International Journal of Physical Medicine & Rehabilitation

Irisawa et al., Int J Phys Med Rehabil 2019, 7:1
DOI: 10.4172/2329-9096.1000507

Case Report Open Access

Analysis of Muscle Strength and Gait after Excision of Hamstrings and Effect of an Ankle – foot Orthosis: A Case Report

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Received date: February 19, 2019; **Accepted date:** February 25, 2019; **Published date:** March 04, 2019

Abstract

Background: Limb-sparing surgery is important for treatment of soft tissue sarcoma, but resection of major neurovascular bundles and/or muscles in the lower extremities causes motor and gait dysfunction. This case report documents the effect of an ankle-foot orthosis on muscle strength and gait in a 52-year-old woman who had limb-sparing surgery for soft tissue sarcoma that removed the common peroneal nerve and hamstring muscles (biceps femoris, semimembranosus, and semitendinosus).

Methods: The patient underwent knee flexor strength testing with and without the ankle-foot orthosis. Gait analysis was performed with and without the ankle-foot orthosis using a 3-dimensional motion analysis system, along with recording of the surface electromyogram and collection of ground reaction force data with a multicomponent force platform.

Results: After surgery, 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.

Conclusions: Using an ankle-foot orthosis allowed gastrocnemius to act more effectively as a knee flexor after resection of the hamstrings. An ankle-foot orthosis may improve the gait of patients with hamstring resection.

Keywords: Ankle-foot orthosis; Electromyogram; Gait analysis; Ground reaction force; Limb-sparing surgery; Synovial sarcoma

Introduction

Limb-sparing surgery is an important treatment for soft tissue sarcoma. When such surgery is performed, major neurovascular bundles or muscles are sometimes resected to achieve a satisfactory margin. Resection of the hamstrings and common peroneal nerve in the lower extremities results in dysfunction of the knee, ankle, and foot [1-3]. We performed muscle strength measurement and gait analysis in a woman who underwent resection of the hamstring muscles and the common peroneal nerve 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 an ankle–foot orthosis (AFO) was prescribed for the patient, these tests were conducted while wearing or 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 a few reports that analyzed muscle strength and gait after limb-sparing surgery for soft tissue sarcoma [4], so we are reporting this case with discussion of the literature.

Case Report

A 52-year-old woman who had no significant past medical history, had a malignant tumor affecting the common peroneal nerve in the distal half of the posterior thigh. After preoperative chemotherapy with ifosfamide, limb-sparing surgery was performed that involved wide resection of the tumor and the common peroneal nerve, as well as the hamstrings (biceps femoris, semitendinosus, and semimembranosus). The pathological diagnosis was synovial sarcoma and the surgical stage was IIb according to the Musculoskeletal Tumor Society Classification [5]. Postoperative chemotherapy or radiotherapy was not performed. After resection of the common peroneal nerve, the patient has no functioning muscles to perform ankle dorsiflexion on the affected side. 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 (Figure 1). The patient was informed that data concerning her case would be submitted for publication and gave written consent according to the guidelines established by the Hamamatsu University School of Medicine Ethics Committee.

Figure 1: We made a custom-made non-hinged thermoplastic solid AFO for the patient.

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.

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).

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 flexion angles of the bilateral hip and knee joints were measured. 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 wearing the AFO and not wearing the AFO.

Results

Knee flexor strength

Maximum torque of the knee flexor muscles was decreased at 17 days after surgery compared with before the operation (5.0 Nm vs. 8.2 Nm, 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. At 17 days after surgery, maximum torque was 5.0 Nm without the AFO and 9.2 Nm with the AFO. Maximum torque with the AFO showed further improvement at 2 and 5 months postoperatively (Figure 2).

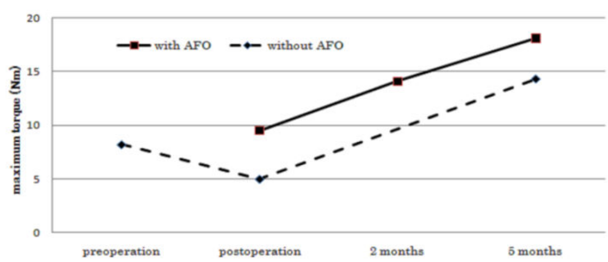

Figure 2: Kinematic testing used a Biodex system-3. The solid line shows the maximum torque when the patient was wearing the AFO and the broken line shows maximum torque without the AFO. Torque was significantly higher ($p<0.05$; paired T-test) when the patient was using the AFO.

Citation: Irisawa H, Morishima Y, Nishimura Y, Nejishima M, Mizushima T (2019) Analysis of Muscle Strength and Gait after Excision of Hamstrings and Effect of an Ankle–foot Orthosis: A Case Report. Int J Phys Med Rehabil 7: 507. doi:10.4172/2329-9096.1000507

Gait

During the swing phase, sagittal rotation angle of the right hip joint showed a higher peak than that of the left hip joint. When the patient was not using the AFO, stance-phase knee flexion (a normal finding in humans) was not detected on the right side. In contrast, the right knee showed the same pattern of movement as on the normal side when the patient was wearing the AFO (Figures 3 and 4).

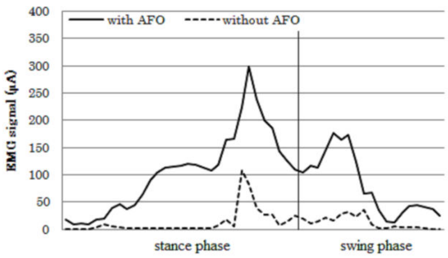

Figure 3: Joint movements when the patient walked without wearing the AFO. Data were obtained by a 3-dimensional motion analysis system. Solid lines show the left side and broken lines show the right side (affected side). Black indicates the hip joint and gray designates the knee joint. Flexion of the right hip (affected side) was increased in the swing phase compared with the left hip.

The EMG showed a marked increase of gastrocnemius activity when the patient was using the AFO (Figure 5). 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.

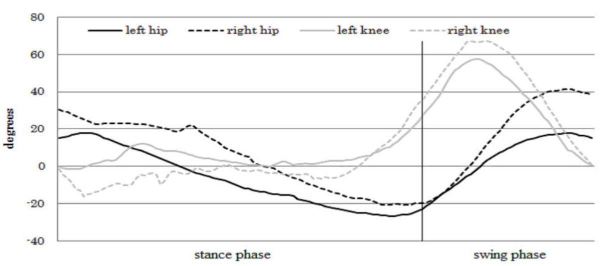

Figure 4: Joint movements when the patient walked while wearing the AFO. With the AFO, the right knee shows similar performance to the left (unaffected) knee.

Discussion

To our knowledge, this is the first case report on the efficacy of an AFO for a patient with resection of the hamstrings. 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 [6]. However, our patient only used an AFO and did not require a crutch when walking.

The hamstrings (biceps femoris, semitendinosus, and semimembranosus) are the main knee flexor muscles. 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 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. 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, while 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 [7]. Stance-phase knee flexion is the third determinant, which reduces the energy cost of walking by decreasing vertical motion of the body [8]. Stance-phase knee flexion was achieved when our patient used the AFO.

The patient underwent resection of the common peroneal nerve to remove her tumor. According to Vlahovic, the characteristic foot drop gait pattern induced by common peroneal neuropathy is associated with excessive knee and hip flexion in the sagittal plane [9]. In our patient, flexion of the right hip was increased in the swing phase, but it was similar with or without the AFO. This suggested that increased hip flexion in the swing phase was not influenced by foot drop.

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 mid-swing phase. In our patient, loss of the antagonist muscles may have led to increased hip flexion in the swing phase due to the unopposed action of the hip flexors.

The surface EMG revealed continuous contraction of gastrocnemius at the end of the stance phase. When the patient was wearing the AFO, contraction of 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 (Figure 5). 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.

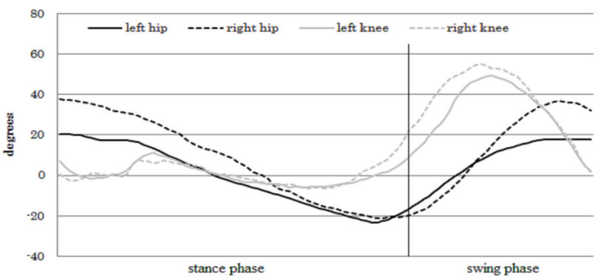

Figure 5: Surface EMG signal recorded over the right gastrocnemius muscle. The solid line is the EMG when the patient was using AFO and the broken line is the EMG without the AFO. Muscle activity showed a marked increase with the AFO and demonstrated 2 peaks, one during the stance phase and the other during the swing phase.

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].

Conclusion

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

Conflicts of Interest

The authors report no conflicts of interest.

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