**Introduction** The axillary crutch is an assistive device that supports the gait in the patients with lower-limb impairments. However, crutch walking has several unresolved issues [1, 2]. Particularly, the axillary pad often deviates from the axilla during the crutch stance phase. If the axillary pad is not held firmly against the chest wall, the crutch tends to get easily displaced from the axilla, possibly leading to falls [3]. Therefore, the cause of the axillary pad deviation from the chest wall should be identified for ensuring user safety. We previously showed that the external rotation of the crutch throughout the crutch stance phase ensures that the axillary pad is held tightly against the chest wall during single-crutch walking [4]. However, this applies only to single-crutch walking. The aim of this study was to analyze the crutch position in the horizontal plane for confirming the stability of the axillary pad during double-crutch walking.

**Method** Twelve healthy young subjects were enrolled in this study. They were asked to take a 5-m straight walk using two crutches (three-point, swing-through gait). No instructions regarding step length and walking speed were provided. The participants repeated the activity five times. The crutch contact in the horizontal plane was defined as the angle between the sagittal (YZ) plane and the long axis of the axillary pad. The direction of the crutch position was determined as follows (Fig.1): (1) Internal rotation indicates that the crutch turns toward the body and (2) external rotation indicates that the crutch turns away from the body. We measured crutch angles and ground reaction forces (Fig.2). The crutch position data were obtained using four infrared reflective markers attached to both the crutches (two markers each on the right and left crutches), and the results were calculated using the data collected by a motion capture system. Positions of both crutches that were measured during the crutch stance phase were calculated using the data on ground reaction forces recorded before the experiment. Repeated-measures analysis of variance and Tukey’s honestly significant test were used to compare crutch angles across three time points during the crutch stance phase (crutch contact, mid stance, and crutch off) in each subject.

**Results** Crutch angles of the two crutches were significantly different across the crutch stance phase in 11 subjects of the 12 subjects. Post hoc analysis showed statistically significant differences for 5 subjects of the 11 subjects in three comparisons (crutch contact vs. mid stance, crutch contact vs. crutch off, and mid stance vs. crutch off) on both sides. As for the other 5 subjects out of the 11 subjects, they exhibited statistically significant differences in three comparisons on one side, whereas the other side showed statistically significant differences in two comparisons out of three (significance here was always observed in the comparison crutch contact vs. crutch off). The remaining 1 subject out of the 11 subjects showed statistically significant differences in one or two comparisons out of three on both sides (significance here was always observed in the comparison crutch contact vs. crutch off). Finally, the remaining 1 subject out of the 12 subjects showed statistically significant differences in three comparisons on one side, but the other side did not show statistically significant differences in these three comparisons.

**Discussion** This study shows that a crutch rotates externally in the horizontal plane during the crutch stance phase in 11 subjects, although there is a difference between the left and right crutch in the crutch angle. In the 1 remaining subject, the crutch rotated externally on one side and did not rotate on the other side during the crutch stance phase. In this case, the crutch is likely to deviate from the chest wall on the side that does not rotate externally. Therefore, we believe that external rotation of the crutch throughout the stance phase ensures that the axillary pad is held tightly against the chest wall during not only single-crutch walking but also double-crutch walking. These results may lead to prevention of falling among crutch users.

**References**


Fig. 1. The definition of the crutch position

Fig. 2. An overview of the analytical system