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Case Report

Gait Disturbance after Excision of Hamstrings and Effect of an Ankle-Foot Orthosis; A Case Report

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Summary

Limb-sparing surgery is important treatment for soft tissue sarcoma, but resection of major muscles in the lower extremities causes motor and gait dysfunction. However, we have experienced limb-sparing patients who have had significant improvement in their ability to walk.

We present the case of a 52-year-old woman who had limb-sparing surgery for soft tissue sarcoma that removed hamstring muscles (biceps femoris, semimembranosus, and semitendinosus). After surgery, the patient suffered from gait disturbance but was able to stabilize her gait by wearing ankle-foot orthosis. The patient underwent knee flexor strength testing and gait analysis with and without the ankle-foot orthosis. The maximum torque of the knee flexor muscles was higher when the patient used the ankle-foot orthosis than without it. Gait analysis demonstrated improvement of knee flexion with the ankle-foot orthosis. The surface electromyogram showed that gastrocnemius activity was increased markedly by using the ankle-foot orthosis.

The ankle-foot orthosis not only fixed the ankle in place to avoid foot drop, but also allowed gastrocnemius to act effectively as a knee flexor muscle after hamstring resection. We recommend using an ankle-foot orthosis to improve the gait of patients who have undergone hamstring resection because of a soft tissue tumor, infection, or trauma.

Key Words: ankle-foot orthosis, electromyogram, gait analysis, ground reaction force, limb-sparing surgery

Introduction

Limb-sparing surgery is an important treatment for soft tissue sarcoma. When such surgery is performed, major muscles are sometimes resected to achieve a satisfactory margin. Resection of the hamstrings results in not only dysfunction of the knee, ankle, and foot, but also gait ability[1-3]. We performed muscle strength measurement and gait analysis in a woman who underwent resection of the hamstring muscles on the right side to treat soft tissue sarcoma. We objectively assessed muscle strength by using a dynamometer system and performed quantitative gait analysis to measure dysfunction. After a common type of plastic ankle-foot orthosis (AFO) was prescribed for the patient, these tests were conducted while wearing and

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not wearing the AFO. In this patient, walking was smoother with the AFO than without it and all functional parameters were improved. To our knowledge, there were few reports that analyzed muscle strength and gait after limb-sparing surgery for soft tissue sarcoma[4]. Previous reports indicate that limb-sparing surgery results in Activities of Daily Living (ADL) loss similar to amputation[5], and it is very rare to improve gait function with the use of a common plastic AFO. Therefore, we are reporting this case with discussion of the literature.

Case Presentation

A 52-year-old woman had felt some swelling at right posterior thigh one month before the initial orthopedic consultation. She did not have any history of trauma and disease of that region. The mass was approximately eight centimeters in circumference on the posterior thigh eleven centimeters proximal to the popliteal fossa and was elastic hard and immobile. Magnetic resonance imaging (MRI) showed the tumor was hyperintense to the muscle on T2-weighted images.

We diagnosed malignant soft tissue tumor by imaging and clinical examination. After preoperative chemotherapy with ifosfamide, limb-sparing surgery was performed that involved wide resection of the tumor and the hamstrings (biceps femoris, semitendinosus, and semimembranosus). Because the tumor involved common peroneal nerve, common peroneal nerve was resected. The pathological diagnosis was synovial sarcoma, and the surgical stage was IIb according to the Musculoskeletal Tumor Society Classification[6]. After resection, the patient had presented severe gait disturbance. Manual muscle testing of the involved limb showed that the muscle strength was 2 for the knee flexor muscles and 0 for the ankle and foot extensors. Therefore, an AFO was prescribed for the patient. It was a custom-made non-hinged thermoplastic solid AFO. The patient could walk smoothly with using AFO for four weeks after the operation.

Knee Flexor Strength Testing

The patient was seated upright in a Biodex system-3 dynamometer (Biodex Medical Systems Inc., New York, USA) and her lateral femoral condyle was aligned with the lever arm axis of rotation. Stabilization straps were placed around the thigh and chest to fix the knee and trunk, respectively. The resistance pad attached to the lever arm was secured around the distal tibia just proximal to the malleoli.

Gravity correction was performed in accordance with the manufacturer's guidelines. The range of knee flexion was set between 10° and 90° by using mechanical stops. The patient placed her hands on the sides of the seat and then performed 3 submaximal concentric repetitions at 60° per min with increasing effort for familiarization. During the session, the patient performed 3 sets of 3 maximal effort knee flexions with a 2-minute rest between each set. The maximum peak torque value was recorded in Newton meters (Nm) at 60° per min for each repetition. Knee flexor strength testing was performed before surgery and 17 days, 2 months, and 5 months after the operation. Each postoperative test was conducted by the same physiotherapist with the patient wearing and not wearing the AFO, and the average peak torque was calculated for both conditions. Independent t-tests were used to detect possible differences between maximum torque. P values less than 0.05 were considered indicative of statistical significance.

Maximum torque of the knee flexor muscles was decreased on the 17th day after surgery compared with before the operation (5.0 Nm vs. 8.2 Nm, $p < 0.05$, respectively), although maximum torque showed an increasing trend during the postoperative period. Moreover, the maximum torque of the knee flexor muscles was higher with the AFO than without it throughout the postoperative period. On the 17th day after surgery, maximum torque was 5.0 Nm without the AFO and 9.2 Nm with the AFO ($p < 0.05$). Maximum torque with the AFO showed further improvement at 5 months postoperatively (Fig. 1).

Gait Analysis

Analysis of the patient's gait was performed at six months after surgery. Gait trials were performed along an 8-m walkway with a built-in force platform and a 6-camera (100 Hz) 3-dimensional motion analysis system (VICON 460, Oxford Metrics Ltd., UK). This system also allowed synchronized recording of the surface electromyogram (EMG) (MyoResearch, Noraxon USA Inc., USA).

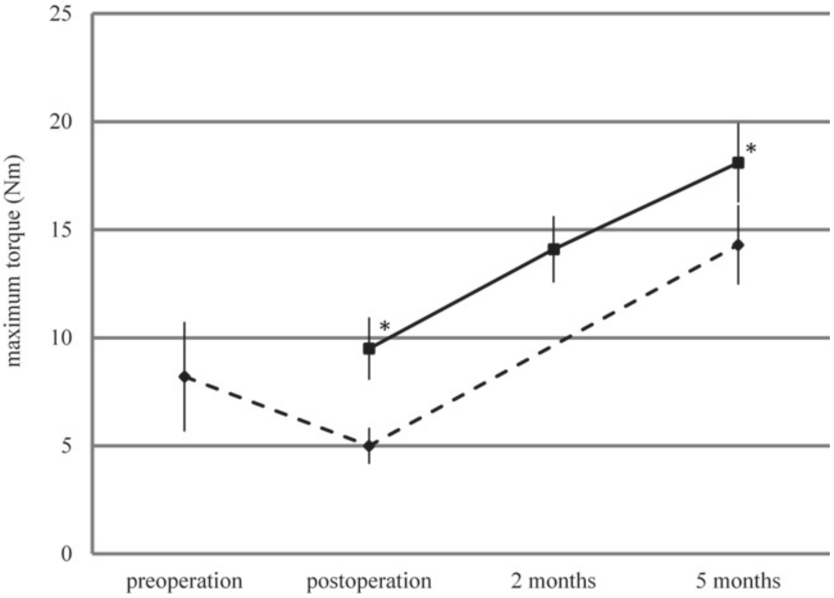

Figure 1

Kinematic testing used a Biodex system-3. The solid line shows the maximum torque when the patient was wearing the AFO and the broken line shows maximum torque without the AFO. Values are mean ± SD. Statistical analysis by standard t-test. *$p < 0.05$.

Ground reaction forces were measured by using a multicomponent force platform that was mounted flush with the walkway. Forces and moments along the 3 principal axes were sampled at 100 Hz. The gait videos and force platform recordings were time-synchronized by using a 3-dimensional motion analysis system that detected the positions of reflective markers glued onto the subject. A total of 13 reflective markers were positioned over landmarks in accordance with the VICON Plug-in-gait marker placement protocol. The patient began each trial by standing quietly on the force platform in a relaxed position. Then she initiated walking and continued walking for 5 min. Trials were performed at a self-selected pace. Three practice trials were immediately followed by 3 data collection trials while wearing the AFO and 3 trials not wearing it (6 experimental trials in total). The average flexion angles of the bilateral hip and knee joints were calculated. In addition, the surface EMG was recorded over the affected gastrocnemius muscle. The duration of muscle activity was averaged during representative walking cycles, and EMG data were compared between the patient not wearing the AFO and wearing the AFO.

During the swing phase, sagittal rotation angle of the right hip joint showed a higher peak than that of the left hip joint (Fig. 2). When the patient was not using the AFO, stance-phase knee flexion (a normal finding in humans) was not detected on the right side (Fig. 3). In contrast, the right knee showed the same pattern of movement as on the normal side when the patient was wearing the AFO (Fig. 3).

The EMG showed a marked increase of gastrocnemius activity when the patient was using the AFO. Moreover, there were 2 distinct peaks of EMG activity (during the stance phase and swing phase) separated by a valley when the AFO was worn. Moreover, when the patient was wearing the AFO, peak muscle activity was markedly increased compared to that without the AFO ($p < 0.05$) (Fig. 4).

Discussion

Despite loss of the hamstrings, the major muscles performing knee flexion, this patient could walk while wearing an AFO. Markhede reported that complete loss of the hamstrings caused severe walking disability[7]. However, our patient only used an AFO and did not require a crutch when walking. It means that wearing AFO is useful for patients who lost their hamstrings muscle.

The hamstrings (biceps femoris, semitendinosus, and semimembranosus) are the main knee flexor muscles.

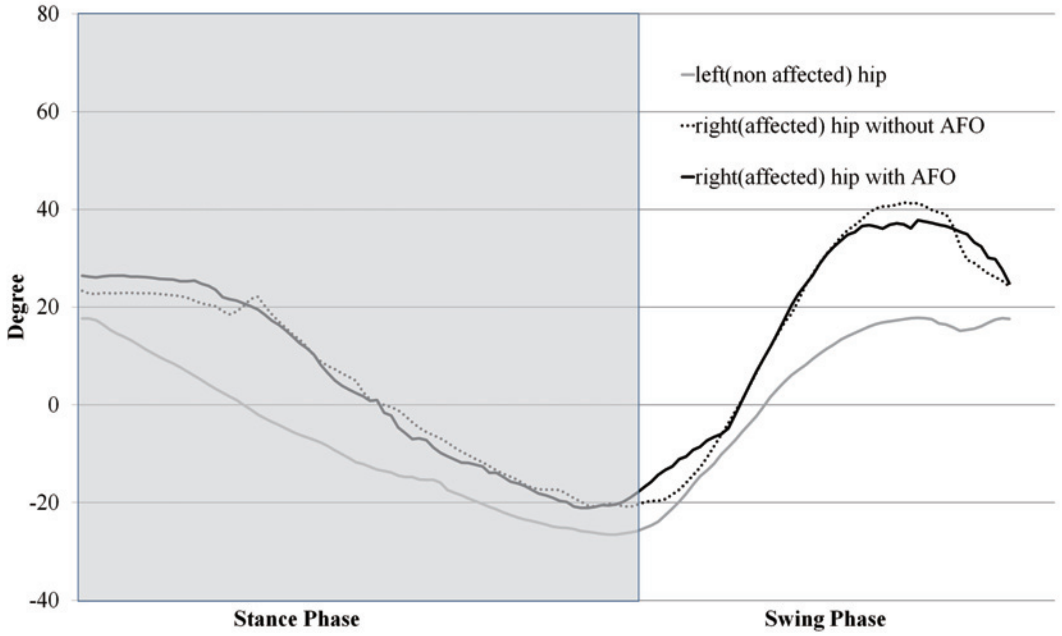

Figure 2

Hip joint angle during walking with or without using AFO was measured by 3-D motion analysis system. The solid gray line is the left (non-affected) side, and the black solid line is the right side (involved side) with AFO. The black broken line is the right side (involved side) without AFO. Stance phase and swing phase are separated by the vertical line.

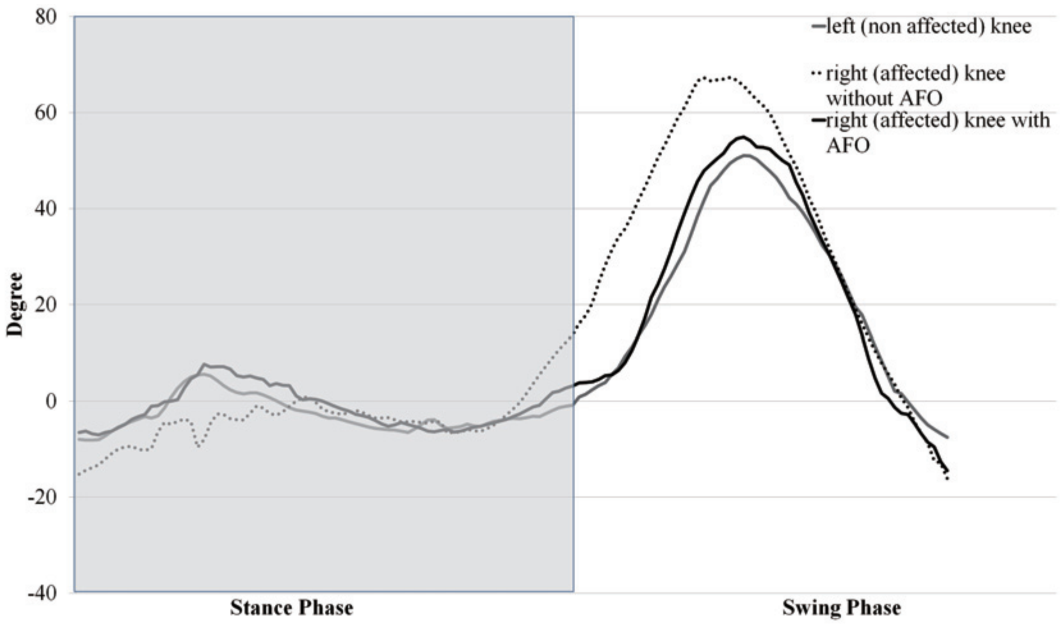

Figure 3

Knee joint angle during walking with or without using AFO was measured by 3-D motion analysis system. The solid gray line is the left (non-affected) side, and the black solid line is the right side (involved side) with AFO. The black broken line is the right side (involved side) without AFO. Stance phase and swing phase are separated by the vertical line.

Because these muscles were resected in our patient, gastrocnemius (a bi-articular muscle) was the residual knee flexor. Normally, gastrocnemius is fixed at the medial and lateral femoral epicondyles, while it contracts at the calcaneal tuberosity. However, gastrocnemius can flex the knee joint if contraction occurs at

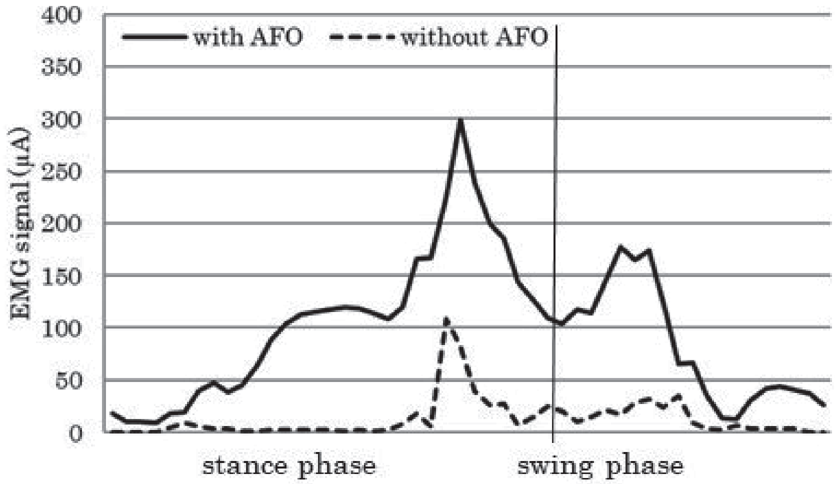

Figure 4

Surface EMG signal recorded over the right gastrocnemius muscle. The solid line is the EMG when the patient was using AFO and the broken line is the EMG without the AFO. Muscle activity showed a marked increase with the AFO and demonstrated 2 peaks, one is during the stance phase and the other is during the swing phase. Stance phase and swing phase are separated by the vertical line.

the part attached to the epicondyles. For efficient flexion of the knee joint, it is important to fix the ankle joint. Therefore, the maximum torque of the knee flexor muscles was higher when the patient was wearing the AFO and her ankle was fixed (Fig. 4). Moreover, gastrocnemius is longer when the ankle joint is in the neutral position than when it is in plantar flexion, and contraction becomes stronger when the initial length of a muscle is increased.

Gait analysis demonstrated improvement of knee flexion when the patient was wearing the AFO. Genu recurvatum was seen in the stance phase on the right side when the patient was not wearing the AFO. Saunders and colleagues identified 6 major energy-saving determinants of normal walking that were claimed to smooth the gait and minimize displacement, and the influence of these factors on gait is generally accepted among clinicians and researchers[8]. Stance-phase knee flexion is the third determinant, which reduces the energy cost of walking by decreasing vertical motion of the body[9]. Stance-phase knee flexion was achieved when our patient used the AFO.

With normal gait, the hamstrings not only act as knee flexors, but also as hip extensors. During the normal gait cycle, the hip flexor muscles (mainly iliopsoas and quadriceps femoris) contract to advance the lower extremity in the early swing phase, while the hip extensors (mainly gluteus maximus and the hamstrings) contract to prevent hyperflexion of the hip in the midswing phase. In our patient, loss of the antagonist muscles may have led to increase hip flexion in the swing phase and decrease hip extension in stance phase due to the unopposed action of the hip flexors.

The surface EMG revealed continuous contraction of the right gastrocnemius at the end of the stance phase. When the patient was wearing the AFO, contraction of the right gastrocnemius was revealed by the EMG from the middle to the end of the stance phase and from the early to middle period of the swing phase, and muscle activity was markedly increased compared to that without the AFO (Fig. 4). The increased EMG activity of gastrocnemius during the mid-stance phase corresponded to the initiation of flexion[10]. Normally, knee flexion during the stance phase is due to contraction of the hamstrings. When our patient was using the AFO, gastrocnemius could induce knee flexion during the stance phase instead of the hamstrings.

An AFO is usually prescribed for muscle weakness affecting the ankle joint and subtalar joints, including weakness of the dorsiflexors, plantar flexors, invertors, and evertors. This type of device can be used for prevention or correction of foot and ankle deformities and for reduction of weight-bearing force[11]. In our patient, the AFO not only fixed the ankle in place to avoid foot drop, but also allowed gastrocnemius to act effectively as a knee flexor muscle after hamstring resection. In addition to stabilizing the ankle, an AFO may also influence knee stability by altering the extent of plantar flexion or dorsiflexion. According to Lehmann, fixing the ankle in dorsiflexion increases the flexion force at the knee and may help to prevent genu recurvatum[12, 13].

The limitations of this study are that we used multi component force platform, but we did not compare with normal walk and we did not assess gait speed, cadence, and other gait-related indicators. These are issue for our future consideration. This is the single subject study, we cannot have opportunity to study the same conditional case. However, we have confidence in the efficacy of the AFO for the gastrocnemius through this study. We recommend prescribing the AFO for the patients who have their hamstrings muscle resected because of soft tissue tumor, infection, or trauma to improve their gait ability.

Conclusion

In the present case, muscle strength testing and gait analysis demonstrated the efficacy of an AFO. An AFO may improve the gait of patients who have undergone hamstring resection because of a soft tissue tumor, infection, or trauma.

Informed consent

The patient approved the publication of this case report and image.

Author Contributions

Hiroshi Irisawa: Concepting this report and wrote the first draft of this paper including figures. Acquisition and analysis of data.

Yukihide Nishimura: Concepting this report and performed the surgery.

Takashi Mizushima: Conception and design of the study and final editing this manuscript.

Disclosure Statement

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