Effect of femur and tibia marker positions on measuring ankle joint angles in optical motion analysis

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Abstract

The positions of the thigh and tibial markers in gait analysis are not strictly defined even in the most widely used Plugin-Gait. This study verified the measurement error of the ankle joint angle by focusing on the thigh and tibial marker positions using the Plug-in Gait model.

Gait analysis plays an important role in the diagnosis of bone and joint diseases that affect gait, clinical decision making for treatment and rehabilitation [1]. Optical motion capture systems, force plates, and inertial sensors have been mainly used for gait analysis. An optical motion capture system consists of multiple cameras which capture the reflective markers attached to the subject. Obtaining the coordinates of reflective markers enables the calculation of kinematic parameters. Gait analysis models such as Plug-in Gait and CAST have been proposed [2]. Each model has an original marker set. The use of marker coordinates enables the calculation of kinematic parameters easily. However, measurement errors may occur due to factors such as incorrect marker placement [3]. One of the factors causing measurement errors is that the joint center position can change due to differences in the position of the markers by only a few millimeters. The positions of the thigh and tibial markers are not strictly defined even in the most widely used Plugin-Gait. The positions of the markers are occasionally different from one measurement to another, which makes it difficult to obtain accurate joint angles. In the previous study, we verified the accuracy by shifting the thigh marker position anterior [4]. The results showed that the knee flexion and internal rotation results differed greatly when the position of the thigh marker was moved anteriorly by 45 degrees. In addition to the thigh marker, verifying the effect of the tibial marker position on measurement is required because the tibial marker position affects the definition of the ankle joint center. Therefore, this study verified the measurement error of the ankle joint angle by focusing on the thigh and tibial marker positions using the Plug-in Gait model.

A healthy male (1.78 m, 55 kg) was examined during the experiment. Following an explanation of the purpose and requirements of the study, the participants gave their written informed consent to participate in the study. Study approval was obtained from the Research Ethics Board, Kogakuin University, and National Institute of Technology, Akita College.

During the experiment, an optical motion capture system (Bonita 10; Vicon Motion Systems Ltd.) and a floor reaction force gauge (9286; Kistler Japan Co. Ltd.) measured the gait. The sampling frequency of both the optical 3D motion analyzer and the floor reaction force meter was 100 Hz.

16 reflective markers were attached to the subject's lower limbs by referring to the Plug-in Gait Lower body marker set (Figure 1). In addition, the additional thigh marker was attached to the anterior left thigh and the additional tibial marker was attached to the anterior left lower leg. Placements of LTHI1 and LTHI2 markers are shown in Figure 2. In figure 2 LTHI1 is the standard thigh marker attached to the outermost distal 1/3 of the thigh segment; LTHI2 is the additional thigh marker attached to anteriorly 1/8th of the thigh circumference R at the same height as the standard thigh marker. Similarly, LTIB1 is the standard tibial marker attached to the outermost distal 1/3 of the lower leg segment; LTIB2 is the additional tibial marker attached to anteriorly 1/8th of the lower leg circumference R at the same height as the standard tibial marker.

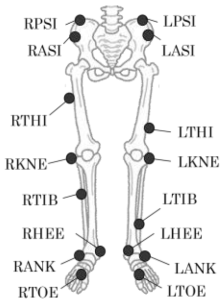
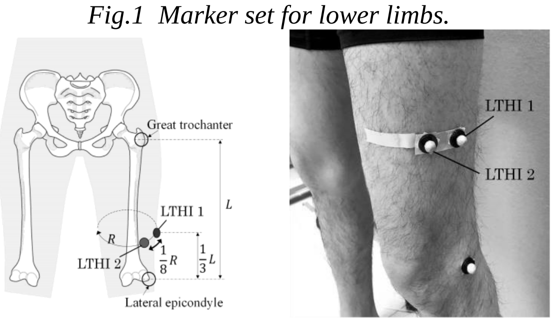


Fig.1 Marker set for lower limbs.



(a) Marker position. (b) Markers attached to subject.
Fig.2 Placements of LTHI1 and LTHI2 markers.

The analysis time was from the stance phase to the end of the swing phase of the left leg. After the experiment, the measurement data were copied into four files. The markers were labeled using analysis software (Nexus2, Vicon). In the first data, the standard thigh marker (LTHI1) was labeled with the LTHI label, and the standard tibial marker (LTIB1) was labeled with the LTIB label. In the second data, the standard thigh marker (LTHI1) was labeled with the LTHI label, and the additional tibial marker (LTIB2) was labeled with the LTIB label. In the third data, the additional thigh marker (LTHI2) was labeled with the LTHI label, and the standard tibial marker (LTIB1) was labeled with the LTIB label. In the fourth data, the additional thigh marker (LTHI2) was labeled with the LTHI label, and the additional tibial marker (LTIB2) was labeled with the LTIB label. The ankle joint angles were obtained by the Plug-in Gait Dynamic pipeline, respectively.

The hip joint center is determined using four markers (LASI, RASI, LPSI, RPSI) which are attached to the pelvis. Figure 3 shows the definition of the left knee and ankle joint centers (LKJC and LAJC). Figure 4 shows the definition of the left femoral and tibial segment coordinate system. LANK indicates the left ankle marker, LAJC indicates the left ankle joint center, and LTOE indicates the left second metatarsal head marker. In the left foot segment coordinate system, the axis from LTOE to LAJC is the Z-axis and the axis from LAJC to LANK is the Y-axis; the X-axis is determined perpendicular to the Z-axis and Y-axis according to the definition of the right-hand coordinate system.

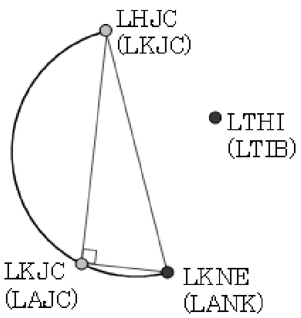


Fig.3 Definition of knee and ankle joint centers.

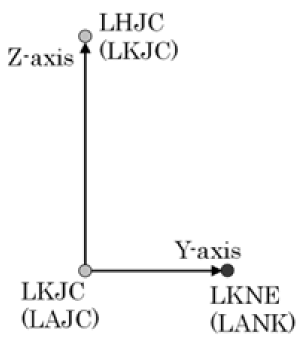


Fig.4 Definition of femoral and tibia segment coordinates.

Figure 5 shows the results of the left ankle joint angles obtained by the four types of marker set using the LTHI1 and LTHI2 markers and the LTIB1 and LTIB2 markers. The results using LTHI1 and LTIB1 markers as LTHI and LTIB markers are represented as Standard – Standard. The results using LTHI1 and LTIB2 markers are represented as Standard – 45. The results using LTHI2 and LTIB1 markers are represented as 45 – Standard. The results using LTHI2 and LTIB2 markers are represented as 45 - 45.

The results of Standard - Standard and Standard - 45 in Fig.5 show the same tendencies as the ankle angle during normal gait of a healthy person. Figure 5(b) shows that the internal/external rotation of the Standard - Standard and 45 - Standard is maintained at 0 degrees, indicating the normal gait of a healthy person, while the Standard - 45 and 45 - 45 maintain a large internal rotation throughout the entire gait cycle. Figure 5(c) shows that the 45-45 maintains 0 degrees throughout the entire gait cycle, however, the other three results show repeated internal and external rotation during the swing phase. The results suggest that the Standard - Standard is the most appropriate position for measuring the ankle joint angle using the Plug-in Gait marker set.

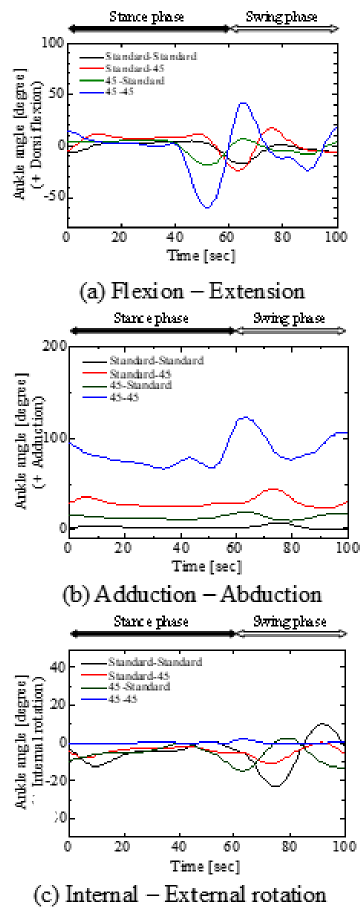


Fig.5 The sagittal ankle angle results.

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