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The Effectiveness of Soft Brace With Pneumatic Muscles on Posture Alignment for Subjects With Postural Kyphosis: Pilot Study

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ABSTRACT

Kyphosis refers to an abnormal increase in the forward curvature of the spine. Among the various types of kyphosis, postural kyphosis, also known as postural roundback, is the most prevalent. The condition arises from poor posture habits, such as slouching, leaning back in chairs and carrying heavy school bags, established during childhood, gradually weakening the muscles and soft tissues of the back. Over time, postural kyphosis can progress, resulting in a chronic deformity and persistent back pain. It typically becomes evident during adolescence, particularly in females. These effects can significantly impact the quality of life for individuals afflicted by the condition, both during their adolescent years and into adulthood. Among the treatment options available, bracing is frequently employed to prevent the progression of the deformity and facilitate correction. The Milwaukee brace, in particular, has been proven as an effective brace for subjects with postural kyphosis. However, one of the challenges associated with its use is wearer discomfort, which can contribute to reduced compliance and treatment efficacy. In this study, a soft textile brace with lightweight pneumatic muscles specifically designed for correcting the posture of individuals with postural kyphosis was developed. In order to evaluate the effectiveness of this new brace, subjects with the condition were recruited to participate in a wear trial. During the trial, head and shoulder posture were assessed including coronal head tilt angle, coronal shoulder angle, sagittal head tilt angle, craniovertebral angle and sagittal shoulder angle. The results revealed significant improvements in sagittal shoulder angle, the subjects wearing the pneumatic padding brace, compared to those without any bracing. These findings suggest that the newly developed brace holds promise for effectively managing postural kyphosis, as it demonstrated positive effects on improving rounded shoulder. By providing more comfort and potentially improving compliance, this brace offers a potential solution to enhance the overall treatment experience for individuals with postural kyphosis.

Keywords: Postural kyphosis, Roundback, Soft textile brace, Pneumatic muscle, Posture correction, Rounded shoulder

INTRODUCTION

Kyphosis, also known as roundback, is a kind of spinal deformity which there is an abnormal forward curvature of the spine along the sagittal plane. In general, postural kyphosis, Scheuermann disease and congenital deformities are the three common types of kyphosis. Unlike Scheuermann disease and congenital deformity which are caused by abnormal vertebral structure, postural kyphosis is caused by poor posture (Kamali *et al.*, 2016; Lam and Mukhdomi, 2023). Postural kyphosis usually starts during the growth stages of adolescence and more girls are affected compared to boys. Previous research indicated that angle of kyphosis increases with increasing age (Zećirović *et al.*, 2021; Park *et al.*, 2022). Studies proved that prolonged poor posture such as slouching, irregular sitting, are the causes for postural kyphosis. Nowadays, modern children have become accustomed to a predominantly sedentary lifestyle. A significant portion of their day is spent sitting while studying, watching TV, using computer or mobile devices or learning other extra static activities. As a consequence, their opportunities for physical activity have significantly diminished, leading to weakened back muscles (Feng *et al.*, 2018; Zećirović *et al.*, 2021; Lam and Mukhdomi, 2023). Brzek and her team pointed out overloaded school bags, asymmetry of the straps of backpack and position of the backpack may also increase the kyphosis angle. For example, if the backpack is placed too high to students' back, they will lean forward, and the spine will be overloaded (Brzek *et al.*, 2017). In addition, psychosocial factors such as depression, anxiety and embarrassment may also be the causes for poor posture, especially for girls who are developing secondary sexual characteristics. Researchers also indicated that kyphosis may occurs to compensate the breast development in girls due to carrying heavy school bags (Lou *et al.*, 2012; Dharmayat and Shrestha, 2017).

Postural kyphosis not only affects the cosmetic appearance of individuals due to forward head and rounded back, but it can also have negative effects on their physical health. Prolonged improper posture puts pressure on the spine, leading to protrusion or rupture of vertebral discs and potentially causing back pain (Lou *et al.*, 2012; Feng *et al.*, 2018). In addition to back pain, posture kyphosis may be associated with several health problems. It can result in decreased physical function, poor balance, impaired respiratory function, increased cervical pain, headaches, and shoulder issues like subacromial syndrome (Lou *et al.*, 2012; Jenkins *et al.*, 2021; Zećirović *et al.*, 2021).

Exercise therapy and bracing are the two most commonly used and traditional treatments for posture kyphosis. Bracing is considered an effective non-operative treatment for patients with kyphosis, as it guides the spine to grow straight before skeletal maturity (Lam and Mukhdomi, 2023). The Milwaukee brace is one of the most widely used braces for progressive thoracic kyphosis curves, applying a three-point corrective force. However, it typically needs to be worn for 16–24 hours a day for several years (Gheitasi, Bayattork and Kolur, 2023). The compliance with this type of brace is often low due to its bulkiness and discomfort, especially in hot weather. It also restricts the wearer's activities, further reducing spinal flexibility (Park *et al.*, 2022). Generally, brace treatment is recommended for adolescents with kyphosis greater than 50 degrees, while milder curvatures may receive minimal treatment such as exercise therapy to strengthen back muscles and increase spinal flexibility, along with instructions to maintain proper posture (Lou *et al.*, 2012). There is a lack of adequate and suitable treatments for adolescents with mild curvature of postural kyphosis. Moreover, existing braces are bulky, uncomfortable, and conspicuous.

Therefore, the aim of this study was to develop a comfortable and low-profile soft textile brace with pneumatic muscles and conduct a preliminary investigation to evaluate its effectiveness in correcting the posture of individuals with postural kyphosis.

EXPERIMENT

Participants

Two healthy young volunteers (age, 27–31 years; weight, 56–61.5 kg; height, 162–178 cm; body mass index, 19.4–21.3 kg/m^2) participated in this study. Subjects were excluded if their shoulders or spine have been injured in past 6 months, had history of shoulder or spinal surgery, upper extremity injury limiting activities, cervical or thoracic fracture, scoliosis, or excessive thoracic kyphosis (> 50°). Informed consent was voluntarily obtained from all the subjects prior to participation in the study.

In this study, Flexicurve ruler method was used to measure the thoracic kyphosis. The Flexicurve ruler, a mouldable plastic measurement device which is a simple, reliable and non-invasive tool for measuring kyphosis index and kyphosis angle (Quek *et al.*, 2013; Kamali *et al.*, 2016; Spencer *et al.*, 2019; Grindle *et al.*, 2020; Elpeze, Usgu and Yiğit, 2023; Lam and Mukhdomi, 2023; Youssef and Yildiz, 2023).

Participants stood in a neutral upright posture with feet shoulder width apart and had their eyes to gaze straight ahead at a target adjusted for body height. The seventh cervical vertebra (C7) and the spinous process of the twelfth thoracic vertebrate (T12) were located and marked by palpated. Then, the Flexicurve ruler was placed along these markers and moulded over the spine midline. The resulting curve was transformed onto paper and the locations of C7 and T12 processes were labelled (Figure 1). Kyphosis index and thoracic kyphosis angle are then calculated. For kyphosis index, it is calculated by the width of apex of the thoracic curve (W) is divided by the length of the thoracic curve (X) and then multiplied by 100 ($W/X \times 100$). An index greater than 13 is considered hyperkyphotic (Lee, Chung and Park, 2015; Spencer *et al.*, 2019; Lam and Mukhdomi, 2023). For thoracic kyphosis angle, the distances between the C7 and T12 points to the point W were measured as X1 and X2, respectively. To calculate the kyphosis angle, the following formula was used: $\arctan(W/X1) + \arctan(W/X2)$ (Elpeze, Usgu and Yiğit, 2023). The calculation of kyphosis index and thoracic kyphosis angle were outlined in Figure 2.

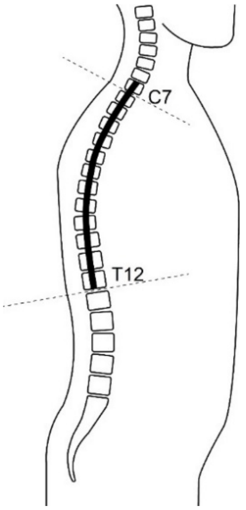

Figure 1: Mould the flexicurve ruler over the spine.

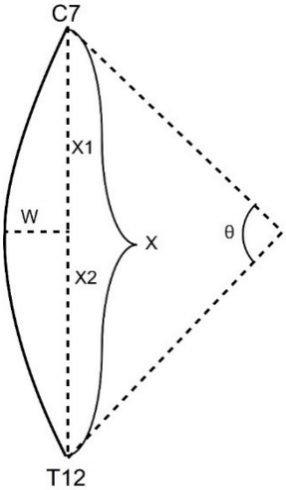

Figure 2: Calculation of kyphosis index and thoracic kyphosis angle.

Assessments

In this study, a soft textile brace with pneumatic muscles was developed to address the issue of postural kyphosis in individuals. The brace design incorporated spacer fabric, chosen for its enhanced breathability and thermal conductivity properties (Tong et al., 2014; Yip & Ng, 2008). Previous studies have demonstrated that spacer fabrics exhibit excellent moisture-wicking capabilities and temperature regulation (Tong et al., 2014; Yip & Ng, 2008).

To ensure adequate external force for correcting the posture of individuals with postural kyphosis, a pneumatic muscle called XoMuscle was utilized. Previous research has shown that XoMuscle, with a sectional area of 10cm^2, is capable of lifting a 20kg bucket with up to 150% contraction and 175% efficiency compared to skeletal muscle (Xie et al., 2023).

The soft brace with pneumatic muscles is illustrated in Figure 3, depicting the design and configuration of the brace.

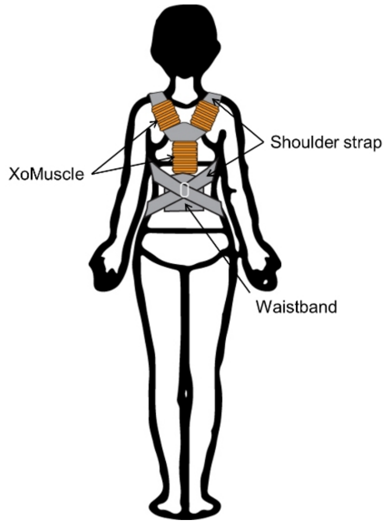

Figure 3: The design of the soft brace with pneumatic muscle for subjects with postural kyphosis.

To evaluate the effectiveness of the soft brace with pneumatic muscle in correcting subjects with postural kyphosis, anterior and profile photographs of the subjects were taken before and after wearing the brace. The subjects were instructed to assume a comfortable standing position with their feet shoulder-width apart and hands hanging by their sides. They were asked to gaze straight ahead at a target adjusted to their body height. A trained therapist palpated and identified specific anatomical points, including the tragus of the ears, canthus of the eyes, coracoid processes, midpoint of the humerus, and spinal process of C7. White non-allergic adhesive stickers measuring 8mm in diameter were used as skin markers.

Photographs were captured using a Sony Alpha 7 digital camera equipped with an FE 1.8/50mm lens. The camera was positioned 2 meters away from the subjects and mounted on a tripod. The tripod was carefully levelled using a bubble spirit level to ensure consistent frontal and sagittal angles. The base of the camera was parallel to the ground to maintain accuracy during measurements. The software Kinovea was employed for calculating the measurements.

Five measurements of head and shoulder posture were assessed, namely coronal head tilt angle (Figure 4), coronal shoulder angle (Figure 5), sagittal head tilt angle (Figure 6), craniovertebral angle (CVA) (Figure 7), and sagittal shoulder angle (Figure 8). In terms of coronal head tilt, a value of 180° indicated a horizontally aligned head. A lower value indicated leftward head tilt, while a higher value indicated rightward head tilt. Similarly, for the coronal shoulder angle, a value of 180° denoted even shoulder alignment. A lower value indicated a higher left shoulder, while a higher value indicated a higher right shoulder. The sagittal head tilt angle, when less than 180°, indicated forward head tilt. Regarding CVA, a lower value indicated a more forward position of the head. In the case of the sagittal shoulder angle, a lower value indicated a more rounded shoulder (Raine and Twomey, 1994, 1997; Lewis, Green and Wright, 2005; Lee *et al.*, 2017).

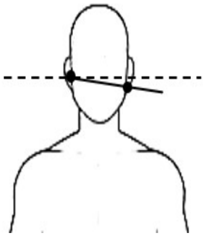

Figure 4: Measurement of coronal head tilt angle.

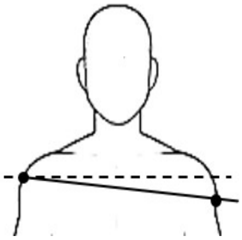

Figure 5: Measurement of coronal shoulder angle.

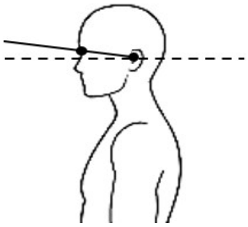

Figure 6: Measurement of sagittal head tilt angle.

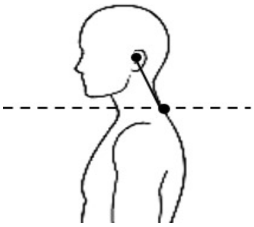

Figure 7: Measurement of craniovertebral angle (CVA).

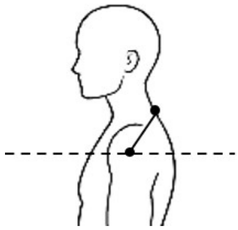

Figure 8: Measurement of sagittal shoulder angle.

RESULTS AND DISCUSSION

In this preliminary study, a wear trial test was conducted to assess the effectiveness of the newly developed soft brace for correcting postural kyphosis. Two subjects, one female and one male, were recruited to participate in the study. The demographic information of the subjects is presented in Table 1.

Table 1. Demographic of subjects.

	Subject 1	Subject 2
Gender	Male	Female
Age	27	31
Weight (kg)	61.5	56.0
Height (cm)	178	162
BMI (kg/m^2)	19.4	21.3
Kyphosis index	13.0	7.9
Kyphosis angle	30.1	18.6

The summarized measurements of coronal head tilt and shoulder angles, sagittal head tilt and shoulder angles, and cervical vertebral alignment (CVA) for each subject are presented in Table 2. Upon analysis of the results, it was observed that the angles of coronal head tilt and coronal shoulder exhibited only a slight increase after the subjects wore the brace. As previously mentioned, when these angles approach 180°, it indicates a more balanced alignment of the head and shoulders. Therefore, the brace may have a minor effect on correcting the level of the head and shoulders in the coronal plane.

Regarding the sagittal head tilt angle, the results obtained from comparing the effects of wearing the brace versus not wearing it revealed minimal discernible differences. The observed outcomes did not exhibit any significant distinctions between the two conditions. This indicates that the impact of brace on the sagittal head tilt angle was negligible, and no conclusive conclusions can be drawn regarding its effectiveness for improving the sagittal head tilting. However, there was a minor increase in CVA when the subjects wore the brace. An increase in CVA indicates a reduced forward position of the head.

In contrast, a notable increase was observed in the sagittal shoulder angle when comparing the results. Larger angles indicate a lesser degree of rounded shoulders. These findings suggest that the proposed soft brace with pneumatic muscles has the potential to correct rounded shoulders.

Table 2. The measurements of head and shoulder postures of subjects.

	Subject 1				Subject 2			
	Without brace		With brace		Without brace		With brace	
Coronal head tilt angle (degree)	173.5		173		177		179	
Coronal shoulder angle (degree)	175		174.5		178		177	
	Left	Right	Left	Right	Left	Right	Left	Right
Sagittal head tilt angle (degree)	161.5	163	162	165	168	165	165	166
Craniovertebral angle (CVA) (degree)	55	53	59	58	52	45	58	56
Sagittal shoulder angle (degree)	67	65	85	85	53	45	91	88

CONCLUSION

In this study, we introduced a novel soft textile brace with pneumatic muscles designed to correct the head and shoulder posture of individuals with postural kyphosis. A preliminary investigation was conducted involving young adults, wherein five measurements related to head and shoulder posture were captured through photography. These measurements included coronal head tilt angle, coronal shoulder angle, sagittal head tilt angle, and cervical vertebral alignment (CVA).

The results revealed that the proposed brace led to marginal improvements in coronal head tilt and shoulder angle, indicating a slight enhancement in achieving a more balanced alignment of the head and shoulders. However, the brace had a negligible impact on the sagittal head tilt angle. Additionally, the findings demonstrated an increase in CVA, signifying an improvement in forward head posture. Moreover, wearing the brace resulted in a noticeable increase in sagittal shoulder angle, suggesting its potential to reduce rounded shoulders.

It is important to acknowledge that this study had certain limitations, primarily the limited number of subjects involved. Hence, future research should focus on further refining the design of the proposed soft brace and expanding the subject pool, particularly by including a more comprehensive sample of adolescents, to enable a more robust investigation.

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