles in the convex side have higher EMG activity than on the concave side (Cheung et al., 2004, 2005). Also, scoliotic trunk's muscles are weaker in rotations toward the concavity (McIntire et al., 2007). Dobosiewicz (1997) found that AIS patients with fast progressive idiopathic scoliosis have a longer latency at the first activation of paravertebral muscles following the postural perturbation than non-progressive scoliotic subjects. It was postulated that the prolonged latency of the silent period can detect progressive AIS in the early stage of the disease which enables an early decision to perform surgery (Dobosiewicz, 1997). Also few authors confirmed that asymmetrical muscle response exist in AIS patients with progressed curvature (Chan et al., 1999; Reuber et al., 1983; Zetterberg et al., 1984). These evidences confirm that evaluation of the back muscles' EMG response has clinical values. Contrary to these studies, some authors did not find asymmetrical activity in back muscles of AIS patients (Bassani et al., 2008; De Oliveira et al., 2011; Gaudreault et al., 2005).

To investigate the muscle responses in scoliotic patients the earlier studies are conducted under various conditions such as in static standing position (Cheung et al., 2005; De Oliveira et al., 2011; Gaudreault et al., 2005), while subject was fixed to an apparatus (De Oliveira et al., 2011; McIntire et al., 2007; Tsai et al., 2010), in

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standing position while wearing a brace (Odermatt et al., 2003), during unloading perturbation in frontal plane (Perret and Robert, 2004) or in standing position over a tilting platform (Kuo et al., 2011). It is shown that muscle responses may vary depending on the task and testing condition. However, it is difficult to compare previous studies because of the different tasks and testing conditions, insufficient number of subjects, lack of control group (Cheung et al., 2005), and inadequate description of the applied materials and methods in those studies (Cassidy et al., 1987; Zetterberg et al., 1984).

Feipel et al. (2002) compared static versus few dynamic tasks to assess the EMG activity of erector spinae muscles in AIS and normal subjects. The authors only observed asymmetrical EMG activity at erector spinae muscles in scoliosis group during dynamic lateral bending task. It was suggested that evaluation of muscles activity in dynamic condition is more appropriate to distinguish between scoliotic and normal subjects. In a recent study, Kuo et al. (2011) also showed that the muscle response in scoliotic subjects during unexpected tilt of the support surface is different from that in anticipatory perturbation. This indicates that task and testing conditions are important factors to detect a possible abnormality in scoliosis group.

Muscle response of scoliotic trunk during dynamic motions without restriction has rarely been studied (Feipel et al., 2002; Mahaudens et al., 2009; Perret and Robert, 2004). Though Feipel et al. (2002) quantified muscle activities in lateral bending motions, raw EMG data were not normalized with a reference muscle contraction. The lack of normalization is a significant limitation for generalization of the results obtained in a clinical study. However, based on the statistical analysis of the ratio of heterolateral to homolateral RMS, Feipel et al. (2002) concluded that EMG evaluation of paraspinal muscles in dynamic condition has clinical value. Voluntary positioning and free dynamic movements of the subject could represent natural behavior of the neuromuscular system which is considered as a major advantage in muscle responses assessments.

The objective of this study was to analyze the EMG responses of erector spinae and lower limbs' muscles to unexpected forward and backward perturbation tests in AIS patients and healthy volunteers. It was hypothesized that AIS patients will present (a) higher muscle activity than the normal subjects, and (b) asymmetrical muscle responses.

2. Materials and methods

2.1. Subjects

In this study10 able-bodied adolescents formed the control group (age: 16.1 ± 1.4 years; mass: 48.7 ± 6.7 kg; height: 158.7 ± 5.6 cm; BMI: 19.3 ± 2.1 kg/m^2), and 10 patients with AIS (age: 16.0 ± 1.3 years; mass: 53.6 ± 4.5 kg; height: 161.4 ± 5.7 cm; BMI: 20.7 ± 2.0 kg/m^2) were included in the scoliosis group (Table 1). The Cobb angle (Cobb, 1948) in scoliosis group varied between 15° and 26° (average: 21.6 ± 4.4°). The curves were all right thoracic and the apex of the curvature was located between T_8 and T_{10}. Based on the Nash and Moe technique (Nash and Moe, 1969), the vertebral rotations at the apex vertebra were grade I in four subjects and grade II in six subjects. Only females took part in the current study. Table 1 represents the Cobb angle for all patients.

In order to recruit AIS subjects, over 2000 female students of middle and high schools in Hamedan city, located in Midwest of Iran, were screened and those with obvious rib hump, scapular imbalance, and deviation of the S_1 spinous process from the plumb line were referred to the orthopedic surgery department at Besat Hospital in Hamedan, Iran, under the supervision of an experienced orthopedic surgeon for scoliosis treatment. Patients did not have any type of previous treatment such as brace or exercise therapy.

The inclusion characters for scoliosis group were having right thoracic curvature of between 15° and 30° and BMI of ⩽25. The exclusion characters were having any history of other physical, neurological or mental disorders, previous exercise, brace, or surgery treatment. Patients did not have any limb length discrepancy.

Control subjects were also recruited through the same screening program from healthy individuals with BMI of ⩽25. The exclusion conditions for control subjects were having limb length discrepancy of greater than 3 mm, asymmetrical shoulder height, deviation of the spinous processes from the plumb line, rib hump, as well as any history of physical, neurological, and mental disorders. All subjects in both groups were right handed with right leading leg determined by throwing a ball (for hand) and kicking a ball (for foot) and did not have any regular physical activity.

The Ethical Committee of Hamedan University of Medical Science approved the protocol (ID: 2012-P/16/35/21). All subjects and the parents were informed about the objectives and methods of the study and signed the informed consent to participate in the study.

2.2. Apparatus

In this study MA300-16 EMG system with pairs of self-adhesive surface bipolar electrodes (12 mm in diameter; 17 mm distance between the center of electrodes; input impedance of >100 MΩ; and common mode rejection ratio of 100 dB at 65 Hz-Lab Systems, Inc., Baton Rouge, LA 70816 USA), were used to measure the EMG activity of five bilateral muscles at the trunk and lower extremities during unexpected FPP and BPP tests. EVA-70 of 3D Motion Analysis System[1] software was used to monitor the MA300 EMG system.

Prior to the surface electrode placement, the skin was shaved and cleaned with 70% alcohol (Ethanol-C2H5OH) to reduce the skin impedance. Double-sided tape was used to fix the bipolar electrodes on the skin. Electrodes were placed over ES muscle, at both ES_{T10} and ES_{L3} levels, BF, RF and G in both the right and the left sides (Fig. 1A). A circular stainless steel electrode (3 cm^2) was used as a ground electrode to reduce acquisition noise.

For ES muscles, electrodes were placed vertically 30 mm from the spinous process at both sides of T_{10} and L_3 vertebrae (Cheung et al., 2005; Hermens et al., 1999; De Seze and Cazalets, 2008). The location of the EMG electrodes for BF, RF and G muscles were determined based on the guidelines provided by SENIAM[2] (Hermens et al., 1999, 2000). All electrodes were placed in line with the related muscle fibers orientation. The reference electrode (ground) was positioned over the manubrium bone.

The lateralis head of gastrocnemius muscle was selected since it has more type II fibers (Akasaka et al., 1997) which results in a sharper reaction to the sudden perturbation and has more reliable signals than the medialis head (Rainoldi et al., 2004). It is also thought to apply propulsion (Goto et al., 1975) as well as medio-lateral forces to the ground (Ohtsuki and Yanase, 1989) that prevent falling to the front or ipsilateral side during postural perturbation.

The signals were digitized at 2500 Hz, gain of 1250, bandwidth filter of 15–450 Hz, and band-stop filter of 50 Hz to reduce electrical interferences from external sources. Root mean square (RMS) was calculated over a 1 s window after the onset of perturbation. This time window reflects muscle voluntary responses to perturbation.

[1] Motion Analysis Corporation, Santa Rosa, CA, USA.
[2] Surface EMG for a Non-Invasive Assessment of Muscles.