Original Article

The Effect of Obesity on Thoracolumbar Flexion Control of Jewett Hyperextension Brace

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ABSTRACT

Objectives: To investigate the effect of obesity on thoracolumbar flexion control of Jewett hyperextension brace.

Study design: Experiment study

Setting: King Chulalongkorn Memorial Hospital, Bangkok, Thailand

Subjects: Fifty healthy volunteers

Methods: Volunteers were stratified into obese and non-obese groups. After wearing the prefabricated Jewett hyperextension brace with adjustment performed by a certified prosthetist orthotist (CPO), the lateral plain TL film was done in a standing upright and in a force, trunk bending against the Jewett brace. The lateral Cobb angles from T9 to L3 were measured and the result was the difference of angle between standing and bending.

Results: The obese group had a significantly higher mean flexion angle than the non-obese group in all positions [in an upright position: 9.73 (SD 6.14) and 3.35 (SD 5.32) degrees, $p < 0.001$; and in the force flexion position: 17.89 (SD 8.09) and 12.80 (SD 6.84) degrees, $p = 0.026$]. The mean bendable angle after applying the brace were 9.45 (SD 5.80) degrees in the non-obese group and 8.13 (SD 6.53) degrees in the obese group and were not statistically different.

Conclusion: Obese volunteers had a significantly higher truncal flexion angle compared with the non-obese groups in all positions. The Jewett brace could control the spinal flexion movement to less than 10 degrees and not significant different between groups.

Keywords: obesity, spine, orthotic devices, brace

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Introduction

Spinal orthoses are externally applied devices that apply force to the spine for the treatment of diseases or spinal conditions. The purposes of spinal orthoses using are spinal motion restriction and stabilizing the affected spinal segments.[1,2]

The thoracolumbar junction is the most likely area where traumatic spine injuries results in vehicle accidents, falls, sports injuries, and other causes.[3] The thoracolumbar orthoses are often used as a part of the treatment consists of many different approaches in the case of conservative management, pre- and post-operative treatments. One the most used thoracolumbar orthoses is the Jewett brace.

Jewett brace is a thoracolumbar hyperextension orthosis. Its function is to limit truncal flexion and helps to reduce the pressure force onto the anterior column of spinal body. The advantages are lightweight and easy to wear, so it is popular in practical use. The principle of spinal control of Jewett brace is 3-point pressure. Two forces from anterior to posterior at sternal pad and pubic pad. Another force from posterior to anterior at lumbar pad. Three pads place on bony landmarks for control spine. For pubic pad, to stabilize pubic bone, the landmark is 1-2 inch above pubic symphysis.

The previous literature about the Jewett brace can be divided into 2 kinds of trials. Those are biomechanical and clinical trials. In biomechanical trials, the main outcomes were force and moment that the orthosis generated and the spinal motion that the orthosis can control, or other physical parameters related to the orthosis. These groups of literature usually recruited normal healthy subject with normal body proportions. Some of the articles indicated that obesity was an exclusion criterion.[2,4] The other group of literature was the clinical trials. These researches explored the clinical outcomes such as spinal pain, disease progression, patient activities, etc.; and the subjects recruited were patients with the spinal problems regardless of the obesity. The results showed little clinical efficacy of spinal orthosis.[5-10] After reviewing literature, it could be concluded that the good biomechanical results of the Jewett brace did not contribute enough to reach a significant clinical outcome. But the authors would want to explore if this assumption results from the different criteria of the subjects regarding the obesity parameters.

The fundamental mechanism of the orthosis is to limit the motion of body segment. The more contact between the

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orthosis and the bony landmark or firm structure of the body, the better in control achieved. The skin and adipose tissues have the property that is soft, smooth, and pliable. They lie between the orthosis and the skeletal landmarks of the body, so the orthosis cannot completely adhere the bone beneath the soft tissue.(11) Obese patients have thicker layer of subcutaneous adipose tissue than non-obese patients that make an increment of the distance between orthosis and bony landmark so the orthosis theoretically cannot completely inhibit spinal motion and may contribute to the failure of conservative treatment by the spinal orthosis. In clinical experience, the authors had observed the difficulty of fitting the suprapubic pad of the Jewett brace in the severe obese patients who had excessive abdominal fat that interferes with the orthosis landmark. So far, there was no study that explored the real biomechanical effect of obesity to spinal motion restriction of the Jewett brace. We hypothesized that obesity might reduce the spinal motion control of the Jewett brace.

Methods

Participants

A stratified sample of fifty adult volunteers (twenty males and thirty females) with varying levels of obesity were recruited. Inclusion criteria were 18-40 years old healthy volunteers who gave a written informed consent before participation. Exclusion criteria were persons with the following: spine conditions or back pain that potentially affect the spine or back motion, neurological condition or balance instability that affect the standing ability or trunk motion, not being able to wear available sizes of Jewett hyperextension brace, and having a contraindication for radiography

After enrollment, the participants who did not meet any of the exclusion criteria were stratified into 5 groups according to the obesity levels using body mass index (BMI) classification by World Health Organization,(12) as follows

BMI < 18.5 kg/m^2	underweight
BMI 18.5-24.9 kg/m^2	normal
BMI 25-29.9 kg/m^2	overweight
BMI 30-34.9 kg/m^2	obese class I
BMI ≥ 35 kg/m^2	obese class II&III

We defined 10 volunteers for each group.

The demographic and anthropometric data that were weight, height, body mass index (BMI), waist circumference, hip circumference, waist/hip ratio and waist/height ratio were recorded. And, we also categorized them into “obese” and “non-obese” groups according to the obesity parameters using multiple criteria as follows:

i. BMI > 25
ii. Waist circumference: (male > 102 cm, female > 88 cm)(13)
iii. Waist/hip ratio: (male > 0.90, female > 0.85)(13)
iv. Waist/Height ratio: (> 0.5)(14,15)

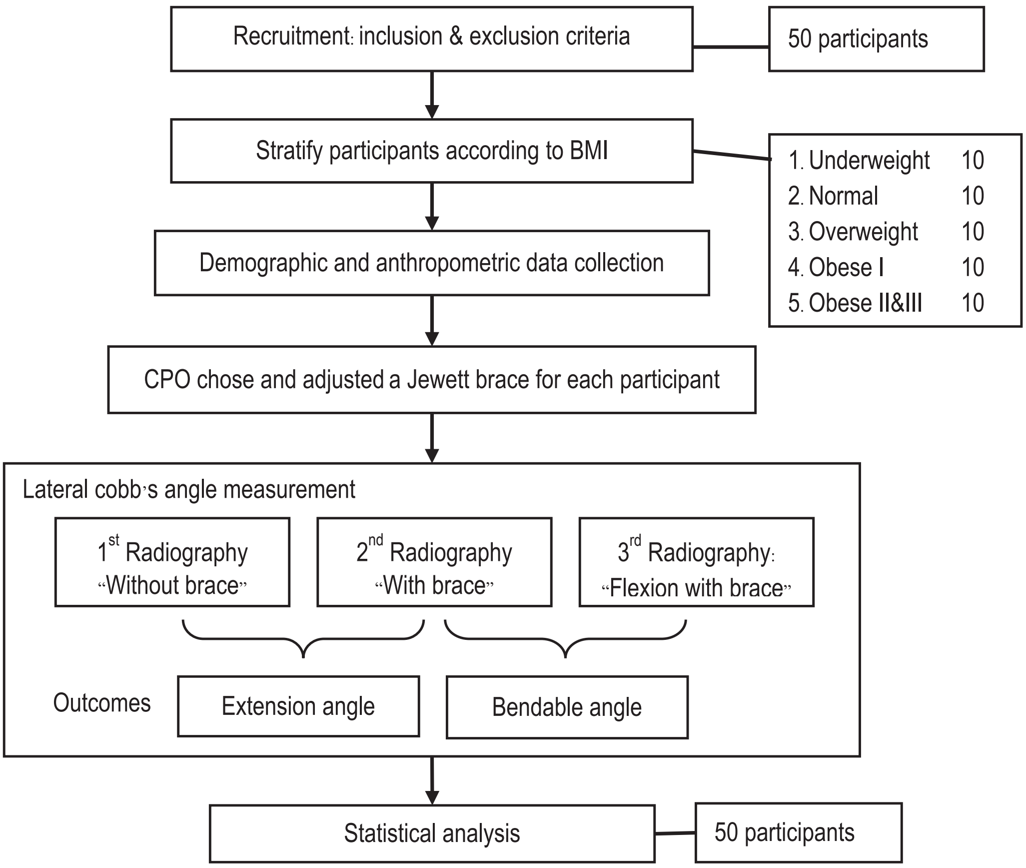

Figure 1. Flow diagram of research protocol
CPO, certified prosthetist-orthotist

Materials

A prefabricated Jewett hyperextension brace was selected for each participant by a certified prosthetist & orthotist (CPO) according to device's size recommendation, and individually adjusted to optimally fit truncal shape and posture without pain or uncomfortable pressure at certain point of contact by the brace.

Outcome measurement

Based on radiography of the thoracolumbar spine lateral view of each participant, the lateral Cobb's angle from T9 to L3 segment defined as the "truncal angle" was measured (Figure 2.) by the authors separately (PY, a physiatrist and NK, a 2nd year resident in training of rehabilitation medicine). This truncal angle was considered as the flexion angle of the spinal segment measured. Thus, the greater value was considered as more flexion posture and lesser value as more extension posture.

Radiographic imaging was recorded in 3 different upright postures as follows:

1. Without brace: participants were standing upright in a comfortable posture without wearing the Jewett brace. This was considered as the baseline truncal angle for each participant.
2. With brace: while wearing the Jewett brace, the participants were advised to standing in a comfortable posture and not resisting the brace. The Jewett brace would theoretically produce more extension forces to the spine, thus create more extension posture. The truncal angle in this posture was expected to be less than the 1st posture.
3. Flexion with brace: the participants were advised to voluntarily bend their trunk as much as possible against the Jewett brace. They were orientated to differentiate the truncal flexion and hip flexion motion and be advised to perform only the truncal flexion, not the hip flexion motion.

Main outcomes

1. Extension angle was defined as the range of motion of the truncal angle from the 1st to the 2nd posture. This angle represented the hyperextension function of the Jewett brace and calculated as follows:

Extension angle = lateral Cobb angle in 1st image - 2nd image

2. Bendable angle was defined as the range of motion of the truncal angles between the 2nd and 3rd posture. This was the angle that participants could still bend their trunk while wearing the brace. This would reflect the efficacy of the brace, the more bendable angle, the less efficacy of the brace in controlling the truncal flexion. The bendable angle was calculated as follows:

Bendable angle = lateral Cobb angle in 3rd image - 2nd image

Statistical analysis

Demographic and anthropometric data were presented with mean and standard deviation (SD). the student T-test and one-way ANOVA were used to compare the spinal motion between male and female groups, and between obese and non-obese groups. The correlation between obesity and flexion control function of Jewett brace was analyzed by using the linear regression model analysis. *P* values less than 0.05 were considered statistically significant. Analysis was done by using SPSS program version 22.

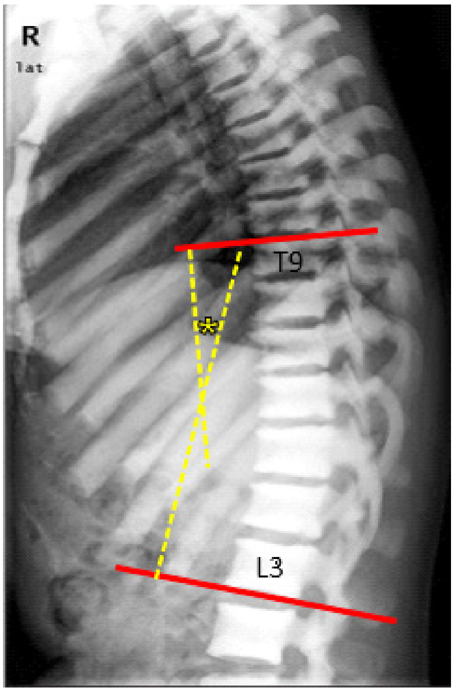

Figure 2. Lateral Cobb angle measurement

Results

The fifty volunteers were recruited between August 2015 to July 2016 and consisted of 20 men (40%) and 30 women (60%). All participants had an average weight of 74.96 kg, height of 163.28 cm and the BMI of 27.74 kg/m^2. More details were shown in Table 1.

Table 1. Demographic and anthropometric data of 50 participants

Parameters	
Age (years)[1]	29.72 (5.60)
Sex[2]	
Male	20 (40)
Female	30 (60)
Anthropometric data[1]	
Weight (kg)	74.96 (27.25)
Height (cm)	163.28 (9.05)
BMI (kg/m^2)	27.74 (8.53)
Waist circumference (cm)	92.24 (20.13)
Hip circumference (cm)	104.64 (15.81)
Waist/hip ratio	0.87 (0.08)
Waist/height ratio	0.56 (0.11)

[1]Mean (SD), [2]number (%)

BMI; body mass index

Comparison of the truncal angles between groups

Radiographic imaging was recorded 3 times as described in the measurement section and the data were shown in Table 2. Male and female groups had the same truncal flexion angle about 9 degrees at baseline and 7 degrees while wearing the Jewett brace. When instructing the participants to flex their trunk while wearing the brace, the male group demonstrated 13.60 degrees of truncal angle, and the female group was 17.33 degrees, and there was not statistically different between the two groups.

In every criterion mentioned-above, we could observe the trend that the non-obese group had a significantly lower degree of truncal flexion than the obese group. The subjects with the BMI < 18.5 kg/m^2 (underweight) had an average truncal angle of 4.6 degrees while the subjects with BMI > 35 kg/m^2 (obesity class II-III) had a truncal angle of 11.5 degrees. (Table 2) These patterns of differences were found in the 1st and the 2nd imaging (without and with the Jewett brace) and reached a statistically significant level at $p < 0.05$. The significant difference in truncal angle was also found in the 3rd imaging (force flexion while wearing the brace) using the BMI and waist circumference criteria but not the waist/hip ratio or waist/height ratio criteria.

Comparison of the extension angle and the bendable angle between groups

Table 3 demonstrates the extension angle representing the hyperextension function. In every obesity criteria classification, the posture of the non-obese group had changed into more degree of extension than in the obese group. But the statistically significant level could only be reached by using the waist circumference criteria which the non-obese group had a 3.57 degree of spinal extension while the obese group had 0.7 degrees of more spinal extension. When wearing the Jewett brace, trunk extension was 2.10 degrees in the male group and 1.97 degrees in the female group, and there was not statistically different between groups.

The bendable angle reflected the limitation in controlling the spinal motion of the Jewett brace. When dividing the participants into groups by the obesity parameters, there was no statistical difference in the bendable angle between groups. The non-obese group had about 9 degrees and the obese group had about 7 to 8 degrees of the bendable angle as shown in Table 3. But when dividing groups according to gender (male/female), there was a statistical difference between groups (p = 0.030) with the bendable angle of 6.35 degrees in males but of 10.20 degree in females. So, females had a more bendable truncal flexion angle of 3.85 degrees than males.

Discussion

Our study demonstrates the objective measurement of the normal subjects' truncal posture regarding the obesity parameters. In the 1st imaging showed the baseline lateral Cobb angle when participants were standing upright and

Table 3. Comparison of the truncal angles between groups classified by gender, BMI, waist circumference, waist/hip ratio and waist/height ratio

Variable	N	1st imaging (without brace)	p-value	2nd imaging (with brace)	p-value	3rd imaging (flex with brace)	p-value
Gender			0.898		0.952		0.104
male	20	9.35 (7.34)		7.25 (6.45)		13.60 (6.00)	
female	30	9.10 (6.27)		7.13 (6.77)		17.33 (8.79)	
5 groups of obesity, classified by BMI (kg/m^2)			0.006*		< 0.001*		0.005*
< 18.5	10	4.60 (5.50)		1.50 (3.89)		12.00 (6.72)	
18.5-24.9	10	8.40 (7.55)		5.20 (6.09)		13.60 (7.23)	
25.0-29.9	10	7.10 (4.04)		4.70 (2.91)		12.40 (5.84)	
30.0-34.9	10	14.40 (5.68)		13.80 (4.85)		22.70 (6.53)	
≥ 35.0	10	11.50 (6.29)		10.70 (6.46)		18.50 (8.62)	
Two groups of obesity, classified by							
BMI			0.017*		< 0.001*		0.026*
Non-obese	20	6.50 (6.72)		3.35 (5.32)		12.80 (6.84)	
Obese	30	11.00 (6.06)		9.73 (6.14)		17.87 (8.09)	
Waist circumference (cm)			0.033*		< 0.001*		0.030*
Non-obese	23	7.04 (6.50)		3.48 (4.96)		13.22 (6.72)	
Obese	27	11.04 (6.32)		10.33 (6.18)		18.07 (8.33)	
Waist/hip ratio			0.036*		0.004*		0.144
Non-obese	24	7.17 (6.55)		4.50 (5.64)		14.13 (8.10)	
Obese	26	11.08 (6.29)		9.65 (6.50)		17.42 (7.61)	
Waist/height ratio			0.036*		0.004*		0.075
Non-obese	17	6.47 (7.30)		3.59 (5.76)		13.06 (7.14)	
Obese	33	10.61 (5.92)		9.03 (6.27)		17.27 (8.06)	

BMI, body mass index; * $p < 0.05$

Table 3. Comparison of the extension angle and the bendable angle between groups

Variables	N	Extension angle	*p*-value	Bendable angle	*p*-value
Gender			0.914		0.030*
Male	20	2.10 (4.18)		6.35 (5.07)	
Female	30	1.97 (4.28)		10.20 (6.51)	
Five groups of obesity, classified by BMI (kg/m^2)			0.488		0.866
< 18.5	10	3.10 (4.28)		10.50 (6.54)	
18.5-24.9	10	3.20 (4.19)		8.40 (5.08)	
25.0-29.9	10	2.40 (4.55)		7.70 (5.96)	
30.0-34.9	10	0.60 (3.17)		8.90 (6.47)	
≥ 35.0	10	0.80 (4.73)		7.80 (7.67)	
BMI			0.121		0.469
Non-obese	20	3.15 (4.12)		9.45 (5.80)	
Obese	30	1.27 (4.14)		8.13 (6.53)	
Waist circumference (cm)			0.015*		0.262
Non-obese	23	3.57 (4.10)		9.74 (5.71)	
Obese	27	0.70 (3.88)		7.74 (6.59)	
Waist/hip ratio			0.300		0.297
Non-obese	24	2.67 (4.02)		9.63 (6.28)	
Obese	26	1.42 (4.35)		7.77 (6.15)	
Waist/height ratio			0.302		0.514
Non-obese	17	2.88 (4.36)		9.47 (5.97)	
Obese	33	1.58 (4.11)		8.24 (6.39)	

BMI, body mass index; * $p < 0.05$

found the obese persons had a significant more truncal flexion posture. The non-obese group had a baseline truncal angle of 6 to 7 degrees while the obese groups had about 10 to 11 degrees with a statistically different between groups.

When applying a Jewett brace, the brace created mild spinal extension motion described as the extension angle in all groups. Every comparison resulted in a non-statistically significant difference except for the waist circumference criteria that showed the non-obese group had a 3.57 degrees extension significantly more than a 0.70 degree from the obese groups. ($p = 0.015$) Even though it was statistically significant, a 3.57 degree more extension is minimal and could not be considered as a significant change of the spinal alignment in clinical use. We can conclude that the Jewett brace could create a non-clinically significant spinal extension in all participants regardless of obesity.

With the significant different baseline truncal posture between the non-obese and the obese groups, and a non-significant spinal extension created by wearing a Jewett brace, we can conclude that the significant difference of the truncal angle in the 2nd posture (wearing brace) was a result from the different baseline angle, not from wearing the Jewett brace.

When instructed the participant to bend their trunk against the Jewett brace to calculate the bendable angle, there was no statistical difference between the obese and the non-obese groups using every obesity criterion. The bendable angle was in the range of 7 to 10 degrees, and the underweight groups (BMI < 18.5 kg/m^2) had the highest angle of 10.5 degrees. But when compared between genders, the bendable angle in males was significantly lower than in the female group (6.35 vs 10.20 degrees, $p = 0.030$). Though the statistically significant level, it was hard to consider a 4-degree difference between males and females as clinically significant.

The lateral Cobb angle in the 3rd imaging could be interpreted as the most flexion truncal angle that could occur while wearing the Jewett brace. This truncal flexion could happen in daily activities when individuals try to bend down to perform various tasks or activities in daily life. From our data, these truncal angles were significantly higher in the obese groups, based on the BMI or the waist circumference criteria. The obese group had approximately 17 to 18 degrees of truncal flexion angle while the non-obese groups had around 12 to 13 degrees ($p < 0.05$). With the non-significant difference of the bendable angle according to the obesity, the significantly higher flexion angle in the 3rd imaging could be the result from the higher baseline flexion angle in the obese groups.

There is no recommendation or definition of how much restriction of the spinal orthosis is needed to be considered optimal or adequate in clinical use. Theoretically, more flexion spinal alignment will create more loading force on the anterior column of the spinal body, thus contribute or involve with various spinal problems.[16] Future research needs to be performed regarding the correlation between the flexion alignment of the spine and the clinical outcome in spinal pathology.

There is no standard recommendation about how to measure the spinal motion using orthosis. In previous studies, various methods were used to measure spinal motion such as gross flexion angle using plain film radiography,[17] computed tomography (CT),[18] magnetic resonance imaging (MRI),[19,20] video-fluoroscopy,[2,21] or the motion capture technology. The CT and MRI cannot demonstrate the movement of the spine due to the method required subject in the supine position. The motion capture method requires putting the reflective markers on each spinal process landmarks on the back of the subject which is limited due to the lumbar pad of the Jewett brace. Video-fluoroscope can demonstrate the movement of the spine in real-time, but the process is more complicated compared with plain radiography. The angles of the spine measured in this research did not require a real-time measurement, so the authors used plain radiography as it can demonstrate the spinal morphology and alignment accurately enough for the lateral Cobb's angle measurement.

In conclusion, wearing Jewett brace can minimally produce more extension of the spine about 0.60 to 3.57 degrees, and Jewett brace can limit the spinal movement not to exceed 7-10 degrees of flexion, the bendable angle was not significant difference between the obesity groups. But the obese group's baseline truncal alignment was significantly more in flexion angle than the non-obese group.

Disclosure

The authors declare no conflict of interest with any financial organization regarding the material discussed in the manuscript.

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