Dynamic Analysis and Effectiveness Evaluation in Hemiplagic Patient with the Dream Plastic Ankle Foot Orthosis

Toshio SOMA[1)]*, Hideaki ONISHI[1)], Mitsuyo MAKITA[1)]
Yukio KUROKAWA[1)], Naritoshi SATO[2)], Toshiro MANABE[3)]

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Ankle Foot Orthoses (AFO) for the hemiplegic play not only a compensatory role for dysfunction but add therapeutic effects, aiding functional recovery and preventing functional decline secondary to stroke when applied to a patient at the early stages of therapy. The principal purpose of orthotic therapy is to enhance the abilities of standing and walking of patients. It is important to get a clearer picture of how their walking abilities can be improved in their daily living and to predict the changes at the same time as improving their abnormal gait.

Dream Plastic Ankle Foot Orthosis (DP-AFO: Fig.1) causes plantarflexion while loading force over the preset value, which is due to the structure of the orthoses that function in a combination of one-way crutch structure of the ankle joint and of friction among other components. In contrast, as dorsiflexion is caused with a subtle force, patients feel the resistance in plantar/dorsi flexion in a single direction (plantar flexion control). DP-AFO features this unidirectional controlling force.

Many have reported on kinematical analyes of AFO[1~19)], however, there is no report on a dynamic and electrographical analysis of DP-AFO applied to the hemiplegic. The purpose of this study is to compare the results of dynamic and electrographical analysis before and after the three-month use of DP-AFO by hemiplegic patients and to evaluate its effectiveness.

Fig.1 Dream Plastic Ankle Foot Orthosis

METHODS

Participant.

One subject with right hemiplegia caused by a stroke (male, age: 67 years, height: 162 cm, body weight: 55 kg) participated in this study after obtaining informed consent. It has been 22 years since the disease developed in 1982. He is able to conduct all activities of daily living on his own. He uses a double upright AFO with a shoe (shoe-AFO: Fig.2) and a T-shaped cane when walking outdoors. The ranges of motion in his leg joints are within the normal range. The participant had

[1)] Department of Physical Therapy, School of Health Sciences, Niigata University of Health and Welfare
3198 Shimami-cho, Niigata-shi, 950-3198 JAPAN
Tel&Fax: 81-25-257-4498, E-mail: soma@nuhw.ac.jp
[2)] Department of Rehabilitation, Niigata Rehabilitation Hospital, Toyosaka-shi, - , Japan
[3)] ORTHO, Inc.
*Corresponding author.

been using the shoe-AFO for approximately 20 years. We requested him to stop using the shoe-AFO and switch to the DP-AFO for 3 months.

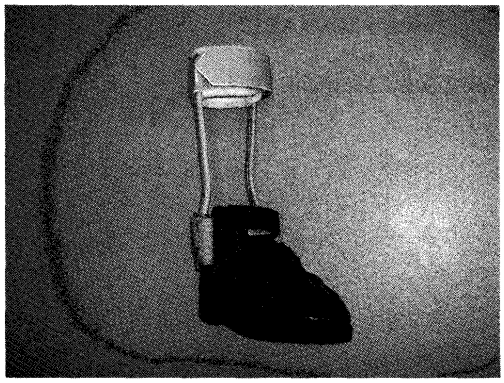

Fig.2 Ankle Foot Orthosis with a shoe.

In this experiment, joint angles and joint moments of the leg with an orthosis were measured when walking on level ground. The measurements taken during the first use of the DP-AFO and after 3 months of use were compared.

Experimental details.

The experiment consisted of a level-ground walk, under the three conditions of (1) with no AFO (wearing a shoe only), (2) with the shoe-AFO, and (3) with the DP-AFO. Walking speed was left to the participant's discretion. During the experiment, (1) and (3) a shoe was worn on the affected leg. The subject practiced to the movement task with the orthosis preceding the study. The subject walked once along a 10 meter walk-way where the force plates were located at its center.

Under conditions (1)-(3) above, relationships between joint angles and joint moments of the hip, knee, and ankle joints of the affected leg, and between electromyograms (EMG activities) and floor reaction force (perpendicular direction (FRFs) were analyzed for the level-ground walk tests.

Calculation of joint angle and joint moment.

We used three-dimensional motion analysis systems including eight CCD cameras and six force plates for motion analysis. 10 infrared reflective markers (below 25mm in diameter: marker) were attached to the shoulder, hip, knee, ankle and the fifth metatarsophalangeal joints of the subject.

Joint moments at the lower extremities and joint angles during walking were examined in the following method. Hip flexion and extension moments were calculated by projecting the FRF from the lower limb with the orthosis onto the prescribed plane by three markers; shoulder, elbow and hip joints, and multiplying the vector by the length of the perpendicular to the line of the action of the force vector projected from the shoulder joint. The hip joint angle was calculated by three markers attached to the shoulder, hip and knee joints. Knee flexion and extension moments, knee joint angles, ankle plantarflexion and dorsiflexion moments and ankle joint angles were calculated in the same way.

EMG activities collection and analysis.

EMG activities were detected from the quadriceps femoris (vastus lateralis), biceps femoris (long head), tibialis anterior and gastrocnemius (lateral head) muscles with bipolar surface electrodes. Each electrode distance was set at 1.0 cm. EMG signals were digitized at a sampling rate of 1KHz using a 12 bit A/D converter (ADXM-98FX, Contec, Kobe). EMG signals were filtered using a bandwidth ranging from 10Hz to 500Hz. Comparative analysis was performed under three conditions on the joint angle, joint moment and EMG activities when the affected leg was grounded.

Results and Discussion

Result 1. Subject with hemiplegia caused by stroke- Joint angles/joint moments of the leg with an AFO: Level ground walk (First time)

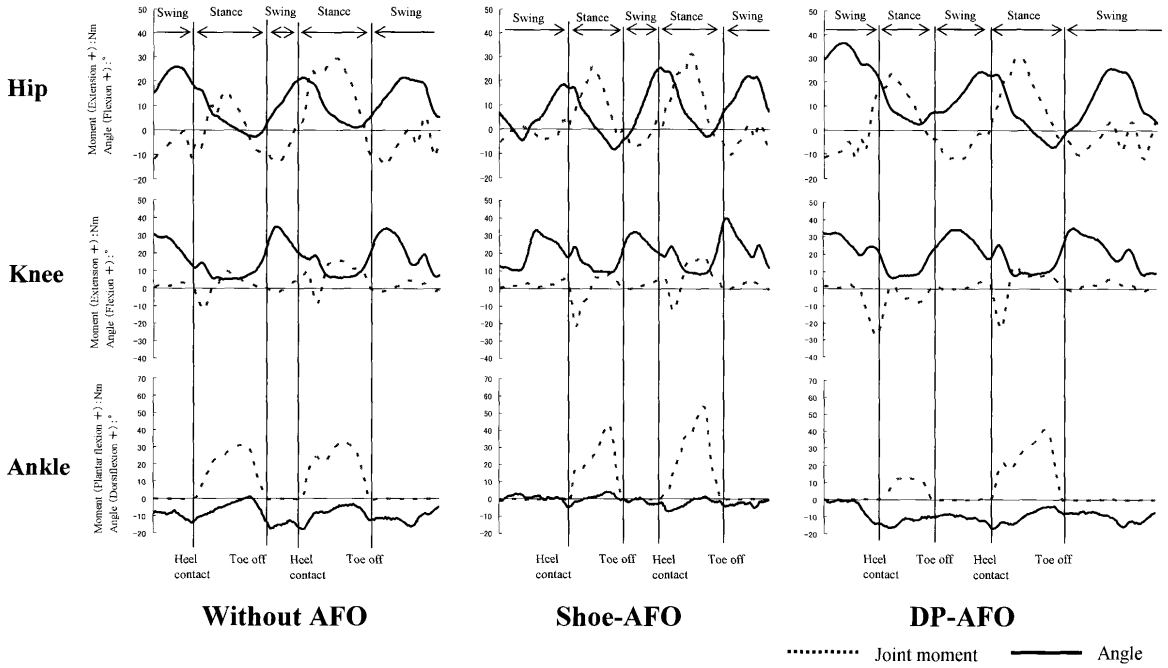

Fig. 3 The joint angles and moments of the affected leg with/without an orthosis during the level-ground test in the hemiplegic patient when the DP-AFO was worn for the first time.

Figure 3 shows the joint angles and joint moments of the leg with an AFO, which were measured during the level-ground test when the DP-AFO was worn for the first time. Dorsiflexion was not seen in the ankle joint of the leg "with the DP-AFO," partially because the participant was using the DP-AFO for the first time. The movement of the ankle joint of the leg "shoe-AFO" was closer to that seen in normal gait.

Ankle joint dorsiflexion was seen slightly in the leg with no AFO and with the shoe-AFO in the late-stance phase, but not in the leg with DP-AFO. The plantar flexion moment of the ankle joint in the late-stance phase and the dorsiflexion angle of the ankle joint in the swing phase were similar under all three conditions.

Result 2. Subject with hemiplegia caused by stroke- Joint angles/joint moments of the leg with an AFO: Level ground walk (3 months later)

Figure 4 shows the joint angles and joint moments of the leg with an AFO, which was measured during the level-ground walk test after 3 months of using the DP-AFO. Three months had passed since the participant switched to the DP-AFO from the shoe-AFO. At this stage, no differences were observed in the wave shapes of the joint angles or joint moments of the leg requiring an AFO, whether it was with no AFO, with the shoe-AFO, or with the DP-AFO. (Similar results were obtained for all conditions.) An extension moment was not observed in the hip joint of the leg with the DP-AFO during the stance phase, since the measuring devise malfunctioned.

The ankle joint dorsiflexion and the plantar flexion of the ankle joint during the late-stance phase were similar under the three conditions. The ankle joint dorsiflexion during the swing phase was not seen in the leg with no AFO or with the shoe-AFO, but it was seen in the leg with the DP-AFO.

Result 3. Subject with hemiplegia caused by

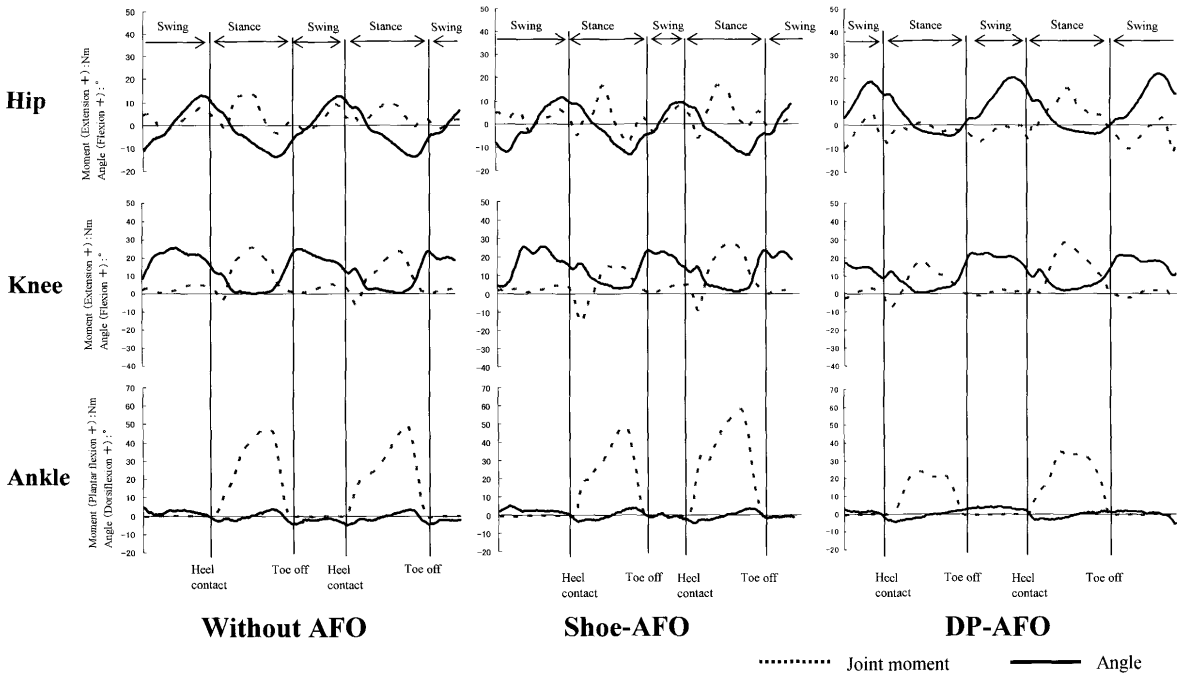

Fig. 4 The joint angles and moments of the affected leg with/without an orthosis during the level-ground walk test in the hemiplegic patient after 3 months of using the DP-AFO.

stroke-Muscular activity of the leg with an AFO: Level ground walk (First time).

Figure 5 shows the muscular activity of the leg with an AFO, which was measured during the level-ground walk test when the DP-AFO was worn for the first time. The results obtained under the three conditions showed similar muscular activities.

Result 4. Subject with hemiplegia caused by stroke-Muscular activity of the leg with an AFO: Level ground walk (3 months later).

Figure 6 shows the muscular activity of the leg with an AFO, which was measured during the level-ground walk test after 3 months of using the DP-AFO. The activity of the anterior tibial muscle of the leg with the DP-AFO and with no AFO increased, but that of the leg with the shoe-AFO decreased. In other words, since the ankle joint dorsiflexion was limited in the leg with the shoe-AFO, the movement of the anterior tibial muscle might have been suppressed.

Result 5. Subject with hemiplegia caused by stroke-Changes in joint angles/joint moments of the leg with no AFO" at the first use of the DP-AFO and after 3 months of use: Level ground walk.

Figure 7 shows the changes observed in the joint angles and joint moments of the leg with no AFO during the level-ground walk test performed at the first use of the DP-AFO and after 3 months of use. The hip joint flexion during the late-stance phase increased after 3 months of use, compared to the first use. The flexion moment of the hip joint was seen during the swing phase on the first use, but not after 3 months of use. The extension moment of the knee joint measured during the mid-stance point was greater after 3 months of use compared to the first use, and that measured during the swing phase was smaller after 3 months of use compared to the first use. These findings might stem from the increased anterior tibial muscular activity after 3 months of use, which enabled the ankle joint dorsiflexion.

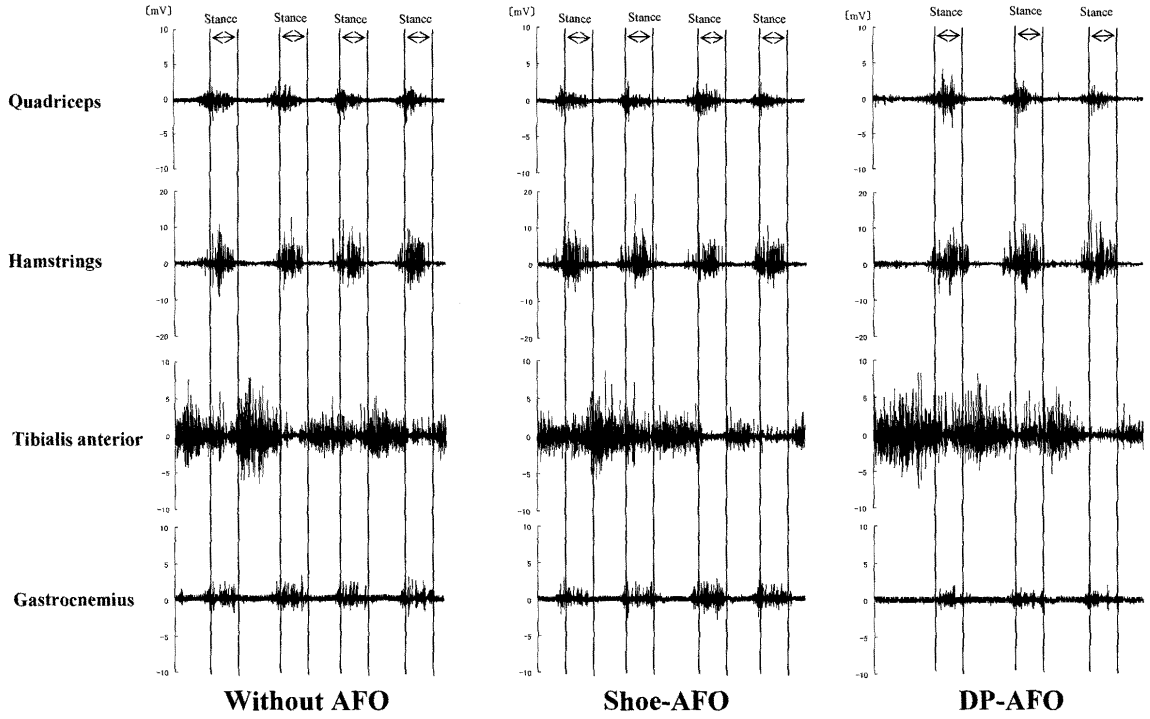

Fig. 5 The activities of four muscles the affected leg with/without an orthosis during the level-ground walk test in the hemiplegic patient when the DP-AFO was worn for the first time.

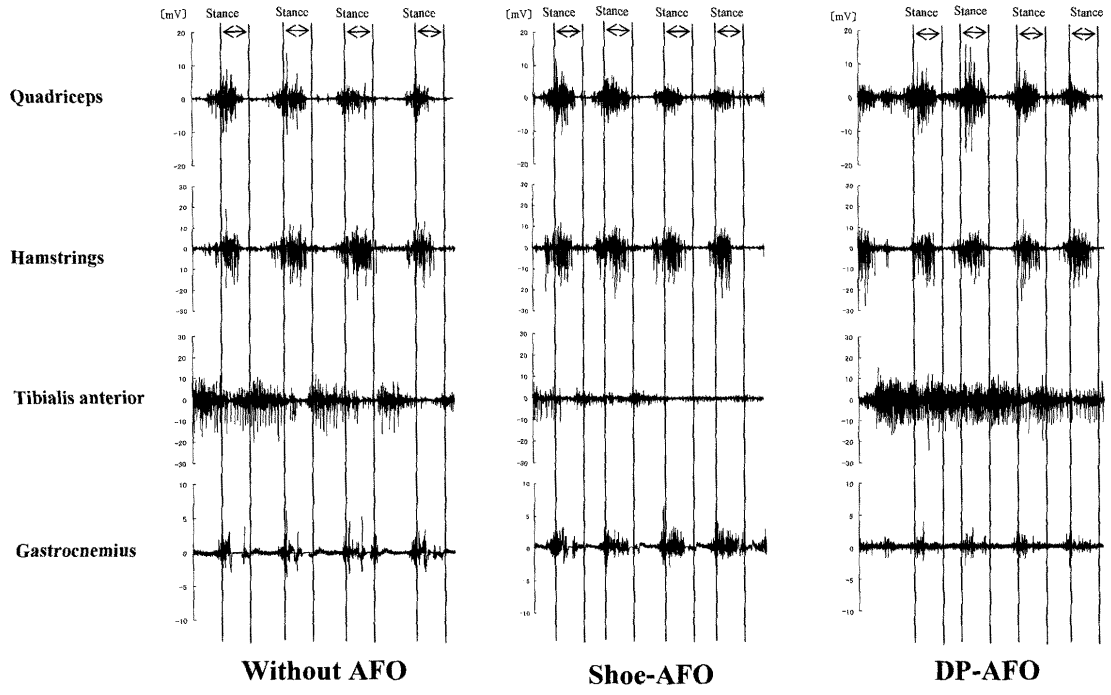

Fig. 6 The activities of four muscles the affected leg with/without an orthosis in the hemiplegic patient during the level-ground walk test after 3 months of using the DP-AFO.

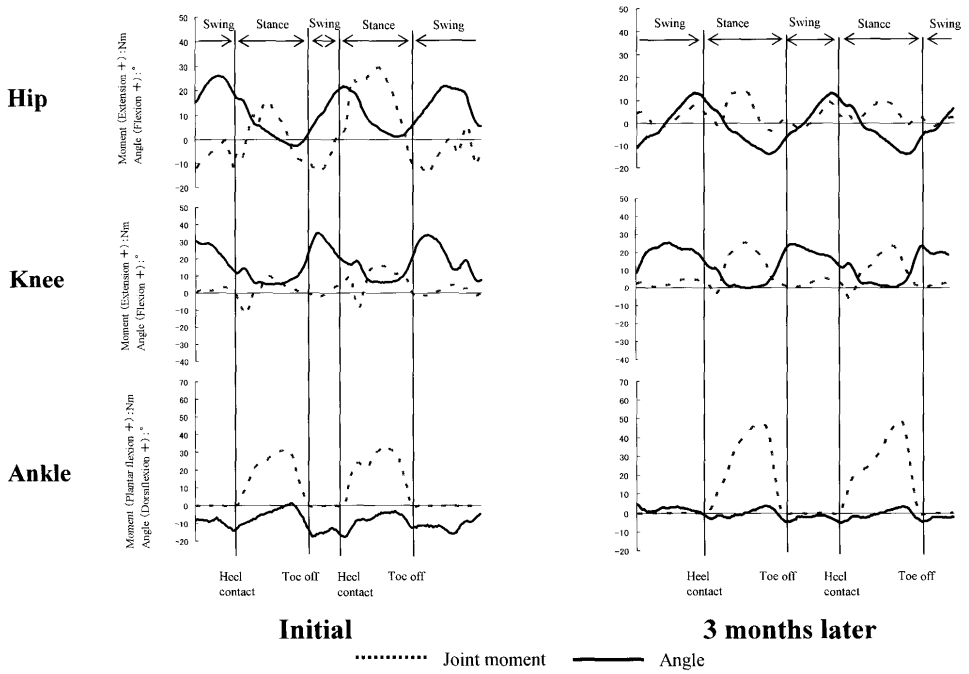

Fig. 7 The changes observed in the joint angles and moments of the affected leg without an orthosis in the hemiplegic patient during the level-ground walk test, which was performed at the first use of the DP-AFO and after 3 months of use.

The dorsiflexion angle of the ankle joint during the stance phase was larger after 3 months of use. Further, the plantar flexion angle of the ankle joint during the swing phase was large at the first use, but the plantar dorsiflexion was almost 0 degree 3 months later. The ankle joint was in the plantar flexion position throughout the gait cycle in the first use, but 3 months later, the participant kept the plantar dorsiflexion at 0 degrees (mid position) as he walked.

Result 6. Subject with hemiplegia caused by stroke- Changes in joint angles/joint moments of the leg with the DP-AFO at the first use of the DP-AFO and after 3 months of use: Level ground walk

Figure 8 shows the changes in the joint angles and joint moments observed during the level-ground test, which was performed at the first use of the DP-AFO and then 3 months later. The extension moment of the hip joint during the mid-stance phase was smaller after 3 months compared to the first use. The flexion moment of the hip joint during the swing phase was smaller after 3 months compared to the first use. The flexion moment of the knee joint during the early-stance phase (heel strike) was also smaller after 3 months compared to the first use. The ankle joint was in the plantar flexion position throughout the gait cycle when the DP-AFO was used for the first time, but 3 months later, it was in the dorsiflexion position from the late-stance phase through the entire swing phase. The plantar flexion moment of the ankle joint before the toe-off during the first DP-AFO use was similar to that of after 3 months of DP-AFO use.

These results showed that the joint angles and joint moments of the leg with no AFO became closer to those of normal gait by using the DP-AFO in daily life. Recovery of muscular function was also suggested. In short, an orthosis such as shoe-AFO, limits plantar dorsiflexion and

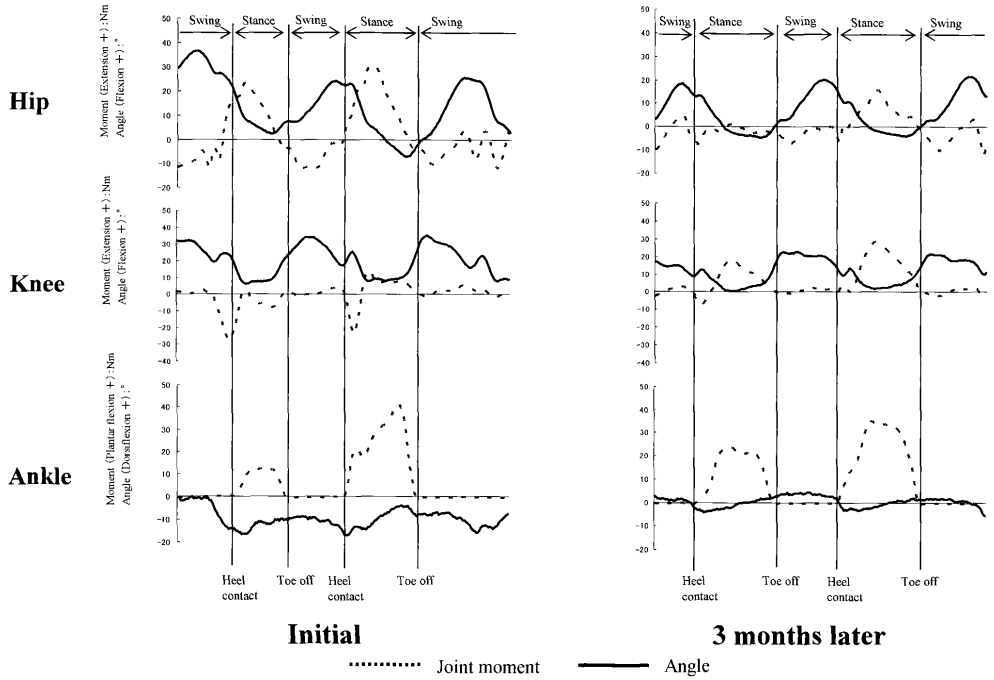

Fig. 8 The changes in the joint angles and moments of the affected leg with DP-AFO in the hemiplegic patient during the level-ground test, which was performed at the first use of the DP-AFO and then 3 months later.

improves movements, but it does not improve muscular functions. Conversely, an orthosis such as DP-AFO, which has no dorsiflexion-inducing characteristics but has more mobility in terms of dorsiflexion direction, has the possible effect of re-educating muscular function.

SUMMARY

Muscular activities and dynamics were analyzed when a healthy adult and a patient with hemiplegia caused by stroke both wore the DP-AFO and took level-ground walk tests. The results demonstrated that the DP-AFO replicates the joint angles, joint moments, and muscular activities that are similar to those observed in normal gait. Further, a possible re-education of muscular function was suggested in the patient with late-phase hemiplegia that resulted from stroke.

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