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Immediate Effects of a Postural Correction Garment Designed for Postural Kyphosis on Adolescents With Thoracic Hyperkyphosis: A Pilot Study

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Abstract

The purpose of this study was to investigate the changes in the flexicurve kyphosis index (KI), the flexicurve lordosis index (LI) and the distance from the inferior angle of the scapula to the nearest vertebral spinous process (DS), as a dependent variable of scapular protraction, after applying of adolescents with thoracic hyperkyphosis using three different garments. A repeated measures design was used. Ten adolescents (15.8±1.0 years) with thoracic hyperkyphosis (40.1±3.7 Cobb angle) were recruited from a university hospital. A flexicurve ruler was used to measure KI and LI and a scoliometer was used to measure DS under three different conditions: wearing-a hospital garment (HG), wearing-a sham garment (SG), and wearing-an experimental garment (EG). KI under EG condition was significantly decreased compared with that wearing the HG. However, there was no significant difference between wearing the SG and HG. LI when wearing the EG was significantly increased compared with that when wearing HG. However, there was no significant difference under SG and HG conditions. DS when wearing the EG was significantly decreased compared with wearing HG. However, there was no significant difference between the SG and HG. The results of this study show that the EG was effective in decreasing KI, but not effective in decreasing LI. Hence, the effect of the EG for correcting sagittal spine angle in adolescents with thoracic hyperkyphosis is still debatable. However, since we showed that DS decreases in the EG, this method could be applied in correcting the scapular protraction.

Key Words: Adolescents; Flexicurve kyphosis index; Flexicurve lordosis index; Scapular protraction; Thoracic hyperkyphosis.

Introduction

Hyperkyphosis is implicated in a long list of negative and undesirable consequences including physical functional limitations (Kado et al, 2005), back pain (Ensrud et al, 1997), restricted spinal motion (Miyakoshi et al, 2003), and mortality (Greendale et al, 2011; Kado et al, 2009). Reports of prevalence and incidence of hyperkyphosis in older adults vary between approximately 20% and 40% among both men and women (Kado et al, 1999; Puche et al, 1995). Average thoracic kyphosis increases with age from 20° in childhood, to 25° in adolescents and to 40° in adults (Fon et al, 1980). As kyphosis angle increases, physical performance and quality of life often declines, making early intervention for hyperkyphosis a priority (Katzman et al, 2010). A recent randomized, controlled trial has found that hyperkyphosis is remediable supporting further study of its prevention and treatment (Greendale et al, 2009).

In recent years, since the amount of time and the frequency of using computers and cellular phones have been increasing in adolescents, improper sitting posture

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may lead to slouching, which can lead to hyperkyphosis (Lou et al, 2006). Even though the relationship between the incidence rate of adolescent hyperkyphosis and usage of computers is not fully understood, the impacts on spinal development are clear (Lou et al, 2006). Several studies confirm that hyperkyphosis is associated with weakness in the spinal extensor muscles (De Smet et al, 1998; Sinaki et al, 2002). Sustained thoracic flexion while starting at a computer monitor causes lengthening of the thoracic extensor muscles which may lead to weakness in these muscles in later life (Zdero et al, 2011).

One of the most common postural problems is having a sitting posture with the trunk leaning forward, which is becoming more prevalent because of the increasing use of computers, TVs, and video games (Blouin et al, 2003). Scapula protraction was often associated with thoracic hyperkyphosis, and shortening of the pectoral muscles in postures where the trunk is leaning forward has been linked to thoracic hyperkyphosis (Balzini et al, 2003). Scapular protraction was found to be a consequence of tightness in the pectoralis minor as the coracoid tilts inferiorly and shifts laterally away from the midline (Burkhart et al, 2003).

The treatments of hyperkyphosis that have been introduced to date include pharmacologic therapies, surgery, exercises, manual therapy, bracing, and taping (Katzman et al, 2010). There have been a few studies, including two small randomized controlled trials, investigating the use of spinal orthoses for hyperkyphosis (Kado, 2009). One study indicated that trunk muscle strength improved, citing an 11% decrease in kyphosis angle after the application of spinal orthosis (Pfeifer et al, 2004). Another study reported that therapeutic taping immediately reduced kyphosis by about 5% compared with 2% in the control taping group; however, it was not clear whether the immediate effects of therapeutic taping would translate into a longer therapeutic effect (Vogt et al, 2008). Several studies of bracing in adolescents have found that this method is the most effective non-operative treatment for adolescences with mild idiopathic scoliosis and Scheuermann kyphosis (Katz et al, 1997; Lonstein and Winter, 1994).

However, few studies have looked into the efficacy of postural correcting garments designed for use on adolescents with thoracic hyperkyphosis. Furthermore, large-scale hyperkyphosis research is often hampered by inherent difficulties in obtaining standardized measurements, measuring the modified Cobb angle (Harrison et al, 2001), including a variable for expense, the limited portability of X-ray equipment, the dangers of X-ray exposure, and the time necessary to conduct, procure and read the radiographic images (Greendale et al, 2011). To facilitate hyperkyphosis research, investigators have developed inexpensive and X-ray-free kyphosis measures, such as the flexicurve ruler (Greendale et al, 2011).

This study measured the changes in the flexicurve kyphosis index (KI) and the flexicurve lordosis index (LI), and used the distance from the inferior angle of the scapula to the nearest vertebral spinous process (DS) as a dependent variable to measure scapular protraction in adolescents with thoracic hyperkyphosis under three different conditions: wearing-a hospital garment (HG), wearing-a sham garment (SG), and wearing-an experimental garment (EG). We hypothesized that the KI, LI and DS would vary under the three conditions.

Methods

Subjects

Ten adolescents (4 males, 6 females) with hyperkyphosis were recruited from the Department of Rehabilitation Medicine, Gangnam Severance Hospital, Yonsei University Health System, Seoul, Korea. All subjects gave written informed consent and participated voluntarily. The subjects all presented with an above mean kyphosis angle according to the criteria described by Fon et al (1980) (normal range: males=25.11±8.2, females=26.00±7.4). Exclusion criteria were as follows: 1) subjects who complained of discomfort when wearing the postural correcting garments, 2) subjects who were diagnosed with other musculoskeletal diseases e.g., scoliosis with or without hyperkyphosis, and 3) subjects who had undergone recent operations or were taking any medications that could be associated with spinal diseases. This study was approved by the Institutional Review Board (IRB) of College of Medicine, Yonsei University. The demographic characteristics of the subjects are presented in Table 1.

Garments

Hospital garment

The HG was made using main fabric (cotton, 100%) and style and color were same as the patient's gown which was used for in-patient of Gangnam Severance Hospital.

Sham garment

The SG was made using the main fabric (nylon, 80%; spandex, 20%) only. The stitching, style and color were same as the EG.

Experimental garment

The EG was made of a combination of spandex and nylon fabrics. Spandex textile filament fiber, a highly elastic fabric, was used to provide higher tension in the thoracic area. The EG was made using a main fabric (nylon, 80%; spandex, 20%) and a power net (nylon, 75%; spandex, 25%). The power net was used for the posterior surface of the EG to increase pressure on the back and correct the posture. The textile filaments of ultra-power net were stitched from both shoulders to the center of the back so that the power net could be used for increasing tension to both shoulders in a horizontal direction. The stitching of the ultra-power net from either shoulder crossed at center of back of the EG. Silhouettes of the neck and shoulder were designed to be as ordinary as possible so that the EG affected the everyday life of the patients as little as possible.

Measurement tools

The KI and LI were measured with a flexicurve ruler[1).]The flexicurve ruler, when gently pressed onto the back, adapts to the thoracic and lumbar contours of the subjects. The researcher then traces the ruler's retained shape onto paper to calculate the flexicurve kyphosis index and flexicurve lordosis index (Greendale et al, 2009; Hinman, 2004) (Figure 1).

The DS was measured in millimeter with a scoliometer[2)] (Curtis and Roush, 2006). This clinical measure of static scapular position is known as the lateral scapular slide test (LSST) and was first described by Kibler (1998). This test involves measuring the distance from the inferior angle of the scap-

Table 1. General characteristics of subjects (N=10)

Parameters	Mean±SD
Age (y)	15.8±1.0
Height (㎝)	164.8±5.5
Weight (㎏)	54.2±8.9
BMI[a] (㎏/㎡)	19.9±2.9
Cobb angle (°)	40.1±3.7
KI[b]	10.6±1.3
LI[c]	13.1±1.2
DS[d]	7.4±.6

[a]body mass index, [b]kyphosis index, [c]lordosis index, [d]distance between inferior angle of the scapula and spinous process of thoracic spine.

1) Flexicurve ruler, Alvin®, CT, U.S.A.
2) Scoliometer, Red Bank®, NJ, U.S.A.

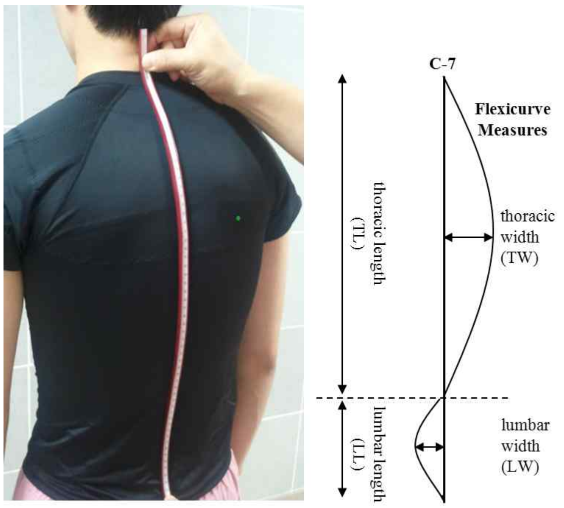

Figure 1. Flexi-curve calculation for the flexicurve kyphosis index (KI) and flexicurve lordosis index (LI), KI=(TW/TL)×100; LI=(LW/LL)×100 (Hinman, 2004).

Figure 2. Measuring the distance from the inferior angle of the scapula to the nearest thoracic vertebral spinous process using a scoliometer (Curtis and Roush, 2006).

ula to the nearest thoracic vertebral spinous process (T7 or T8) using a scoliometer (Thomas et al, 2010) (Figure 2). Curtis and Roush (2006) found that the intraclass correlation coefficients (ICC) ranged from .87 to .95 when standing with the shoulders in a neutral position and that this method of measuring the LSST using a scoliometer is reliable in screening the scapular position.

Data collection procedures

Prior to data collection, the maximum erect posture was explained to all subjects (Hinman, 2004). In the maximum erect posture, the head and cervical spine are aligned comfortably with the trunk when standing vertically. The subject was asked to stand in the maximum erect posture and stabilize their gaze by looking at a predetermined dot located at a position level with the eyes 1 m away from them. After familiarization with the maximum erect posture, two separate examiners collected the measurements as described below.

For measuring the KI and LI, the primary investigator palpated and marked the spinous process of the seventh cervical vertebra (C7) and the superior aspect of the first sacrum (S1) on the garment with 1×1 ㎝ sticker. The flexicurve ruler was then placed over the spinous processes of the thoracic and lumbar spine and was shaped to fit the contours of these spinal curves. The instrument was then carefully removed and its shaped traced onto a piece of plain white paper. A vertical line was drawn to connect the C7 and S1 landmarks.

For measuring the DS, one examiner first locked the knobs of the scoliometer to insure that the caliper was fixed. The scoliometer was then handed to the primary investigator, who silently read and recorded the measures. The scoliometer was then reset to zero and the other examiner repeated this procedure a second time. An average of the two readings was used for data analysis.

This procedure was repeated to collect data on KI, LI and DS under the three different conditions: wearing-a HG, wearing-a SG, and wearing-an EG. The wear order of the three different garments was randomized. The standardized experimental position was practiced using verbal and tactile cues before commencing data collection. All subjects felt relaxed and comfortable after a familiarization period of 1 min wearing each garment.

Statistical Analysis

SPSS version 12.0 program was used for statistical analysis. One-way analysis of variance with repeated measures was employed for comparison of the three different garments (hospital garment vs. sham garment, and hospital garment vs. experimental garment). Since the comparison of the HG and SC, and the HG and EC had been planned before the data were collected, a priori contrast tests were performed. In all analyses, $p<.05$ was taken to indicate statistical significance.

Results

The means and standard deviations of the KI, LI and the DS under the each different garment are presented in Table 2. KI in the EG was significantly decreased compared with that in the HG ($F=15.076$, $p=.004$). However, there was no significant difference between the SG and HG ($F=.008$, $p=.931$). LI in the EG was significantly increased compared with that in the HG ($F=11.538$, $p=.008$). However, there was no significant difference between the SG and HG ($F=2.040$, $p=.187$). DS in the EG was significantly decreased compared with that in the HG ($F=18.778$, $p=.002$). However, there was no significant difference between the SG and HG ($F=2.436$, $p=.153$).

Discussion

The present study was performed to compare changes in the KI, LI and the DS of adolescents with thoracic hyperkyphosis under three different conditions: wearing-a HG, wearing-a SG, and wearing-an EG. The hypothesis of this study was that the KI, LI and DS would vary under the three conditions. However, the hypothesis was partially supported because that KI, LI and DS were significant differences in the condition of wearing-an EG only.

KI in the EG was significantly decreased compared with that the in HG. However, there was no significant difference between the SG and HG. These findings are similar to another recent study (Jiang et al, 2010). The elastic orthotic belt resulted in a significant decrease of thoracic kyphosis with an average decrease of 10.4°. The elastic orthotic belt is designed with the intention to straighten up the spine and to correct the hump back using two tension straps. The EG was designed for extending thoracic hyperkyphosis, therefore the inside surface of the upper back of the EG was made of an elastic textile. Tension in the elastic textile caused this decrease in KI.

Another mechanism that may have been responsible for this decrease in KI in the EG is the principle of "mechanical biofeedback therapy" described by Coillard et al (2003). They developed a dynamic orthosis named "SpineCor" to control scoliotic deformities by

Table 2. The means and standard deviations of KI, LI and DS under each different garment

Parameters	Conditions	Mean±SD
KI[a]	HG[d]	10.6±1.3
	SG[e]	10.6±1.2
	EG[f]	9.1±1.4
LI[b]	HG	13.1±1.2
	SG	13.3±1.2
	EG	14.0±1.1
DS[c] (cm)	HG	7.4±.6
	SG	7.4±.6
	EG	6.7±.8

[a]kyphosis index, [b]lordosis index, [c]distance between inferior angle of the scapula and spinous process of thoracic spine, [d]hospital garment, [e]sham garment, fexperimental garment.

applying dynamic harnesses to the patient. These harnesses provided dynamic control of the shoulder and thorax and limited adverse movements. Textile filaments of the ultra-power net on the posterior surface of our EG limited the way the trunk leaned forward, dynamically controlling the position of the shoulder and thorax in much the same way as "SpineCor".

LI in the EG was significantly increased compared with that in the HG. However, there was no significant difference between the SG and HG. These findings are in accordance with a recent study by Jiang et al (2010), who found significant differences in LI after applying an elastic orthotic belt for scoliosis. They described how lumbar lordosis was found to be significantly smaller after wearing the Milwaukee brace, however, there was no significant decrease after wearing an elastic orthotic belt.

The major correcting mechanism behind the conventional rigid brace in cases of idiopathic scoliosis is the application of external forces by a three-point principle (Labelle et al, 1996). However, our EG was designed so that the extension force came only from the tensional composition of the textile filaments. This 'upward extension' effect could act as a 'pulling strength' that leads to a straightening of the spine after applying the neck ring and external coupling straps in the Milwaukee brace (Jiang et al, 2010). In our EG, however, this extension effect and pulling strength was necessarily smaller than that in braces of a rigid type. No force was applied to the lumbar region in our EG, so there was no resistance to the increased pressure during hypokyphosis effect in the thoracic region. Hence, increased LI could be the result of the overall altered sagittal alignment in structural linkage that is correlated with a decrease in KI.

However, in our EG design, limited tension was applied around the waist, compared to that applied to the thoracic surface, which minimized discomfort, since breathing difficulties could be caused by compressional forces when wearing a corrective brace (Priftis et al, 2003). This increase in LI could be brought about by combining the hypokyphotic effect with the effect of the textile filaments in the ultra-power net in posterior thoracic area and comparable loosening in the lumbar spine. Therefore, supplemental features, including a device for decreasing lumbar lordosis in the EG, should be considered in further studies.

DS in the EG was significantly decreased compared with that in HG. However, there was no significant difference between the SG and HG. These changes of DS in the EG may have been due to the textile filaments in the ultra-power net in the EG and the effect of mechanical biofeedback. The elastic textile caused a decrease in the distance between the scapulae as a consequence of decreasing KI. Hence, these results could be explained by the same mechanism that decreased KI in the EG.

There were several limitations to this study. First, because the changes were measured immediately after applying the garments, long term effect of treatment could not be guaranteed. Second, because only adolescents were included in this study, the results could not be generalized. Third, because changes in functional and psychological aspects were not considered in the procedures, the effects of garment cannot be used as fundamental data to resolve functional and psychological problems in patients with thoracic hyperkyphosis. Further studies are required to measure functional and psychological factors and include subjects of various ages using a longitudinal experimental design to verify the therapeutic effect of the EG in patients with thoracic hyperkyphosis.

Conclusion

The results of this study showed that the EG was effective in decreasing KI, but not effective in decreasing LI. The effect of the EG in correcting the angle of the sagittal spine angle in adolescents with thoracic hyperkyphosis is still debatable; however, by decreasing the DS, this EG could be applied to correct the static position of scapular protraction in these subjects.

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