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Hip And Knee Abductor Moments In Normal Subjects And Subjects With Idiopathic Scoliosis During Level Walking: Comparative Study

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ABSTRACT

Background: Kinetic analysis appears to be useful in providing objective information regarding the gait abilities of scoliotic patients, which is difficult to be observed in a clinical setting. Objective: the aim of the study was to analyze and compare the hip and knee peak abductor moments in subjects with idiopathic scoliosis and normal subjects during level walking. Methodology: Forty-four male subjects was aged 14-17 years participated in the study. They were assigned into two groups, scoliosis, and control groups. The scoliosis group included 22 subjects with idiopathic moderate right dorso-lumbar curve. The control group contained normal 22 subjects. 3D motion analysis system and force plates were used for data collection for hip and knee abductor moment. MANOVA was used to study the difference between normal and scoliotic groups' hip and knee abductor moments in both lower limbs at an alpha level of significance of 0.05. Results: During free walking, there was a significant increase in the hip abductor moment contralateral to the scoliotic side, while the ipsilateral side showed non-significant increase when compared with normal subjects. There was a significant increase in the knee abductor moment ipsilateral and contralateral to the scoliotic side when compared with normal.
Conclusion: Idiopathic scoliosis could affect the hip and knee gait kinetics in the frontal plane.

Keywords: Scoliosis, Hip, and knee abductor moment.

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INTRODUCTION

Scoliosis is defined as abnormal curvature of the vertebral column. It may be a single side-to-side curve (like the letter C), or a more complicated S shape (two curves) in which the primary C shaped one is compensated by a secondary curve that forms an S shape) (1). It is a structural curve >10°. Scoliosis can be a consequence of congenital spinal anomaly, neuromuscular disease, bone dysplasia, trauma, infection, and metabolic conditions (2). Scoliosis most commonly develops in the thoracolumbar region or the upper or lower back. The physicians describe scoliosis by the shape of the curve, its direction, its magnitude, and its causes if possible (3).

Researchers have investigated the possible causes of scoliosis which could be physical abnormalities, problems in coordination, genetic abnormalities, other biological factors, or idiopathic scoliosis (4). Idiopathic scoliosis frequently occurs in relatives and seems to be hereditary. It is not known why the curve is developed, or why some curves progress more than others (5). Teenage idiopathic scoliosis has a high prevalence rate with an incidence of 0.47–5.2 % in the literature. Scoliosis occurs in females twice its occurrence in males. In particular, the value of Cobb angles in girls exceeds that of in boys: The female to male ratio increases from 1.4:1 in curves from 10° to 20° up to 7.2:1 in curves >40°. Genetic factors and age of onset together influence the curve pattern and prevalence of scoliosis (6).

Burwell et al. (5) stated that this abnormality creates rib-vertebra angle asymmetry which may result in failure of rotation control mechanisms in the vertebrae. Also, they believed that we could use kinetic gait parameters to understand the pathogenesis and etiology of scoliosis. The angle of the trunk rotation is considered one important factor that detects the severity of scoliosis. The mild curves are the curves of less than 20 degrees and these accounts for most cases. Curves that exceed 20 degrees require medical intervention. (7).

Studies have indicated that the cause and progression of idiopathic scoliosis may be attributed to kinematic differences in the spine and lower limbs during ambulation. (9). So kinetic parameters can help in understanding the pathogenesis and etiology of scoliosis (8). The Kinetic analysis appears to be useful in providing objective information regarding gait abilities which is difficult to be observed in a clinical setting (10).

Detection of hip and knee musculature abnormalities could help in the prevention of the progression of the back deformity. Avoidance of further progression of the scoliotic curve would help in the prevention of many complications of this spinal deformity as respiratory problems, circulatory problems, and development of gait deviations. There is an urgent need to increase awareness and reduce risk of further complications in scoliotic patients. So, the aim of the study was to analyze and compare the hip and knee peak abductor moments in subjects with idiopathic scoliosis and normal subjects during level walking which will help in more understanding of the consequences of idiopathic scoliosis on lower limb kinetics.

METHODOLOGY

Study setting:
The study was conducted at the physical therapy department, College of Applied Medical Sciences, Taif University.
Study design:

A Case-control study was done to analyze and compare the hip and knee peak abductor moments in subjects with idiopathic scoliosis and normal subjects during level walking. All participants underwent the initial clinical examination by the same investigator at the beginning of the study.

Participants:

Forty-four male subjects participated in the current study. They were assigned into two groups, normal group (GI) and scoliotic group (GII), each contained 22 participants. Subjects were selected from the secondary schools. Their dominant leg was the right leg (regarding scoliotic subjects the right dominant leg is the leg ipsilateral to the scoliotic side and the non-dominant left leg is contralateral to the scoliotic side). The dominant leg was recognized by asking the subject which leg you prefer to kick the ball. For detecting scoliosis, a screening hyperemia test was done with Adam's forward bending test. Subjects with trunk asymmetries were referred to a specialized physician. The severity of scoliosis was diagnosed through x-ray using the cobb method. The subjects' criteria were: the age was ranged from 14-17 years, the height was ranged from 145-160 cm, the weight was ranged from 50-70 Kg, they were free from any musculoskeletal abnormalities that affect walking, they have no visual or auditory impairments. Regarding the patients' group, they had a single right dorso-lumbar scoliotic curve with moderate severity "the cobb angle ranged from 25 to 35 degrees" (11).

Instrumentations and procedures:

Body mass index:

A Seca digital scale (Seca model 770, made in Germany) and a calibrated measuring rod (Seca Road Rod) were used to detect the participants' weight and height. The body weight was measured and recorded while the subject was bare feet with minimal clothing. Height was measured while the subject was standing straight against a wall in bare feet. BMI then detected by dividing the weight (kg) by height (m) squared.

Hip and knee abductors' moments

The Vicon nexus (1.8.5) three-dimensional motion analysis system and a force plates were used for measuring the hip and knee abductors' moments. Eight high-speed Vicon cameras with a frame rate of 120 Hz were used. The cameras were supported on the lap's walls and it could be easily adjusted for proper position before capture. The basic principle is to expose infrared reflecting markers to infrared light emitted from the cameras and the cameras detect the light reflected by the markers. An active wand was used for the calibration of the system. It provides the camera system with measurement points to be used for analysis. Thirty-nine reflective markers of 30 mm^2 Surface area were used. These markers were adhered to bony landmarks using double-faced adhesive tape. Two AMTI (advanced mechanical technology Inc., USA) force plates were embedded in the middle of a 10 meters walkway. Its dimensions were 40 x 60 cm. The sampling rate of the plate was 120 Hz. It incorporated four strain gauge transducers situated at the four corners of the plate. These transducers record force-time data in three planes during the activity.

At first, the system was calibrated using a software calibration technique to enable the cameras to pick up the positions of the markers throughout the procedures. For kinetic analysis preparation, the force plate was captured. The duration of force plate capture was 5 seconds. We recorded and calculated all subjects' anthropometric parameters which was required by the software. All subjects were fully instructed about the testing procedures.

Thirty nine reflective markers were placed at anatomical landmarks using a double-faced adhesive tape as follows: one markers on each acromion process, one marker on the middle of each arm, one marker on each of the lateral epicondyles of both humeri, one marker on each of the medial epicondyles of both humeri, one marker on the middle of each forearm, one marker on each of the lateral styloid processes, one marker on each of the medial styloid processes, one marker on the middle of each hand, one marker on the 12th thoracic vertebra, two markers placed on both anterior superior iliac spines, two markers fixed on both posterior superior iliac spines, two markers on greater trochanters, one markers in the middle of each thigh, one marker fixed at the superior edges of each patella, one marker placed over each lateral knee joint line, one marker placed over each tibial tuberosity, one marker on the middle of each leg, one marker placed over each lateral malleolus, one marker fixed over each foot between the bases of the 2nd and 3rd metatarsal bones, and one marker fixed over each heel. All subjects were fully instructed about the testing procedures.

All participants were instructed to walk at their normal speed along a 10 meters walkway for two trials to be familiarized with the procedures. Three successful walking trials were recorded for each subject. The walking trial was considered a successful trial when only one foot touched each force plate form. Data of the hip and knee abductor moments normalized to the body weight for both lower limbs were collected as the mean of the three successful trials.

Consent form:

All participants' guardians signed a written consent form before starting the procedures. Regarding confidentiality and anonymity, we considered the confidentiality and anonymity of all data that was collected from the participants. Ethical approval was obtained from the ethical committee at the research and studies department, directorate of health affairs- Taif, KSA, (approval number was 331).

Statistical and study design:

This study used the case-control design. The dependent variables were hip, and knee peak abductor moments of both lower limbs, and the independent variable was grouping factor (scoliotic and normal). The sample size was calculated using G power at effect size 0.4, pillai v 0.28, and power of 0.9. All results were analyzed by using SPSS for Windows" Version 26. The alpha level of significance was set at 0.05. MANOVA was used to study the difference between normal and scoliotic groups' hip and knee abductor moments in both lower limbs.

RESULTS

The aim of the current study was to analyze and compare hip and knee abductors' peak torque normalized to the body weight during level walking in normal subjects (GI) and subjects with idiopathic scoliosis (GII). The demographic data and the study variables' data of both groups were explored for normality using the Shapiro Wilk test, Box's test, and inspection of histograms with normal distribution curves, normal QQ plots, and Box plots. Shapiro Wilk and Box's tests showed significance of more than 0.05 for all variables and the inspection of all graphs indicated that the data of the current study was near to the normal distribution.

Demographic data

MANOVA test was used to compare age, weight, height, and BMI for both groups. There was no significant difference between both groups regarding any of the previously mentioned variables. Table (1) shows descriptive statistics, MANOVA and pairwise comparisons using the Bonferroni test for demographic data.

Table (1) descriptive statistics, MANOVA and pairwise comparisons for demographic data.

Effect		Value	F	Sig.
Group	Wilks' Lambda	0.951	0.505	0.732
		GI M±SD	**GII M±SD**	**P value**
Age (years)		15.82± 0.91	15.79±0.92	0.892
Weight (Kg.)		54.95± 3.69	54.18± 4.45	0.535
Height (cm)		159.95± 3.08	159.55± 3.62	0.692
BMI		21.47± 1.25	21.15± 1.31	0.408

1-Hip abductor moment in normal and scoliotic subjects:

Statistical analysis using MANOVA and the Bonferroni test revealed that there was no significant difference (P>0.05) between the dominant and non-dominant hip abductor moment in the normal subjects, while there was a significant increase (P<0.05) in the hip abductor moment contra-lateral to the scoliotic curve when it was compared with the non-dominant side in normal subjects and with the hip abductor moment ipsilateral to scoliotic curve. The increase in the hip abductor moment ipsilateral to the scoliotic curve was not significant when it was compared with the dominant side in normal subjects (P>0.05). Table (2) summarizes the previous results.

2-Knee abductor moment in normal and scoliotic subjects:

Using MANOVA and Bonferroni test, there was no significant difference (P>0.05) between the dominant and non-dominant knee abductor moment in the normal subjects or between the knee abductor moment ipsilateral and contralateral to the scoliotic side. On the other hand, there was a significant increase (P<0.05) in the knee abductor moment ipsilateral and contralateral to the scoliotic side when compared with the dominant and non-dominant sides in normal subjects respectively. Table (2) summarizes the previous results.

Table (2): MANOVA and pairwise comparisons for the study variables' data.

Effect		Value	F	Sig.
Group	Wilks' Lambda	0.120	303.99	.000
side		0.206	160.006	.000
Group *side		0.179	190.90	.000
		Bonferroni test		**P value**
Hip joint abductor torque (M±SD)		HND (0.35±0.05)	HNND (0.33±0.044)	0.17
		HIS (0.38±0.05)	HSC (0.8±0.1)	.000
P value		.06	.000	
Knee joint abductor torque (M±SD)		KND (0.23±0.06)	KNND (0.21±0.05)	0.35
		KSI (0.46±0.1)	KSC (0.44±0.07)	0.62
P value		.000	.000	

HND: Dominant hip abductor moment in normal
HNND: Non dominant hip abductor moment in normal
HSI: Hip abductor moment ipsilateral to the scoliotic curve
HSC: Hip abductor moment contra-lateral to the scoliotic curve
KND: Dominant knee abductor moment in normal
KNND: Non dominant knee abductor moment in normal

KSI: knee abductor moment ipsilateral to the scoliotic curve KSC: knee abductor moment contra-lateral to scoliotic curve

DISCUSSION

The hip and knee abductors' moments normalized to the body weight were measured by using the Vicon nexus (1.8.5) three-dimensional motion analysis system and a force plates which is considered one of the most objective methods used in gait analysis. (12).

Concerning the hip abductor moment in normal and scoliotic subjects, the results revealed that there was no significant difference between the dominant and non-dominant hip abductor moment in the normal subjects. On the other hand, the hip abductor moment contralateral to the scoliotic side showed a significant increase when it was compared with the hip abductor moment ipsilateral to the scoliotic side and with the non-dominant side in normal subjects.

This may be attributed to the fact that the neural control on the body tends to keep zero moments around the spine through the muscular activities. The even alignment of the normal spine is accompanied by symmetrical muscular activities, but the curved scoliotic spine is accompanied by asymmetrical muscular activities. The trunk muscles have the inherent ability to correct the lateral spine curves, but in scoliosis, the natural neural signals directing them to do so apparently are deficient. This asymmetry presents as increased activities in the para-spinal muscles of the convex side of scoliosis as well as in the gluteus medius and tensor fascia lata muscles of the concave side of the curve. (13)

Machida (14) found that the development of scoliosis is due to muscle imbalance. He suggested that the body compensates for the curvature by increasing the electrical activity in the muscles on the convex side. The laterally curved spine causes asymmetric moments around it. The muscular contraction is needed to restore balanced moments around the spine. This demands asymmetric muscular contraction. These asymmetric moments may be due to the compensation of the body for the curvature to neutralize moments around the spine.

In addition to that, these results may be due to the displacement of center of gravity which occurred because of structural alteration. This displacement changes the amount of torque generated around the vertebral articulations. So, the adjustment in the muscle action was required to maintain equilibrium. Also, these findings were supported by Hopf et al. (15), who investigated 23 subjects with idiopathic scoliosis by computerized electromyography and the results indicated that there was an increase in the muscular activities on the convex side which indicates the asymmetries in the para-spinal muscles in idiopathic scoliosis patients. Additionally, there was an increase in the activity of gluteus medius and tensor fascia lata muscles on the concave side of the curve.

Concerning the Knee abductor moment in normal and scoliotic subjects, the results revealed that there was no significant difference between the dominant and the non-dominant knee abductor moment in the normal subjects or between the knee abductor moment ipsilateral and contralateral to the scoliotic side. On the other hand, there was a significant increase in the knee abductor moment ipsilateral and contralateral to the scoliotic side when compared with the normal subjects. The non-significant difference between the knee abductor moments on both sides in scoliotic subjects may be attributed to the compensation of the scoliotic deformity at the pelvis level, which alleviates the stresses of asymmetry induced by the deformed spine on the knee joint.

Barrack et al. (16) supported our results when they studied proprioception and gait on 17 subjects with idiopathic scoliosis. They found that the asymmetry in the proprioceptive sensation between both knees in the scoliotic subjects was not significant. This indicates that the deficit of asymmetry in scoliotic subjects because of mechanical or neural problems associated with scoliosis is not obvious on the level of the knee joint. Moreover, the significant increase in the scoliotic patients' knee abductor moment on both sides than the normal average may be attributed to the increased stresses that scoliosis put on the lower limb musculature during walking. This come in agreement with Chow et al. (17) who compared gait patterns between normal and idiopathic scoliotic adolescent girls, and they concluded that idiopathic scoliosis affects gait pattern like carrying loads. The increase in the scoliotic patients' knee abductor moment during gait may also be an attempt to increase the control around the knees which have a deficit in the proprioceptive sense (16)

on the other hand, Grègoire et al. (18) contradicted our results when they conducted a reliability study to evaluate the knee muscles' strengths in subjects with idiopathic scoliosis by using the handheld dynamometer and compared them with healthy subjects. They concluded that there was a decrease in the muscle strength around the knee joint in subjects with idiopathic scoliosis and the degree of the scoliosis was moderately correlated with the muscle affection around the knee joint.

CONCLUSION

Regarding the scoliotic patients, there was a significant increase in the hip abductor moment contra-lateral to the scoliotic curve when it was compared with the normal peers or when it was compared with the hip abductor moment at the ipsilateral side of the scoliotic curve. The increase in the hip abductor moment ipsilateral to the scoliotic curve was not significant when compared with the normal subjects. Also, there was a significant increase in the knee abductor moments of both sides in scoliotic subjects when compared with normal. It can be concluded that idiopathic scoliosis could affect the hip and knee gait kinetics in the frontal plane.

Limitations:

only male children were examined without having female participants because of cultural values in Saudi Arabia.

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