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Effect of Tactile Feedback on Trunk Posture and EMG Activity in People With Postural Kyphosis During VDT Work

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Abstract

Background: Recently, there has been an emphasis on the use of interventions with biofeedback information for the maintenance or correction of posture.
Objects: This study assessed the change of trunk posture and trunk muscle activation when people exhibiting postural kyphosis performed visual display terminal work with or without a contact feedback device (CFD).
Methods: Eighteen right-handed individuals were recruited. Thoracic angle and right thoracic erector spinae (TES) muscle amplitude were analyzed. There were two sessions in these experiments. The control session involved 16 minutes of typing without a CFD, and the CFD session involved 16 minutes of typing with a CFD. The visual analog scale score was analyzed with a paired t-test, and the kinematic and electromyography data were analyzed through two-way repeated analysis of variance.
Results: The paired t-tests revealed that subjects had significantly less pain after the CFD sessions than after the control sessions ($p<.05$). Significant main effects by session and by time were observed in the thoracic kyphosis angle ($p<.05$). There was a significant session×time interaction for TES amplitude ($p<.05$), along with significant main effects by session and by time ($p<.05$).
Conclusion: The CFD caused people with postural kyphosis to straighten and to activate their TES continuously, even though they were habituated to bend their bodies forward. Therefore, the CFD was a beneficial treatment tool.

Key Words: Feedback device; Postural kyphosis; Sitting posture; Thoracic erector spinae; Visual display terminal.

Introduction

These days, people spend considerable amounts of time sitting at visual display terminal (VDT) such as desktop computers, laptop computers, smart-phones, and so on. Many studies have reported the frequent observation of a kyphotic thoracic posture and a forward head posture among people who spend prolonged hours working while seated in front of VDT (Brandt et al, 2004; Burgess-Limerick et al, 1999; Carter and Banister, 1994; Fujimaki and Mitsuya, 2002; Marcus et al, 2002). In particular, a high prevalence of postural kyphosis has been reported among VDT workers who spend extended lengths of time sitting (Gigante et al, 2005). Postural kyphosis is the most common type of kyphosis. Unlike constructive kyphosis, which cannot be reversed even if a person pays attention to his/her posture and makes an effort

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to sit and stand up straight, postural kyphosis presents as a smooth rounding of the back upon forward bending and can be corrected entirely at the will of the individual through the extension of the back muscles (Neumann, 2013).

Neumann (2013) reported that sitting with a kyphotic posture increases the stress on spinal structures including muscles, ligaments, bones, discs, apophyseal joints, and spinal nerve roots. The superficial thoracic erector spinae (TES) is stretched, and the spinal structures are loaded with excessive biomechanical stress. If these structures are loaded with stress for a long time, the TES will become very weak and the vertebral endplates will cause the vertebrae to become wedge-shaped, thereby worsening the kyphotic curve (Hart et al, 2010). Thus, without proper postural correction, postural kyphosis can progress to constructive kyphosis, which is more difficult to treat.

Even though people know the negative impacts of slouching, once they become habituated to slouching, they find it challenging to change their sitting posture. Therapeutic exercises and orthoses have commonly been used for the correction of postural kyphosis (O'Sullivan et al, 2013). Recently, there has been an emphasis on the use of interventions with biofeedback information for the maintenance or correction of posture. Biofeedback information provides individuals with augmented sensory input about their own posture, and helps them to concentrate consciously on their own postural/functional changes while correcting particular problems (O'Sullivan et al, 2013). Yoo et al (2006) reported a significant reduction in the forward head and slouching posture during VDT work when proximity biofeedback sensors were placed at the T10 and T12 levels. An audible alarm sounded from the sensors when thoracic kyphosis increased and the thoracic spinous process approached the back rest.

Generally, when people sit in an upright posture, the shoulders and chest are maintained in the vertical direction. On the other hand, when people sit in a kyphotic posture, the shoulders are located relatively forward and the chest is relatively backward. In this study, we used a tactile contact feedback device (CFD) (Figure 1), which is designed to provide tactile feedback about whether the shoulders and chest are in the vertical direction as a means of correcting kyphotic posture. While Yoo et al (2006) used a biofeedback device posterior to the thoracic vertebrae, the CFD is placed anterior to the chest and gives tactile feedback to remind the VDT worker to maintain contact with the pad. We hypothesized that the kyphotic angle would decrease and the electromyography (EMG) activity of the TES would increase when participants performed VDT work with the CFD. Therefore, we assessed the change of trunk posture and activation of the trunk muscles when people exhibiting postural kyphosis performed VDT work while seated in a chair with and without a CFD.

Methods

Subjects

As a first step, we observed the trunk posture of 240 physical therapy students while they were sitting in a class for one hour, and selected 32 students who had kyphotic tendencies in the classroom. Ultimately, 18 right-handed individuals (male: 8, female: 10) who met the following inclusion and exclusion criteria were recruited for this study. The inclusion criteria were having back and shoulder pain (Milne and Williamson, 1983) during VDT work and an index of kyphosis (IK)

Figure 1. Contact feedback device (Emdel Pad, Emdel, Ansan, Korea).

greater than 13. Details about the flexicurve ruler and the IK are described in the experimental procedure section (Figure 2). Previous studies have reported that an IK score of 13 was the clinical cut-point for kyphosis (Eum et al, 2013; Sawdon-Bea, 2010). The exclusion criteria were having had surgery in the upper or lower back, thoracic spine fracture, severe deformity of the spine, neurological disease, and pregnancy. Participant characteristics are presented in Table 1. All subjects signed written consent documents and were aware of all their rights. The experimental procedure was approved by Yonsei University Wonju Institutional Review Board (approval number: 1041849-201510-BM-051-02).

Experimental procedures

1. Measurement of thoracic kyphosis for screening

The severity of kyphosis was measured with a 45.7 ㎝ flexicurve ruler (C-Thru Ruler Flexicurve, Acme United Corporation, Connecticut, USA) by a trained physical therapist. The flexicurve is a bendable strip of lead covered with synthetic rubber and holds its shape when molded. The IK has been used as an indirect measure of the degree of curvature of the upper spine, and can be determined with the flexicurve (Hinman, 2004). The subject was instructed to stand in his/her normal comfortable posture, and the flexicurve was placed with one end at the spinous process of C7 and the other end at the T12 vertebra. Then, the instrument was molded to the spinous processes between these two landmarks. The flexicurve was removed from the subject and placed on a piece of paper so that the spinal curves could be traced with a pencil. A straight ruler line between the positions of C7 and T12 was defined as the length of postural thoracic kyphosis (thoracic length: TL). The perpendicular line from the highest point of the traced spine curvature to the line of the TL was defined as the width of the thoracic kyphosis (TW). The index of kyphosis was calculated as (TW/TL)×100 (Figure 2) (Cutler et al, 1993). A higher value of the IK indicates a greater degree of thoracic kyphosis. In previous study, the inter-rater reliability of flexicurve measurements was found to be .94 (Hinman, 2003).

Table 1. General characteristics of subjects (N=18)

	Age (year)	BMI[a] (㎏/㎡)	Index of kyphosis
Subject	21.6±1.4[b]	21.5±1.9	13.6±.7

[a]body mass index, [b]mean±standard deviation.

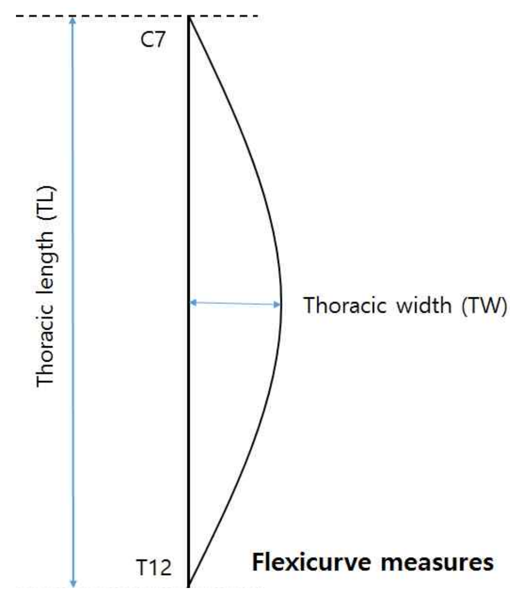

Figure 2. Flexicurve measurement technique.

2. VDT task

The desk and stool heights were adjusted so that subjects' elbows, hips and knees were positioned at 90° angles and their feet were fixed on the floor in the starting position. Both hip and knee angles were measured with a goniometer. The horizontal distance between the eyes and the middle of the computer screen was standardized at 60 ㎝ (Seghers et al, 2003). To minimize the undesirable effects of the monitor position, such as neck and shoulder discomfort, we adjusted the monitor height so that the viewing angle was 5° to 15° below the horizontal sight line (Liao and Drury, 2000). After sitting comfortably in this position, the subjects were asked to focus completely on a 16 minutes typing task which was provided by a commercial typing practice program (Hancom 2015, Hancom, Gyeonggi-do, Korea). Subjects could achieve higher scores by completing the exercise at a higher speed with fewer errors.

3. CFD session

All participants performed VDT tasks in two different sessions: a control session and a CFD session. In the control session, they performed a 16 minutes typing task without a CFD (Figure 3A), while in the CFD session, they performed the same task with a CFD (Figure 3B). We did not randomize the order of the testing conditions, so as to prevent possible learning effects of good posture from the CFD session. The rest time period between the control and CFD sessions was 20 minutes.

In the CFD session, the top of the CFD was placed on xiphoid process. The CFD pad was a soft cushion in the shape of a 14 ㎝ square. We asked all subjects to try to maintain contact between their xiphoid process and the CFD, but we prohibited leaning toward the CFD. An examiner monitored the amount of leaning pressure on the CTD using a Footscan program (F-Scan Versa System, Tekscan Inc., MA, USA). If the examiner detected any unwanted leaning through the pressure sensor during the recording screen, the examiner gave a verbal cue not to lean on the pad. The verbal cue usually was given during the first minute and was not needed after 3 or 4 minutes.

Outcome measures

1. Visual analog scale (VAS)

Upon completion of each session of typing, subjects were asked to record the level of pain in their trunks on a visual analog scale (VAS) ranging from 0 to 10. The VAS has been considered as a reliable (intra-class correlation coefficient=.97) and convenient tool for measuring pain intensity (Bijur et al, 2001).

2. Thoracic kyphosis angle

Kinematic data were recorded with a VICON MX system (Oxford Metrics Group, Oxford, UK) with six infrared cameras. Four spherical reflexive markers were attached along the thoracic curve on the 7th cervical (C7) vertebra, 10th thoracic (T10) vertebra, SP1 and SP2. The SP1 and SP2 markers were attached along a straight line between the C7 and T10 markers at the same interval (Ahn et al, 2013). The angle between the C7-SP1 line and the SP2-T10 line in the midsagittal plane was defined as the thoracic kyphosis angle, where a lower value represents more severe thoracic kyphosis. The thoracic kyphosis angles were analyzed with the MATLAB R2008a pro-

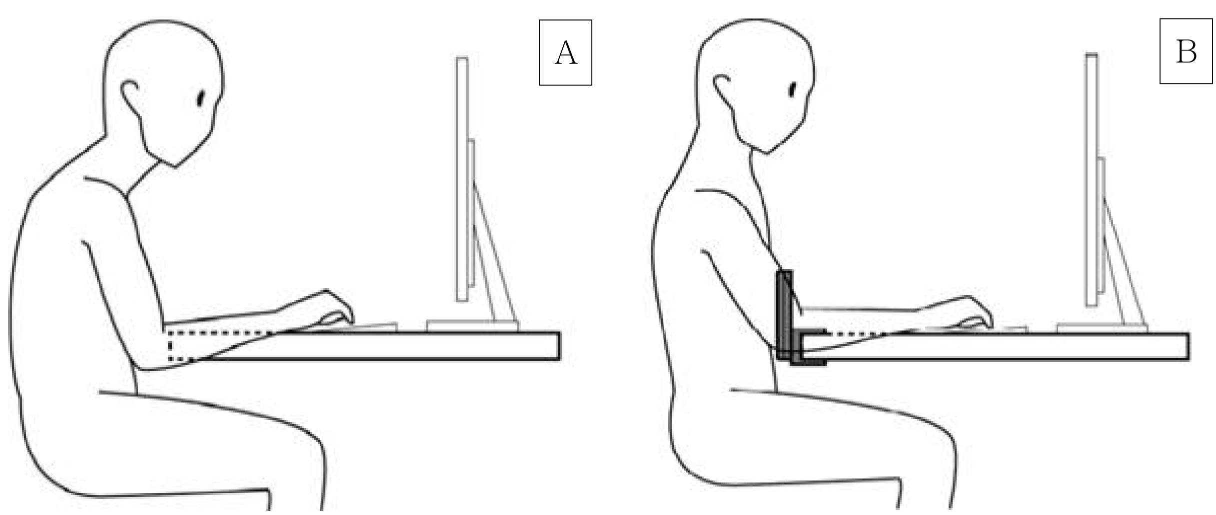

Figure 3. The posture during VDT work without the CFD (control session) (A) and with the CFD (CFD session) (B).

gram (MathWorks Inc., Natick, Massachusetts, USA). During both sessions of the experimental procedure, kinetic data were recorded four times for one minute each, during the intervals of 0-1 minute, 5-6 minutes, 10-11 minutes, and 15-16 minutes.

3. Electromyography amplitude

Activation of the right TES was recorded with a Noraxon Telemyo 2400T DTS Telemetry system (Noraxon, Inc., Scottsdale, AZ, USA). Prior to electrode placement, the skin was shaved and abraded with 80% ethyl alcohol. Then, 1.8 ㎝ diameter bipolar Ag-AgCl surface electrodes were placed on the TES bilaterally at a 2 ㎝ inter-electrode distance. The EMG electrodes were placed 3 ㎝ lateral to the T12 spinous process on each side.

During the experimental procedure, EMG data were recorded at 1500 ㎐ during the four previously mentioned time periods of the VDT work. EMG data were analyzed with MyoResearch Master Edition 1.08 XP software (Noraxon, Inc., Scottsdale, AZ, USA). We compared the median frequency values of the TES EMG during the first 1 minute of VDT work in each session, in order to verify whether muscle fatigue resulting from the VDT work during the 16 minutes control session influenced the CFD session. The root mean square (RMS) EMG value was used as a measure of EMG amplitude. First, the recorded raw EMG signals were filtered through a band-pass filter (between 20 and 450 ㎐) and a notch filter (60 ㎐) before the frequency analysis. After that, the TES EMG data were smoothed through the RMS with a moving window of 50 ㎳. All EMG amplitude data were normalized to the RMS amplitude during the maximum voluntary isometric contraction (MVIC) of the right TES. MVIC data were obtained while the participant was prone with the head and upper trunk extending off the table from about the nipple line, with the head, shoulders, and chest raised to table level. Then, the participant performed three five second upper trunk extensions off the table against the manual resistance of the examiner (Florence et al, 1992).

Statistical analysis

Data were analyzed with PASW Statistics ver. 18.0 (SPSS, Inc., Chicago, IL, USA). The VAS score and median frequencies were analyzed with a paired t-test, and the kinematic data and EMG amplitudes were compared through two-way repeated analysis of variance (sessions×time). The Greenhouse-Geisser epsilon correction of the degree of freedom was applied due to repetition of the measure. When interaction effects were observed, Bonferroni comparison was used as a post-hoc test. Statistical significance was set at .01.

Results

Visual analog scale (VAS)

In paired t-tests, the post-VDT-work VAS score was significantly lower after the completion of the CFD session than after the control session ($p<.05$) (post control session VAS: 1.05±.22, post CFD session VAS: 2.94±.62).

Fatigue effect

There was no significant difference in median frequency between the CFD and control sessions; the median frequencies of the 0-1 minute EMG data from both sessions were compared ($p>.05$) (control session: 48.95±10.48, CFD session: 49.01±10.52).

Thoracic kyphosis angle

There was no significant session×time interaction were observed for the thoracic kyphosis angle ($p>.05$) but significant main effects by session and by time ($p<.05$). The thoracic kyphosis angle was significantly lower in the control session than in the CFD session at every time point ($p<.05$) (Figure 4A). In addition, the thoracic kyphosis angles at 5-6 minutes, 10-11 minutes, and 15-16 minutes were significantly lower than those at 0-1 minute ($p<.05$).

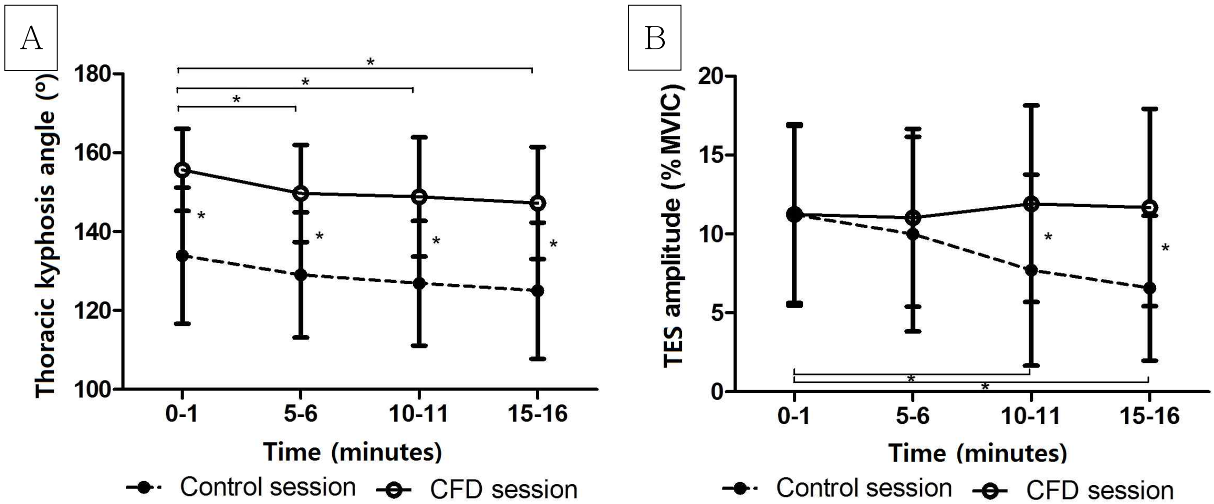

Figure 4. Post-hoc results of thoracic angle by session (A), Post-hoc results of EMG amplitude by session (B) (*p<.05).

Thoracic erector spinae electromyography amplitude

There was a significant session×time interaction for right TES amplitude ($p<.05$), along with significant main effects by session ($p<.05$) and by time ($p<.05$). Post-hoc results by session revealed that the TES amplitudes in the control session were significantly lower than those in the CFD session at 10-11 minutes and 15-16 minutes. In addition, only in the control session, the TES amplitudes were significantly reduced at 10-11 minutes and 15-16 minutes from the amplitude at 0-1 minute ($p<.05$) (Figure 4B).

Discussion

This study investigated the effects of CFDs on postural kyphosis patients. The CFD was designed to provide tactile feedback to the chest as a reminder to maintain an upright posture for VDT workers who perform prolonged VDT tasks. We found that the amount of thoracic kyphosis and TES EMG activation were maintained while the subjects performed 16 minutes of typing work with the CFD; however, EMG activity decreased without the CFD.

The straight extended thoracic posture is considered to be a desirable sitting position. A slouched sitting posture induces kyphosis, rounding of the shoulders, and a forward head posture, and reduces lumbar lordosis (Neumann, 2013). Persistently working in a slouched sitting posture for a long time causes unavoidable occupational hazards by inducing inappropriate changes in the body scheme (Lewis and Valentine, 2010). Many studies have suggested the use of various ergonomic chairs, back and arm rests, and workstations designed to correct inappropriate sitting postures. However, these pieces of ergonomically designed office furniture cannot fully reflect individual differences in posture, and furthermore, most of them lack reminding functions to help users detect their own erroneous working postures. Recently, Epstein et al (2003) suggested that feedback in the form of continual cautioning was necessary if people were to be reeducated to maintain a good sitting posture, even within the proper ergonomic environment. Once people have successfully recognized their errors and learned what the “proper posture” is through repetitive feedback, they can effectively apply what they have learned about a good sitting posture (Lou et al, 2012; Seidi et al, 2013). In this study, subjects started VDT work in a more upright posture and maintained the straight posture they achieved (150°) during 16 minutes of typing when the CFD was provided. On the other hand, without the CFD, subjects were significantly more flexed forward (128°) in their starting thoracic posture than they were with the CFD, and their kyphosis increased progressively over time.

The flexion-relaxation phenomenon (FRP) is defined as sudden myoelectric silencing of the paraspinal muscles during global trunk flexion (Colloca and Hinrichs, 2005; Panjabi, 1992). This can be caused by the transfer of extensor moments from active structures (paraspinal muscles) to passive structures (ligaments or capsules). Most of the traditional studies on the FRP focused on related EMG changes during full forward bending of the trunk. However, Callaghan and Dunk (2002) reported that an increased kyphotic curvature (slouched posture) is the main factor that activates the FRP. Orthopedists and physical therapists have asserted that a low level of muscle activation due to persistent occurrence of the FRP results in gradual de-conditioning of the back structures and atrophy of the paraspinal muscles (Mörl and Bradl, 2013). Actually, kyphotic patients were reported to have a higher proportion of fat deposits in the multifidus and erector spinae (Kang et al, 2007) and weaker back extensors (Sinaki et al, 1996). The FRP may also be problematic, as the loading responsibility for maintaining an upright trunk posture is transferred from weak extensor muscles to non-contractile passive structures, causing repetitive and prolonged stretch loads to the passive structures. In this process, excessive sustained elongation may lead to the accumulation of micro-damage, which can cause pain in the paraspinal structures (Mörl and Bradl, 2013).

In our study, TES EMG activity was maintained in relatively the same range when the CFD was used during the 16 minutes typing task. However, when the CFD was not used, TES EMG activation gradually decreased over time. The reduced TES EMG activation coincided with increased kyphosis. The findings in the session without the CFD can be partially explained by the FRP. Furthermore, TES EMG activation was significantly lower at 10-11 minutes than at 0-1 minute. This may indicate that an unconscious reduction in the activation of the back muscles occurred after subjects had performed the VDT task for 10 minutes, and that postural kyphosis patients should be advised to straighten their backs or stand at least every 10 minutes during intensive typing work. Our study also found that subjects with postural kyphosis perceived thoracic back pain (VAS: 3) after the 16 minutes typing task, and that the pain decreased with use of the CFD (VAS: 1).

Postural thoracic kyphosis can be treated with posture reeducation and focused strengthening of the extensor muscles (Seidi et al, 2013). Based on the findings of this study, sitting with a CFD is highly beneficial for postural kyphosis patients who unconsciously flex their thoraxes while performing their occupational duties. It encouraged not only the maintenance of a straight posture, but also the continuous activation of the TES. Furthermore, previously introduced feedback devices were special chairs or clothing that users needed to purchase in order to obtain proper feedback information (Lou et al, 2012; Yoo et al, 2006). The CFD is a lost-cost device that can be installed anywhere to increase one's comfort of moving, and thus is likely to have improved patient acceptance and facilitate effective treatment.

There was a limitation of this study: our data were obtained for 16 minutes, a relatively short period of time in which to observe the effects of the CFD. However, a 20 minutes typing task without stretching or standing evoked severe pain from people with postural kyphosis in a pilot test. Thus, we determined that 16 minutes would be the appropriate period for the experiment. Furthermore, longitudinal studies over one month or six weeks are required for examination of the long-term influence of the CFD.

Conclusion

The present study examined the influence of CFD use on posture and muscle activation in the thoracic regions of people with postural kyphosis. Kyphosis patients are usually considered to have poor postural control and maintain low activation of the erector spinae while seated. However, by providing tactile feedback to the body, the CFD caused people with postural kyphosis to straighten for 16 minutes and to activate their TES continuously, even though they were habituated to bend their bodies forward. Therefore, the CFD was a beneficial treatment tool for postural kyphosis patients.

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