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Original paper

The influence of knee marker placement error on evaluation of gait kinematic parameters

EWA SZCZERBIK*, MAŁGORZATA KALINOWSKA

Department of Paediatric Rehabilitation, The Children's Memorial Health Institute, Warszawa, Poland.

Vicon motion system is an accurate equipment for objective gait analysis. According to clinical experience the most important source of errors in kinematics is marker misplacement. It seems that knee marker placement is especially important because of its direct influence on two body segments: thigh and shank. There is little data in the literature on how the misplacement of knee marker determines the changes of kinematic parameters. Therefore the aim of this study was to collect the kinematic data of subjects with different knee pathologies (one with knee flexion contracture, the second with knee hyperextension) while knee marker position was changed in a systematical way. They were walking with their natural, preferred speed.

The data were collected using VICON460 motion system, the Helen Hayes marker set and Plug-In-Gait model. Then they were processed based on Polygon software. The results of both subjects showed the changes of kinematics, depending on the knee marker misplacement. The assessed joint ranges of angle change were: in knee, 18° in sagittal plane and 20° in frontal plane; in hip, 10° in sagittal plane and 24° in transversal plane; in ankle, 10° in sagittal plane and 25° in transversal plane. This paper presents the detailed data which could help the users of such systems to interpret the kinematic data.

Key words: *knee marker placement, objective gait analysis, evaluation of gait kinematic parameters*

1. Introduction

Optoelectronic motion systems allow very accurate objective gait analyses. The protocol of marker placement depends on the model used in the software and usually is fully described in system manual. Marker placement is based on the identification of the characteristic anthropological points of body (bony landmarks). In clinical practice, it happens that patient cannot stand patiently long enough or cannot perform tasks that allow the examiner to place marker in a perfect way. According to the data published in the literature the most important source of errors in the results obtained is marker misplacement, which causes up to 75% failures of kinematic parameters [1]. Another study proved the great influence of marker placement on the kinematics of knee joint [2]. In the systems based on the Helen Hayes marker set, a knee marker is placed on lateral femoral epicondyle. This marker is directly connected to shank and thigh segments, so theoretically it influences three joints: hip, knee and ankle. That was proved by GROEN et al. [3] who additionally assessed that marker placement of 10 mm in anterior/posterior and up/down directions resulted in the errors greater than the normal variability range during gait.

Therefore the aim of this study was to assess the changes in kinematics (values and directions) introduced by systematical changes of knee marker position around "perfect" (i.e., established rigorously according to manual directions) position. The calculation was done using a standard, clinical protocol of Vicon system. The results of this study can be of practical importance and can serve as an indication to clinical users to help them interpret gait kinematics

* Corresponding author: Ewa Szczerbik, Department of Paediatric Rehabilitation, The Children's Memorial Health Institute, al. Dzieci Polskich 20, 04-730 Warszawa, Poland. Tel: +48-22-8151748, e-mail: e.szczerbik@czd.pl

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and distinguish patient's disorder from examiner's mistake.

2. Material and method

2.1. Subjects

Two subjects with two different knee problems in a sagittal plane (established in static position) participated in the study: one woman, 50-years old without any neurological or orthopaedic problems in the past and with knee hyperextension (the worker of gait laboratory) and one 16-years old girl with cerebral palsy, with knee flexion contracture and great stability of ankle joint in all planes. The girl, a patient of hospital, who had come systematically for gait analysis in the past and this exam was a part of a standard visit. Both subjects were informed about the aim of this test prior to the study and everyone (parent of patient also) agreed to participate in it.

2.2. Methods

The subjects were walking with their self-selected, preferred speed. The data were collected using optoelectronic motion system of VICON 460. The Helen Hayes marker set and Plug-In-Gait model were used. Captured data were further processed with Polygon Software (standard clinical application of that system).

First, an ideal knee marker position was captured. Then 8 sessions were repeated with left femoral epicondyle marker systematically replaced every 45 degrees (as shown in figure 1). The range of shift (the distance between central points of marker in ideal and tested positions) was 14 mm (the dimension of standard marker). Each session consisted of 6 trials. The positions of other markers were the same during all sessions.

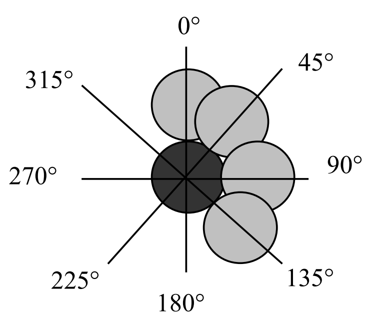

Fig. 1. The rule of left femoral epicondyle marker displacement

Gait events were identified and all data were presented within the gait cycle. The averaged data: mean values and standard deviations were calculated for pelvis, hip, knee and foot kinematics (separately for left leg and right leg) in 3 planes (sagittal, frontal and transversal).

3. Results

Generally the character of changes in kinematic parameters was similar in both subjects. The only differences were in pelvic rotation and in foot alignment, where the changes in hyperextension subject were smaller and in an opposite direction.

Figure 2 presents the sample plots of one subject with 3 different knee marker positions being used for further analysis. Figure 3 shows the plots of differences for each subject with respect to segments and planes between a "proper" marker position and every "new" position.

4. Discussion

The results show clearly that the position of knee marker is very important for a researcher to obtain reliable information about joint kinematics from optoelectronic motion analysis systems. It influences not only knee joint kinematics, but also hip and ankle joints. The maximal differences between kinematics observed in the "proper" and "new" positions of knee markers of both subjects are as follows: knee joint changes from –10° extension to 8° flexion in sagittal plane and from –15° valgus to 5° varus in frontal plane, hip joint changes from –5° extension to 5° flexion in sagittal plane and from –12° external rotation to 12° internal rotation in transverse plane, and ankle joint changes from –5° plantarflexion to 5° dorsiflexion in sagittal plane, from –5° external rotation to 20° internal rotation in transversal plane. Additionally pelvic rotation changed from 1° to 3° of internal rotation and foot alignment from 5° to 10° of internal rotation in the case of CP patient, and in the case of the subject with knee hyperextension from –2° to 0° and from –5° to 0° of external rotation.

These results showed that the trend for the influence of marker placement on kinematics (except for pelvic rotation and foot alignment) is independent of knee pathology of the subject. The asymmetry of those kinematics may be caused by the great asymmetry of

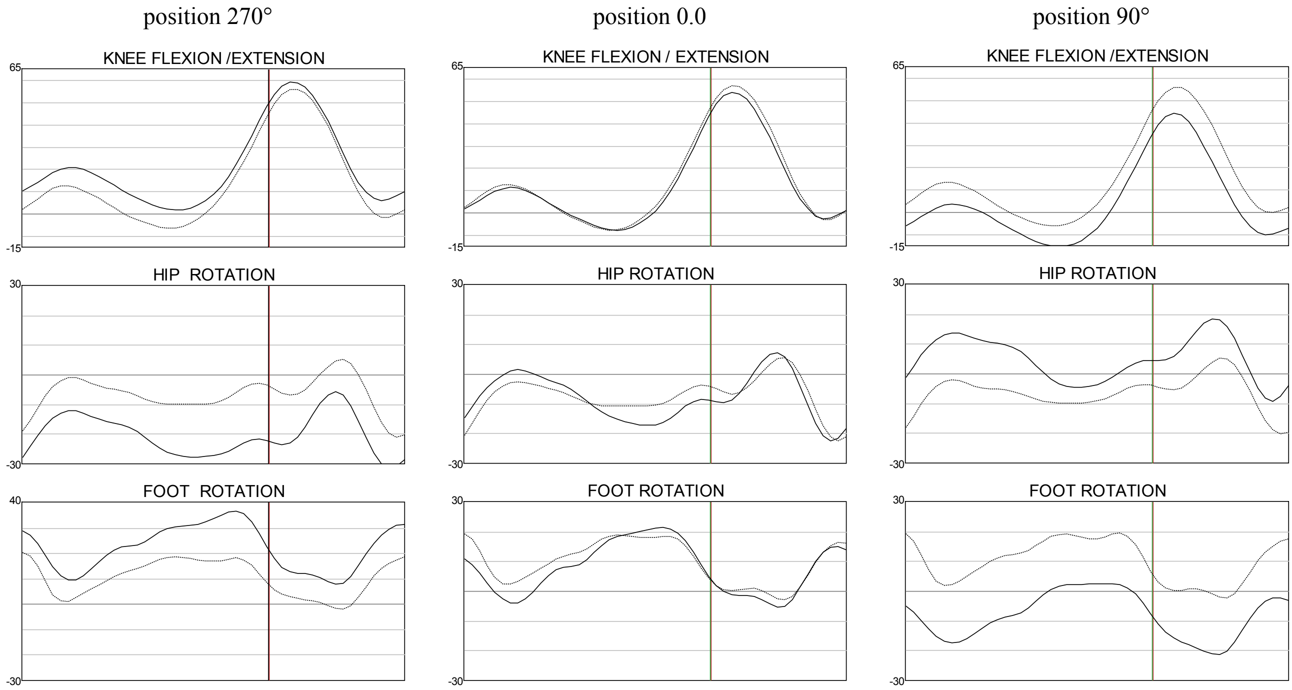

Fig. 2. Sample kinematic graphs of one subject and three knee marker positions (bold curve – left leg, light curve – right leg; vertical axis: degree (in knee: positive – flexion, negative – extention, in hip and foot rotation: positive – internal rotation, negative – external rotation), horizontal axis: gait cycle (%)). Marker posiotions were changed only on left leg

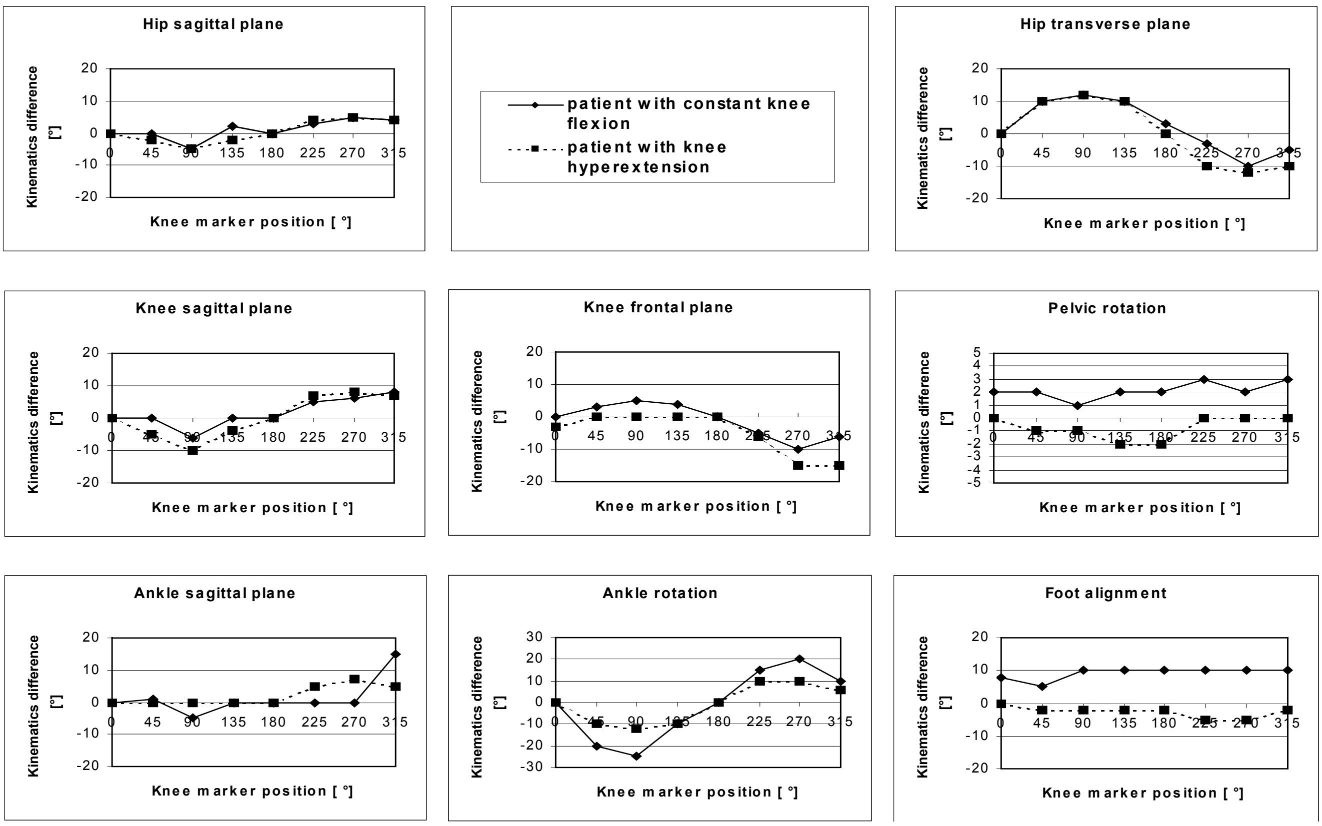

Fig. 3. Differences in left kinematic graphs referred to knee marker position (solid line – patient with knee flexion contructure, dotted line – patient with knee hyperextension; horizontal axis: kinematic differences (°) between "proper" and "new" knee marker positions; vertical axis: knee marker position (°) – "new" position versus "proper" position, change rule in figure 1, points 0°, 45°, 90°, 135°, 180°, 225°, 270°, 315°)

foot alignment in CP subject (20° of internal rotation of left ankle and 5° of right ankle and –5° of the second subject).

GORTON et al. [1] proved that there is no significant difference between trials in gait analysis within day in healthy subject. They suggested that we should be careful in generalizing that conclusion to subjects with pathological gait. Our study confirmed, based on our CP subject, that standard deviation of the kinematics parameters was similar during all 9 sessions. So the conclusion that there are no significant kinematic changes within a day is acceptable also for patients with pathological gait if their gait pattern is established.

This study has practical implications for clinical practice. It shows that simultaneous knee hyperextension, internal hip rotation and external ankle rotation can be caused by back knee marker misplacement, and simultaneous knee overflexion, external hip rotation and internal ankle rotation may be influenced by forward knee marker misplacement. Therefore if such phenomena are represented by kinematic graphs, their presence should be confirmed by video registration prior to the formulation of clinical conclusions.

Some authors [3]–[5] developed the methods which were useful in minimizing the effect of knee marker misplacement (OLGA, KAD, TEA) but in none of them the range of changes was presented. Other procedures were based on minimizing an optimization function in which data from gait kinematics, anthropometric measurements and statistically derived morphological parameters were properly weighed [6] while implemented with other than VCM marker set.

Sometimes gait kinematics is used as an input to mathematical model or for validating model procedures. In such cases, a correction method should be applied with proper optimisation algorithm [7], [8]. This is time and economically justified in science application, but not acceptable in everyday clinical experiences, when time between data capture and ready report is limited.

Nevertheless, there are some efforts to combine standard, clinical gait analysis with new modelling methods (with regression function) that are based on joint moments and powers. They seem to provide software makers with indications of how they should implement modelling procedures to eliminate errors which can influence medical decision making [9].

The shortcoming of this study is a limited number of subjects (2 persons). Therefore the statistic analysis was not possible to perform. The aim of the study was to assess how and to what extent a knee marker misplacement influences kinematics and whether the type of knee deformity influences the changes. Therefore, this study was rather a methodological one. More subjects could be enrolled for a future study but the results from the present one give useful preliminary suggestions.

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