Kinetic and kinematic analysis of gait pattern of 13 year old children with unilateral genu valgum

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Abstract. – OBJECTIVE: Genu valgum is a common knee deformity in growing children. It alters the alignment of the lower extremity, body posture, and gait pattern of the children. Understanding of kinematic and kinetic parameters of gait in genu valgum is essential for planning and implementing the intervention to correcting the valgus deformity. The aim of this paper is to investigate the kinetic and kinematic gait differences in children with genu valgum.

PATIENTS AND METHODS: A 13-year old girl with left side unilateral genu valgum and a closely matched healthy counterpart were recruited to compare the kinetic and kinematic parameters of their gait performances, and they were captured by The VICON motion analysis system.

RESULTS: The results showed that the child with genu valgum had lower left and right knee angles (39.6°; 30.2°) and higher ankle angles (35.6°; 28.4°) than the healthy subject (64.2°, 60.2°). In addition, the child with genu valgum had lower moments on the left side of the knee (42.1 mm.N) than unaffected right knee (73.9 mm.N). Also, the ground reaction force was (0.7 N) lower in the affected knee of the child with genu valgum than the normal subject.

CONCLUSIONS: This study revealed that there were decreased knee and ankle moments and lower knee and ankle ground reaction forces in the affected genu valgum extremity when compared with the healthy counterpart. These changes might be responsible for the altering gait pattern of the child with genu valgum.

Key Words
Genu valgum, Unilateral genu valgum, Knock knee, VICON, Gait analysis.

Introduction

Genu valgum, also known as knock-knee, is one of the common orthopedic conditions in children. It is characterized by medial angulations of knee joints, and lateral deviation of femur and tibia in the long longitudinal axis. Children with severe genu valgum are having difficulties in keeping the feet together in the standing position. Certain degrees of genu valgum are considered as normal up to the age of 7-8 years old[1-7]. This condition is generally referred as physiological genu valgum, and it gradually disappears after the age of 7-8 years. However, in some cases, genu valgum is still remaining over the age of eight years. It occurs due to knee injuries, syndromic and metabolic problems[8]. Also, genu valgum occurs due to other etiological factors such as vitamin deficiencies, developmental problems, inflammatory conditions, osteomyelitis, Ellis-van Creveld syndrome, obesity, tumor, and Cozen's fracture[9-11]. Generally, the weight bearing axis of the lower limbs passes through the midline of medial and lateral compartments of the knee in the normal standing position. But, in genu valgum, the weight bearing axis passes through the lateral compartment of the knee; it leads to more compressive forces in the lateral compartment of the knees. Therefore, the persons with genu valgum are suffered by misalignment of patellar bone, knees discomfort, ligamentous instability, and other functional disturbances such as altered gait pattern, postural instability, and difficulties in standing, walking, running, and stair climbing[12-13]. Also, muscles of the lower limbs play an important role to maintain the

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stability while walking and standing. But, medial hamstrings weakness induces the abnormal position of the knee with lateral tibial rotation in genu valgum patients[14]. Normally, the human gait cycle is composed of 60% stance phase and 40 % of swing phase[15-17]. Very few studies have been conducted to analysis the gait pattern of genu valgum. Therefore, this work aims to investigate the gait parameters in children with unilateral genu valgum. These finding would be useful to prepare early medical intervention to normalize the gait pattern of the patient.

Patients and Methods

Patients

A convenience sample of 13-year-old girl with unilateral genu valgum (left side) and a closely age-matched healthy subject were recruited for this study. Demographic data for both participants was collected (Table I). The left leg length (780 mm) was slightly shorter than right leg length (800 mm), and right knee width (140 mm) was less than left knee (150 mm) about 10 mm in the child with genu valgum. Before starting the experiment procedure, informed consent was obtained from both subjects.

Equipment

There are numbers of motion analysis system is presently available in the market. Recently, VICON (VICON Motion Systems, Oxford, UK) system is mostly used for gait analysis in clinical setting[18]. There are four different kinds of gait data (Kinetics, Kinematics, energy consumption, and neuromuscular data) can be collected by using VICON system. Body moments and force data can be obtained from the kinetic analysis. This experiment was conducted at the Laboratory of Applied Neurosciences (Department of Rehabilitation Sciences) with using VICON 8 camera system. Totally, 16 anatomical reflective markers were selected for the plug-in-gait model as shown in Figure 1, according to the Newington-Helen Hayes gait model[19-21].

Data collection and procedures

In the first experiment session, the patient's leg length, knee width, and ankle width were recorded. Totally, sixteen selected markers (14 mm diameter) were attached to the following selected anatomical location based on the Plug-in-gait model: Left anterior superior iliac spine (LASI), left posterior superior iliac spine (LPSI), right anterior superior iliac spine (LASI), right posterior superior iliac spine (LPSI), right side of thigh (RTHI), left side of the thigh (LTHI), right knee (RKNE), left knee (LKNE), right tibia (RTIB), left tibia (LTIB), right and left lateral malleolus (RANK & LANK), MTP joints of second toe (RTOE & LTOE), and right heel (RHEE) and left heel (LHEE) of the foot. The static and dynamic data were recorded by using VICON at the sampling of 100 HZ with four OR6-7 AMTI force plates (1000 Hz) (American Mechanical Technology Inc., Watertown, MA, USA). At the beginning, the subject was instructed to stand on the first force plate to calibrate and then, the static trial was conducted with the genu valgum subject. In the dynamic trial, the subject was instructed to walk for 10-meter distance in a self-walking pattern. All the captured data saved into 1.7.1 Nexus data management system of VICON. In the second session, the same procedures were followed for the normal subject to collect the gait data.

Table I. Characteristics of patient and healthy control.

Parameters	Side	Patient	Healthy control
Age		13.6 (yrs.)	13.4 (yrs.)
Height		155 (cm)	154 (cm)
Weight		50 (kg)	38 (kg)
Leg length	L	780 (mm)	860 (mm)
	R	800 (mm)	860 (mm)
Knee width	L	150 (mm)	120 (mm)
	R	140 (mm)	120 (mm)
Ankle width	L	110 (mm)	110 (mm)
	R	110 (mm)	110 (mm)

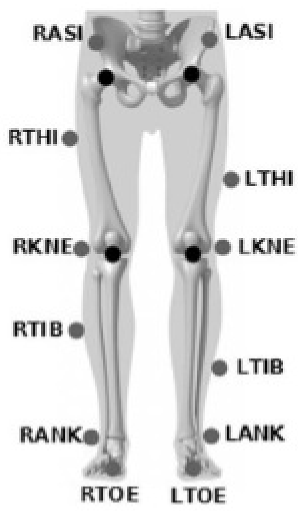

Figure 1. Plug-in-gait model (Source: Baudet et al, 2014).

Data processing and analysis

The collected data was processed by using Nexus software to get the XYZ (sagittal, frontal, transverse planes) coordinates. The following kinetic and kinematic parameters were obtained in sagittal plane-motion: maximum of knee angle, ankle angle, and moment and ground reaction force. Analysis of joint kinetics is an essential part of gait analysis. Because there will be internal joint forces which are developed by muscle actions and ligament tensions[22]. The kinetic data including knee moments in sagittal plane were calculated. Also, knee and ankle ground reaction forces (GRF) were calculated.

Results

The Table II shows that results of kinetic and kinematic characteristics of the patient and healthy subject. The patient attained the 39.6˚ maximum of knee angle in the affected lower extremity. At the same time, the unaffected knee angle in the sagittal plane was 30.2˚. Both right and left knee angles were lower in the patient than the healthy subject. However, the ankle angles of the patient (35.6˚) were higher than the healthy subject (27.1˚). In the evaluation of kinetic parameters, the right knee had higher peak moment (73.9 mm.N) in the patient than the healthy subject. Figure 2 shows that the lower extremity motion in a sagittal plane during the gait cycle.

Table II. Kinematic and Kinetic characteristics of patient and healthy control (sagittal plane motion).

Parameters	Side	Patient	Healthy control
		Sagittal plane	
Kinematics			
Knee angles	L	39.6˚	64.2˚
(Max)	R	30.2	60.2˚
Ankle angles	L	35.6	27.1
(Max)	R	28.4	27.9
Kinetics			
Knee moment			
(mm.N)	L	42.1	56.2
	R	73.9	49.1
Ankle moment			
(mm.N)	L	1498.0	1705.3
	R	1432.3	1681.2
Ground reaction forces			
Knee (N)	L	0.7	1.8
	R	1.5	3.2
Ankle (N)	L	8.2	8.9
	R	9.1	10.7

Discussion

The main purpose of this study is to compare the kinetic and kinematic parameters between healthy and unilateral genu valgum subject. The evaluation of gait pattern of the patient would be useful to intervene the abnormal gait by shoe modification or surgical intervention. Therefore, the evaluation of kinetic and kinematic parameters is necessary to interpret the pathological gait with the normal subject in objective measurement. Based on the results of gait analysis, the patient had lower left and right knee angles than the healthy subject. It might be due to the malalignment of the knee joint structures in the patient. These differences of knee misalignment of knee structure are recommended for further treatment; otherwise, it leads to several problems such as the decreased base support, severe disturbances of gait, and in-toeing gait problems[23-24].

Conclusions

Differences in knee angles, ankle angles, knee moment, and ankle moment were observed in the subject with unilateral genu valgum when compared to the healthy control. In addition, this study observed that there is a leg length difference in affected lower extremity. These findings revealed that the leg length discrepancy might also be the reason for altering the gait pattern and induce the force on the right side of the knee in the patient.

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Conflict of Interests

The Authors declare that they have no conflict of interests.

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