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

B. GANESAN1,3, K.N.K. FONG2, A. LUXIMON1, A. AL-JUMAILY3

1The Hong Kong Polytechnic University, Hung Hom, Hong Kong
2Department of Rehabilitation Sciences, The Hong Kong Polytechnic University, Hung Hom, Hong Kong
3Faculty of Engineering and Information Technology, University of Technology, Sydney, Australia

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 old1-7. 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 problems8. Also, genu valgum occurs due to other etiological factors such as vitamin deficiencies, developmental problems, inflammatory conditions, osteomyelitis, Ellis-van Crevelsd syndrome, obesity, tumor, and Cozen’s fracture9-11. 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 climbing12,13. Also, muscles of the lower limbs play an important role to maintain the
stability while walking and standing. But, med-
dial hamstrings weakness induces the abnormal
position of the knee with lateral tibial rotation
in genu valgum patients. Normally, the human
gait cycle is composed of 60% stance phase and
40% of swing phase. Very few studies have
been conducted to analysis the gait pattern of
genu valgum. Therefore, this work aims to in-
vestigate 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 partici-
pants 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 ob-
tained 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. There are four different kinds of gait
data (Kinetics, Kinematics, energy consump-
tion, and neuromuscular data) can be collected
by using VICON system. Body moments and
force data can be obtained from the kinetic anal-
ysis. This experiment was conducted at the Lab-
atory 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 Newing-
ton-Helen Hayes gait model.

Data collection and procedures
In the first experiment session, the patient’s
leg length, knee width, and ankle width were re-
corded. Totally, sixteen selected markers (14 mm
diameter) were attached to the following select-
ed anatomical location based on the Plug-in-gait
model: Left anterior superior iliac spine (LASI),
left posterior superior iliac spine (LPSI), right an-
terior 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 sam-
ping of 100 HZ with four OR6-7 AMTI force
plates (1000 Hz) (American Mechanical Technol-
ogy Inc., Watertown, MA, USA). At the begin-
ing, the subject was instructed to stand on the
first force plate to calibrate and then, the static tri-
al 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 pat-
tern. All the captured data saved into 1.7.1 Nexus
data management system of VICON. In the sec-
ond session, the same procedures were followed
for the normal subject to collect the gait data.

Table I. Characteristics of patient and healthy control.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Side</th>
<th>Patient</th>
<th>Healthy control</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>13.6 (yrs.)</td>
<td>13.4 (yrs.)</td>
<td></td>
</tr>
<tr>
<td>Height</td>
<td>155 (cm)</td>
<td>154 (cm)</td>
<td></td>
</tr>
<tr>
<td>Weight</td>
<td>50 (kg)</td>
<td>38 (kg)</td>
<td></td>
</tr>
<tr>
<td>Leg length</td>
<td>L: 780 (mm)</td>
<td>860 (mm)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>R: 800 (mm)</td>
<td>860 (mm)</td>
<td></td>
</tr>
<tr>
<td>Knee width</td>
<td>L: 150 (mm)</td>
<td>120 (mm)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>R: 140 (mm)</td>
<td>120 (mm)</td>
<td></td>
</tr>
<tr>
<td>Ankle width</td>
<td>L: 110 (mm)</td>
<td>110 (mm)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>R: 110 (mm)</td>
<td>110 (mm)</td>
<td></td>
</tr>
</tbody>
</table>
**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\textsuperscript{27}. 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>
<thead>
<tr>
<th>Parameters</th>
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<th>Patient</th>
<th>Healthy control</th>
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<tbody>
<tr>
<td>Kinematics</td>
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<tr>
<td>Knee angles</td>
<td>L</td>
<td>39.6˚</td>
<td>64.2˚</td>
</tr>
<tr>
<td>(Max)</td>
<td>R</td>
<td>30.2˚</td>
<td>60.2˚</td>
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<tr>
<td>Ankle angles</td>
<td>L</td>
<td>35.6˚</td>
<td>27.1˚</td>
</tr>
<tr>
<td>(Max)</td>
<td>R</td>
<td>28.4˚</td>
<td>27.9˚</td>
</tr>
<tr>
<td>Kinetics</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Knee moment (mm.N)</td>
<td>L</td>
<td>42.1</td>
<td>56.2</td>
</tr>
<tr>
<td></td>
<td>R</td>
<td>73.9</td>
<td>49.1</td>
</tr>
<tr>
<td>Ankle moment (mm.N)</td>
<td>L</td>
<td>1498.0</td>
<td>1705.3</td>
</tr>
<tr>
<td></td>
<td>R</td>
<td>1432.3</td>
<td>1681.2</td>
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<tr>
<td>Ground reaction forces</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Knee (N)</td>
<td>L</td>
<td>0.7</td>
<td>1.8</td>
</tr>
<tr>
<td></td>
<td>R</td>
<td>1.5</td>
<td>3.2</td>
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<tr>
<td>Ankle (N)</td>
<td>L</td>
<td>8.2</td>
<td>8.9</td>
</tr>
<tr>
<td></td>
<td>R</td>
<td>9.1</td>
<td>10.7</td>
</tr>
</tbody>
</table>

**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\textsuperscript{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.

**Acknowledgements**

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**Conflict of Interests**

The Authors declare that they have no conflict of interests.

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