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PHYSICAL THERAPY RESEARCH

REVIEW

The Past, Present, and Future of American Cancer Rehabilitation

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ABSTRACT. Cancer rehabilitation in the United States has gone from a small obscure rehabilitation subspecialty to an area of intense interest. American cancer rehab's recent growth can be attributed to the ever increasing number of cancer survivors. The future of cancer rehabilitation may be accelerated by the concept of exercise as cancer medicine.

Key words: Rehabilitation, Future, American, United States

(Phys Ther Res 24: 187-194, 2021)

The field of American cancer rehabilitation has undergone a tremendous increase in interest over the past 15 years from both oncology and rehabilitation professionals. This narrative review article will discuss where the subspecialty has come and where it is going.

The Past

In part due to cancer being viewed largely as an incurable disease in the past century, the field of cancer rehabilitation is very young compared to other subspecialties within rehabilitation. The Handbook of Physical Medicine & Rehabilitation 1st and 2nd editions published in 1965 and 1970 did not have a paragraph regarding cancer rehabilitation. It was not until the late 1970's that we begin to see some major literature regarding oncology rehabilitation including influential articles published by Dietz in 1980[1] and Lehmann in 1978[2]. Physical medicine & rehabilitation at MD Anderson Cancer Center, the largest American cancer hospital, did not begin until the mid-1990's.

In Lehmann's 1978 article, multiple barriers to implementing cancer rehabilitation were identified including a lack of identification of patient rehabilitation related problems by oncologists, lack of appropriate referral from oncologists, patients who are often too ill to participate, patients denying a need for rehabilitation, too poor of a cancer prognosis, unavailable rehabilitation, and the lack of financial resources[2]. Sadly, many of these barriers continue to exist today in our field. Andrea Cheville, an influential American cancer physiatrist, has studied many of these barriers. In many oncology cases, rehabilitation is dismissed because the perceived expected outcome is unchanged by oncologists[3]. The outcome that many oncologists are focused on is survival.

Our past could be characterized by not only a lack of interest from oncologists but also by rehabilitation professionals themselves perhaps due to a lack of clinical demand. Cancer rehabilitation education opportunities were few at conferences and within training programs up until the past 10 years.

The Present - The Era of the Cancer Survivor

The present period of cancer rehabilitation has been associated with a dramatic wave of interest to unprecedented levels. The main driver for this wave of interest is the rapidly increasing numbers of cancer survivors. First, the definition of cancer survivor must first be clarified because it is a bit different from the traditional definition of survivor. Traditionally, the term "survivor" is used to characterize someone who has made it through an unpleasant or life-threatening event like a hurricane, earthquake, or illness. However, in the oncology world, a cancer survivor is anyone who has ever been diagnosed with cancer from the

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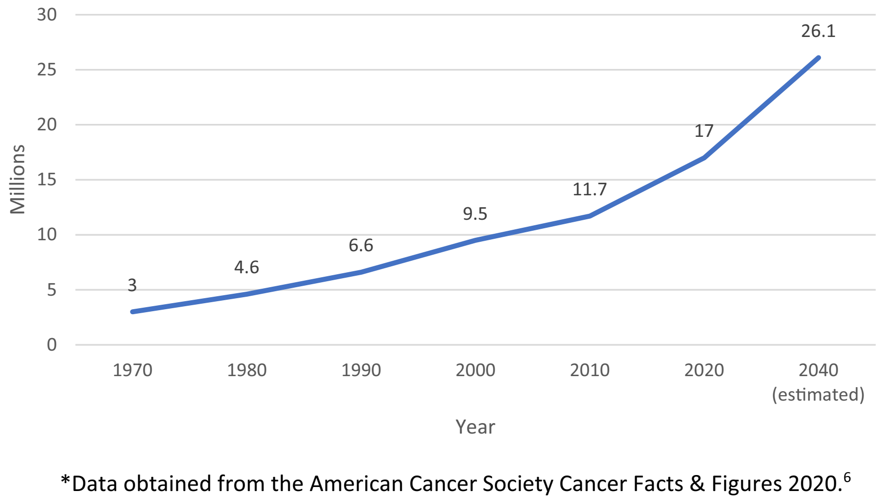


Fig. 1 Number of American Cancer Survivors

initial diagnosis until death[4]. Therefore, someone diagnosed with cancer 5 minutes ago, 5 weeks ago undergoing ongoing chemotherapy, and 5 years ago with no evidence of disease are all considered cancer survivors.

There are a number of contributors to the ever-increasing number of cancer survivors both in the United States and around the world. The first contributor is an increased American population from 106.5 million in 1920 to 328.2 million in 2020 (the world population has increased from around 1 billion in 1804 to approaching 8 billion today). If a certain percentage of people will get cancer, then the number of cancer survivors would also increase. Second, the percentage of Americans over the age of 65 has been increasing in part due to increased life expectancy. The greater the numbers of Americans over the age of 65 means a greater incidence of diseases that primarily affect the elderly including strokes, neurodegenerative disorders (like Parkinson's and Alzheimer's), and cancer. Approximately 50% of American cancer survivors are over the age of 70 and 72% are over the age of 60[5]. The last and most remarkable part of this phenomenon is that survival rates for cancer have been increasing due to more effective cancer treatments. In the mid 1970's, the five-year relative survival rate for all cancer sites was only 49%. 40 years later, the survival is at 70%[6]. These three factors have led to increasing numbers of American cancer survivors from 3 million in 1970 to 17 million in 2020 (Fig. 1)[6,7]. An estimated 4.8% of the US population in 2016 were cancer survivors. For many, cancer has become a chronic disease like diabetes or Alzheimer's. While patients may eventually succumb to their disease, many can live with cancer for years. There are more American cancer survivors than the combined numbers of American traumatic and non-traumatic spinal cord injury survivors (up to 353,000)[8], traumatic brain injury survivors (5.3 million)[9], and stroke survivors (7 million)[10] combined. Yet the rehabilitation infrastructure for cancer rehabilitation pales in comparison to that of neurorehabilitation.

Cancer survivors can suffer from a number of impairments that can be addressed through rehabilitation interventions. Deconditioning, asthenia, and cancer related fatigue are very common in cancer patients before and after cancer treatment. Chemotherapy induced peripheral neuropathy can lead to neuropathic pain but also functional impairments like reduced balance and coordination. Chemo-brain is a multi-factorial syndrome (including other cancer related symptoms) which can lead to prolonged cognitive dysfunction including memory and executive function deficits. Steroid myopathy is also quite common due to long term steroid use in stem cell transplant patients for graft versus host disease prevention as well as in a number of other cancer treatments. Steroid myopathy often can be identified by the pattern of significantly greater proximal weakness out of proportion to distal weakness. Patients often have difficulty with sit to stand transfers but do relatively well once standing and ambulating. Lymphedema is common amongst breast cancer patients but can affect any cancer patient where lymphatic damage has occurred (e.g. head and neck as well as gynecologic cancers). Post-mastectomy reconstruction syndrome in breast cancer patients and radiation fibrosis syndrome in head and neck cancer patients are common and are due to radiation related nerve damage and/or nerve stretching/traction damage during surgical dissections. Neuro-rehabilitation may be necessary for spinal cord injury (often due to primary tumors, metastatic tumors, or radiation late effects), brain injury (due to primary brain tumors, metastatic brain tumors, or radiation late effects), and leptomeningeal disease.

A number of recent studies have demonstrated continued difficulty with under-recognition and under-referral by oncology that was described by Lehman et al.[2] Oncology specialists often experience tunnel vision where they are focused on cancer staging and cancer progression/recurrence and do not consider factors that can affect quality of life. Movsas et al. found 87% of inpatient oncology unit patients had motor/functional needs but only 18% received physiatry consults[11]. Cheville et al. found 92% of metastatic breast cancer patients had at least one physical impairment but only 30% received rehabilitation treatment which was mostly inpatient[12]. In another study by Cheville of 244 outpatient cancer survivors, 65.8% self-identified functional needs but there was minimal reference in oncology medical records to functional problems[13]. Finally, despite the high number of cancer patients with functional needs, only 31.8% of patients with late stage cancer expressed an interest in cancer rehabilitation[14].

Present Challenges

Due in large part to the rapidly increasing numbers of cancer survivors, demand for cancer rehabilitation has outpaced supply. Many cancer centers have tried to quickly establish cancer rehabilitation programs including recruiting cancer physiatrists. Unfortunately, currently the needed army of cancer rehabilitation professionals is just not available to meet demand. Educating rehabilitation professionals through school and residency is crucial. However, schools and residency programs are also trying to quickly adapt to incorporate additional cancer curriculum. Currently, the cancer rehabilitation exposure for physiatrists varies dramatically between physiatry residency programs[15]. Because of inadequate cancer rehabilitation exposure in residency training, physiatry cancer rehabilitation fellowships have been developed to provide additional training (nine cancer physiatry fellowships in North America). The Commission on Accreditation of Rehabilitation Facilities (CARF) began a certification of cancer rehabilitation programs in 2014. Education and didactic lectures during major rehabilitation conferences have also increased dramatically. The American Congress of Rehabilitation Medicine (ACRM) has grown its Cancer Rehabilitation Networking Group and features multiple continuous tracks of cancer rehabilitation lectures during its annual conference. The American Academy of Physical Medicine & Rehabilitation (AAPM&R) has increased its cancer rehabilitation lectures and a group called the Cancer Rehabilitation Physician Consortium has become an active voice for cancer rehabilitation within physiatry. The National Institutes of Health (NIH) held its first Cancer Rehabilitation Summit in June 2015. In addition, the American Physical Therapy Association (APTA) continues to publish Rehabilitation Oncology, a quarterly cancer rehabilitation journal and recently began an educational course (with hands-on and online components) towards a Certificate of Achievement in Oncology Physical Therapy.

The annual number of cancer rehabilitation research publications has quadrupled since 1992[16]. While this is a dramatic increase, more quality research is sorely needed. Our specialty has made significant progress within oncology and rehabilitation; however, public policy makers and payers including health insurance companies have been slower to join. Cancer rehabilitation research studying the beneficial economic impacts of cancer rehabilitation on survival and cost savings are sorely needed.

Influential oncology organizations including the Commission on Cancer, the National Comprehensive Cancer Network (NCCN), the American College of Surgeons Cancer Program, and the American Cancer Society have established that rehabilitation should be a part of cancer care. However, our specialty must do more to advocate for public policy change in the American federal government and within Medicare and create clinical practice guidelines that are endorsed by major and respected cancer organizations[17].

The Future - The Era of Exercise as Cancer Medicine

Rehabilitation has traditionally been a specialty about improving the quality of life and not as focused on improving survival or saving lives as other medical specialties. There are exceptions to this: we as rehabilitation professionals treat life threatening complications on our rehabilitation unit like autonomic dysreflexia and pulmonary embolism but most of what we do is geared towards improving quality of life. Our efforts are noble, and patients are grateful for the qualitative improvement in their lives obtained through rehabilitation interventions.

However, we are beginning to see a new era in cancer rehabilitation on the horizon. Can our rehabilitation interventions make patients live longer and survive cancer? We've known that patients with better performance status are more likely to endure cancer treatment and live longer. What if we tried to improve performance status through rehabilitation interventions to improve survival? There has been an increasing body of evidence that supports that physical activity can improve survival in a number of cancer populations[18].

The Era of Exercise as Cancer Medicine is taking shape along the cancer rehabilitation continuum described by Dietz in 1980 (preventative, restorative, supportive and palliative)[1]. The area of prehabilitation has gained immense interest over the past decade. Cancer prehabilitation is similar in concept to Dietz's preventative cancer rehabilitation. Prehabilitation involves interventions (which can include exercise, nutrition, and education) aimed at improving patients' health before an anticipated upcoming major cancer intervention with the goal of improving outcomes[19]. Prehabilitation is not unique to cancer rehabilitation and had been used in other areas of rehabilitation for decades. However, it has recently garnered intense interest (in particular in sur-

Fig. 2 Breaking the Cycle of Fatigue, Inactivity and Deconditioning with Exercise

gical oncology for pancreatic cancer patients before Whipple resection). The concept of prehabilitation is not unlike a military boot camp. Just as a military boot camp prepares new military recruits for the challenges of upcoming combat, a prehabilitation program can prepare cancer patients for the challenges of upcoming cancer treatment. The concept could be applied before any major cancer intervention including chemotherapy, hematopoietic stem cell transplant or Chimeric Antigen Receptor T-cell (CAR-T) therapy.

The concept of exercise as cancer medicine could also be applied during the supportive phase of cancer rehabilitation. In other words, increasing physical activity during ongoing cancer treatment. These rehabilitation interventions could consist of ongoing physiatry follow-up with consultation with physical therapists or exercise physiologists. There are a number of reasons that improved performance status could positively impact cancer survival. The first is that performance status does impact treatment decisions. If a weak patient who is bedridden presents to his oncologists, he/she is less likely to be offered aggressive cancer treatments. The second is treatment completion rates could be better in those with better performance status. Patients with a better performance status may be able to endure the toxicities of cancer treatment more than lower performance status patients (this has been observed in the START and HELP trials)[20]. Third, death from other causes may also be lower in patients with better physical conditioning such as cardiovascular disease. Forth, there may be improved treatment response in physical fit patients and lastly, disease progression may be less in patients with superior performance status[21].

There are a number of mechanisms for the beneficial survival effects of physical activity in cancer patients including hormonal changes and reduction in inflammation. Inflammation is an area of significant academic interest. High levels of inflammation have been known to be associated with the development of a number of chronic diseases including cardiovascular disease, Type II diabetes, neurodegenerative disorders (such as Alzheimer's Disease) and cancer[22]. Ironically, cancer and cancer treatments (including chemotherapy and radiation) are pro-inflammatory. That increased inflammation may actually help cancer progress. The substantial symptom burden in cancer patients undergoing active treatment can be attributed to the increased inflammation generated by cancer and its treatment. Many cancer patients feel like they have they have the flu. Fatigue, insomnia, cognitive dysfunction, anorexia, pain, dyspnea, and nausea are common in both an influenza infection and cancer[23,24]. In both situations, inflammation is elevated due to the immune response to a systemic influenza infection or the pro-inflammatory effects of cancer and its treatments[25]. These symptoms can have a tremendous negative impact on quality of life.

Physical activity has been demonstrated in a number of studies to be anti-inflammatory. Myokines, which are anti-inflammatory cytokines produced by muscle activation, are produced with physical activity[26]. Therefore, physical activity reduces inflammation and the reduced inflammation reduces cancer related symptoms. Cancer patients with high symptom burden typically do not feel well and this can discourage physical activity. Breaking through this barrier, can be challenging for cancer rehabilitation professionals. Patient education regarding how physical activity will actually make patients feel better is key[27]. Figure 2 demonstrates steps to break the cycle of inactivity and fatigue. For example, in a patient who has been bedridden long term due to an extended intensive care unit (ICU) stay, the first step towards increasing activity is often starting to sit in a chair daily. Patients are encouraged to gradually increase the duration of chair sitting in addition to participating in physical and occupational therapy offered.

Unfortunately, patient discussions and education are infrequent. If exercise is cancer medicine, we have a responsibility to make patients aware of its benefits. Less than half of cancer survivors maintain their pre-diagnosis activity and only 21.5% of cancer survivors can recall a discussion about exercise with a healthcare professional (compared to 24% of adults without cancer). 84% of cancer survivors have indicated that they would like to discuss exercise during their cancer treatment experience[28]. More emphasis needs to be placed on physical activity during cancer treatment. When discussing exercise with patients, the guidelines most often utilized are the 2019 American Col-

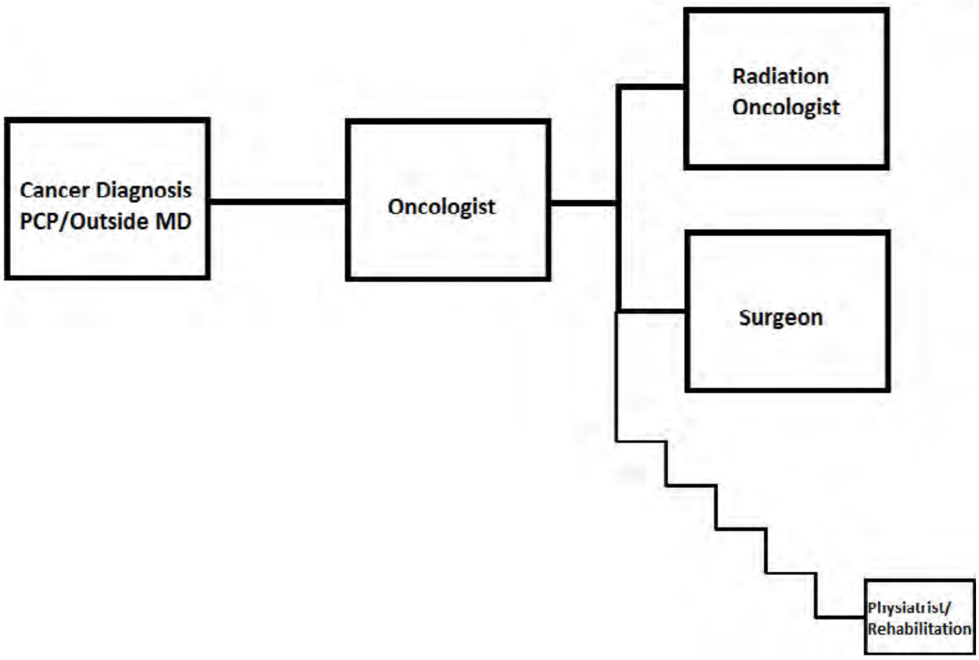
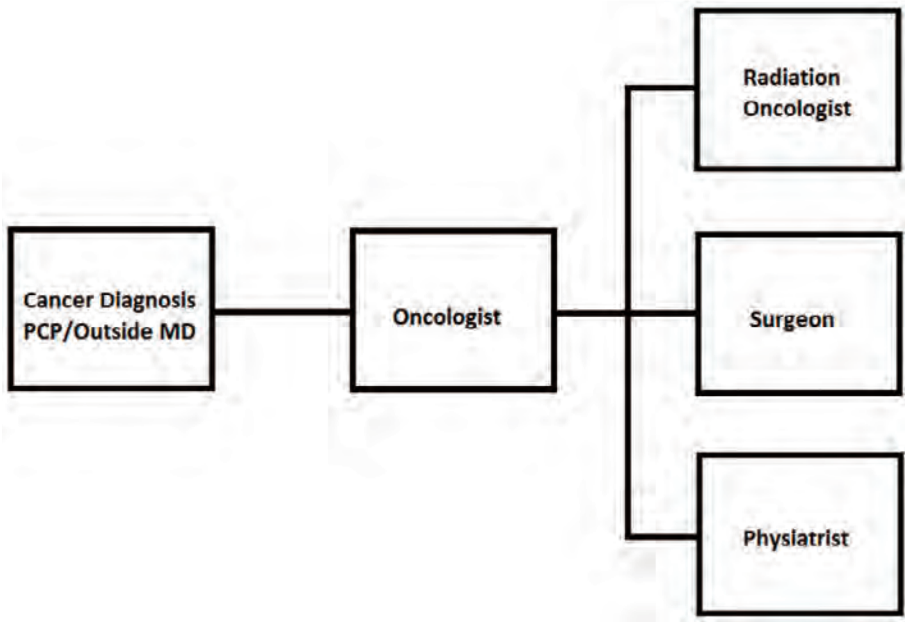


Fig. 3 The Present-Day Cancer Rehabilitation Referral Model



After cancer diagnosis, patients are referred to an oncologist. In the case of a new breast cancer diagnosis, for example, the oncologist will refer the patient to a surgeon for mastectomy, a radiation oncologist for post-mastectomy radiation, and a physiatrist for prehabilitation and monitoring of the anti-inflammatory effects of exercise.

Fig. 4 The Potential Future Cancer Rehabilitation Referral Model

lege of Sports Medicine Exercise Guidelines for Cancer Survivors which recommends at least 30 minutes of moderate intensity aerobic exercise three times per week and at least 30 minutes of strengthening exercise 2-3 times per week[29].

The guidelines are still broad and additional tailoring to a patient's capabilities is recommended. If exercise is a medicine, it should be dosed like a medicine. We can "underdose" or have inadequate amounts of exercise, but we can also "overdose" or have excessive exercise (e.g. exces-

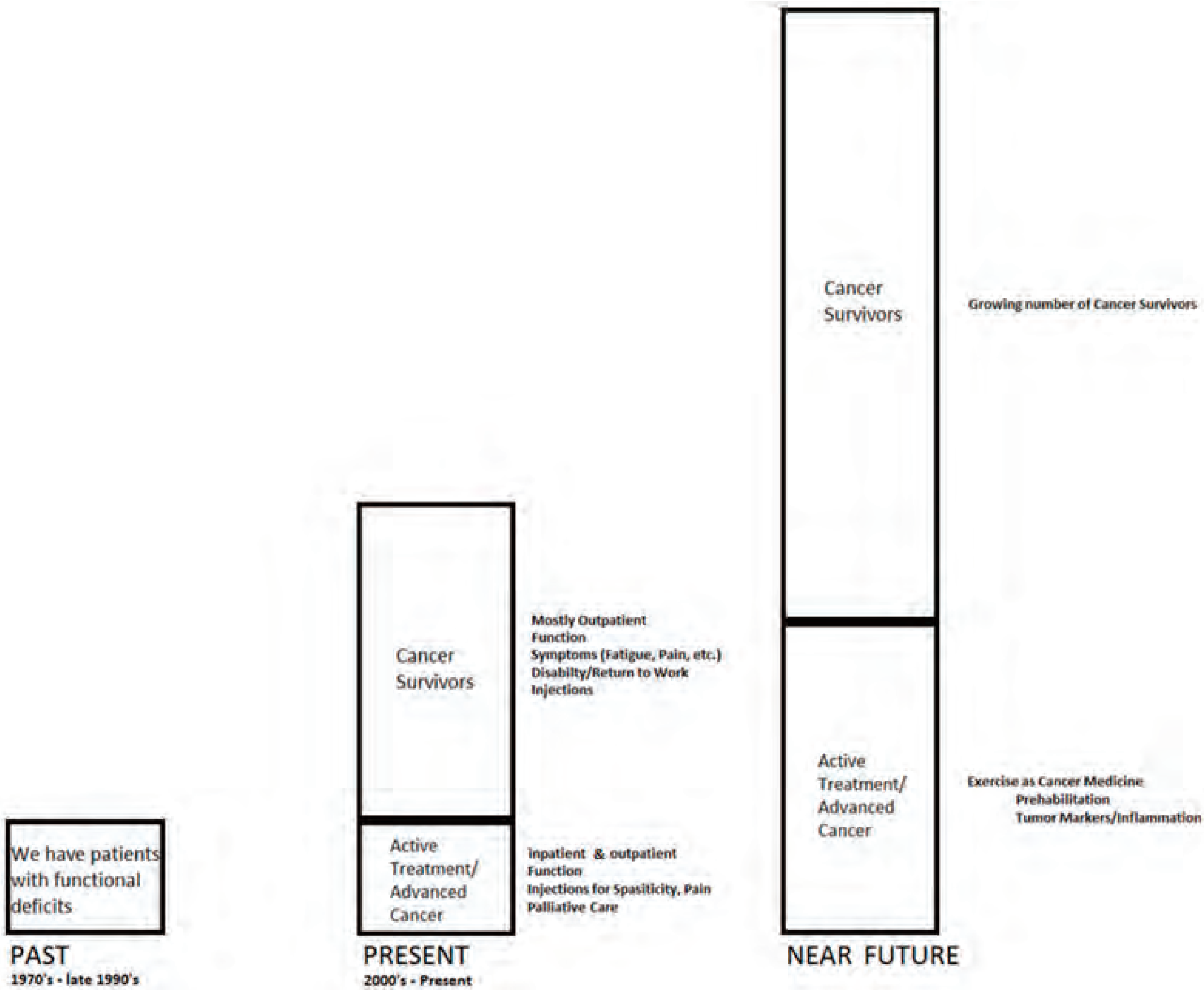


Fig. 5 The Past, Present, and Future of Cancer Rehabilitation

sive exercise may lead to too little inflammation and make already immunocompromised cancer patients more susceptible to infection). Determining the right dose is still very much an art rather than a science. We just don't know enough to really get exercise prescriptions for cancer patients down to a science. Perhaps in the future, regular blood tests of inflammatory cytokine levels could be performed. By then, more detailed knowledge of the myokine effects of aerobic vs anaerobic exercise, isotonic vs. isometric vs. isokinetic strengthening exercise, and the different muscles themselves (e.g. quadriceps vs pectoralis) would be known. In addition, the optimum anti-inflammatory anti-cancer cytokine levels would also be known. Currently, there is much that needs to be learned, but the future of this emerging area in cancer treatment is exciting.

The role of nutrition in reducing systemic inflammation in cancer treatment cannot be overlooked. Data from the Women's Health Initiative, a study of over 122,000 post-menopausal women, found a high inflammatory diet was associated with increased mortality in breast cancer patients[30,31)]. An anti-inflammatory diet has been associated with a lower risk of colorectal cancer[32)]. Patient education and promoting the intake of anti-inflammatory foods such as fruits and vegetables that are rich in anti-oxidants is important. Protein intake is often emphasized for cachectic cancer patients and typically includes encouraging the intake of meat (which can be pro-inflammatory). While ingesting anti-inflammatory foods may be beneficial, ingesting anti-inflammatory supplements or medications is more controversial. The intake of anti-oxidant anti-inflammatory vitamin supplements has not been shown to reduce cancer mortality and may increase mortality[33)]. There has also been interest in the use of anti-inflammatory medications, such as non-steroidal anti-inflammatory drugs (NSAID's), in the treatment of cancer. However, the evidence to support the use of NSAID's has been mixed[34)].

The current model for cancer rehabilitation referral has been characterized by under-referral and late referral (Fig. 3). The future cancer rehabilitation referral model may be characterized by more frequent rehabilitation referral early on in cancer treatment (Fig. 4).

Conclusion

American cancer rehabilitation has undergone tremendous growth in interest from a small obscure rehabilitation subspecialty to becoming a major component of mainstream rehabilitation. The rise of cancer survivor numbers has fueled much of the recent growth in demand for cancer rehabilitation. That trend will continue as cancer treatments continue to become increasingly effective. In addition, the new and emerging field of exercise as cancer medicine will emerge as another major driver of growth in cancer rehabilitation (Fig. 5).

Conflict of Interest: The authors declare no conflicts of interest.

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REVIEW

A Narrative Review of Alternate Gait Training Using Knee-ankle-foot Orthosis in Stroke Patients with Severe Hemiparesis

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ABSTRACT. Impairments resulting from stroke lead to persistent difficulties with walking. Subsequently, an improved walking ability is one of the highest priorities for people living with stroke. The degree to which gait can be restored after a stroke is related to both the initial impairment in walking ability and the severity of paresis of the lower extremities. However, there are some patients with severe motor paralysis and a markedly disrupted corticospinal tract who regain their gait function. Recently, several case reports have described the recovery of gait function in stroke patients with severe hemiplegia by providing alternate gait training. Multiple studies have demonstrated that gait training can induce "locomotor-like" coordinated muscle activity of paralyzed lower limbs in people with spinal cord injury. In the present review, we discuss the neural mechanisms of gait, and then we review case reports on the restoration of gait function in stroke patients with severe hemiplegia.
Key words: Knee-ankle-foot orthosis (KAFO), Stroke, Gait, Hemiparesis, Inverted pendulum

(Phys Ther Res 24: 195-203, 2021)

Globally, the estimated total number of stroke patients was 33 million in 2010[1)]. Stroke is the second leading cause of death and a major contributor to disability worldwide[2)]. Impairments resulting from stroke often lead to persistent difficulties with walking. Subsequently, an improved walking ability is one of the highest priorities for people living after a stroke[3)]. In addition, walking ability has important health implications in providing protective effects against secondary complications that are common after a stroke, such as heart disease or osteoporosis[3)].

The degree to which gait can be restored after a stroke is related to both the initial impairment in walking ability and the severity of paresis of the lower extremities[4-8)]. Wandel et al.[7)] reported that only 21% of stroke survivors with lower limb paralysis regained the ability to walk. In other words, there is no doubt that severe paralysis of the lower limbs and muscle weakness are factors closely related to the ability to walk. However, there are patients with severe motor paralysis and a markedly disrupted corticospinal tract who regained their gait function[9,10)]. In addition, Sivaramakrishnan and Madhavan[11)] reported that there was no association between transcranial magnetic stimulation-induced tibialis anterior and rectus femoris motor evoked potentials, which are neurophysiological parameters of lower limb function, and walking speeds. Indeed, many patients have regained gait function even after experiencing severe hemiparesis[12-16)]. Recently, several case reports[12-14)] described the restoration of gait function in stroke patients with severe hemiplegia after the provision of alternate gait training (AGT). Multiple studies have demonstrated that gait training can induce "locomotor-like" coordinated muscle activity of the paralyzed lower limbs in people with spinal cord injury[17-19)].

In the present narrative review, we will discuss the

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neural mechanisms of gait, and then review case reports on the restoration of gait function in stroke patients with severe hemiplegia.

Alternative Gait Training Using Knee-ankle-foot Orthosis (KAFO) for Stroke Patients with Severe Hemiplegia

1) Neural mechanisms of gait, and ideas for restoring gait in stroke patients with severe hemiplegia.

Decerebrate cats, with an absence of the forebrain, can walk, trot and gallop. When decerebration occurs at precollicular-postmammillary level, the cat initiates locomotion by electrical or chemical stimulation applied to the mesencephalic or midbrain locomotor region[20-23]. To date, three locomotor regions have been identified in animals: the midbrain locomotor region in the mesopontine tegmentum, the subthalamic locomotor region, and the cerebellar locomotor region in the mid-part of the cerebellum[24]. Human imaging has demonstrated that the organization of these supraspinal locomotor centers was preserved during the transition to bipedal locomotion in humans[25].

The regulation of human upright posture and locomotion is based on the finely tuned coordination of muscle activation between the two legs[17]. For example, when a disturbance causes an initiation or prolongation of the swing phase on one side, the stance phase of the contralateral leg compensates accordingly, in both human infants and cats[17]. Unilateral leg displacement during stance and gait evoke a bilateral response pattern with similar short (i.e., spinal) onset latencies on both sides[17]. This interlimb coordination is necessary to keep the body's center of gravity over the feet[17,26].

In cats, there are two main sources of afferent input that lead to rhythm entrainment and/or resetting of locomotor activity[17]. Such input can either block or induce switching between the alternating flexor and extensor locomotor bursts. One afferent input source is related to hip position, and the other is related to load[17,27]. For example, for the initiation of the swing phase, the significance of hip position was essential for human infant stepping, similarly to what was described for the cat with chronic spinal cord transection[17]. Furthermore, in previous studies, load receptor input for the regulation of stance and gait was important for cats[28] and humans[29]. It was assumed that this effect was mediated by group Ib afferent input[30].

Further studies have indicated that even in completely paraplegic patients, a locomotor pattern can be evoked by bilateral alternating stepping[31,32]. In these studies, load receptor input was essential for leg muscle activation during stepping movements[17]. Habli and Dietz[19] found that load- and hip-joint- related afferent input is of crucial importance during locomotor training, as it leads to appropriate leg muscle activation, and thus increases the efficacy of rehabilitative training. According to previous reports, gait function is influenced by the following: the control system of voluntary function, such as the corticospinal tract; the control system of involuntary motor function, such as the mesencephalic-reticulospinal neuron; and the central pattern generator in the spinal cord[33-35].

In patients with spinal cord injury, alternate stepping movements with afferent input from load receptors induce a patterned leg muscle activation similar to that induced in healthy subjects[17,18]. In other words, these inputs induce lower limb muscle activity in patients with difficulties in voluntary lower limb movement. Therefore, we hypothesized that earlier improvement of gait function could be achieved by providing an alternate gait pattern for patients with severe hemiplegia, because it facilitates the afferent load and proprioceptive receptor inputs. In particular, afferent information from both bilateral hip joints seems to be essential for the generation of locomotor-patterned leg muscle activation; however, unilateral stepping movements lead to inadequate leg muscle activation[17,18]. Indeed, patients with severe hemiparesis commonly have poor lower limb stability on the paretic side and difficulty in walking without lower limb support. To achieve good stability, patients benefit from strong external support, such as a KAFO, which provides both stability and enables the ankle to perform alternate stepping. We hypothesized that patients may regain gait function earlier if gait training is implemented using a KAFO. We defined AGT as walking with alternate large hip flexion and extension when using a KAFO with an oil damper ankle hinge.

2) Technique for providing AGT using a KAFO with an oil damper ankle hinge

A KAFO for use in AGT has a ring lock hinge for the knee joint and an oil damper hinge for the ankle joint[36,37]. (Fig. 1) The hinged oil damper can resist plantarflexion during swing, and produce plantarflexion after heel contact[36-38]. Therefore, the loading response period is properly constructed because the first rocker function is maintained[36-38]. Moreover, using a KAFO with an oil damper ankle hinge has other merits as it matches the inverted pendulum movement that is observed in normal walking (Fig. 2A, B) because the hinged oil damper does not hinder dorsiflexion[36-38]. An inverted pendulum model of the stance leg is crucial for effective, economical, and stable ambulation in biomechanical features[39]. AGT is provided by a physical therapist (Fig. 2C), and if AGT cannot be performed with therapists providing external assistance, step training is utilized for each of the affected and unaffected lower limbs. AGT is then started shortly after step training. After resolution of the problem of knee instability, an ankle-foot orthosis (AFO) is used. Before transitioning from KAFO to AFO (known as "cutting down"), we confirm that subjects can walk with an alternate gait pattern with AFO alone.

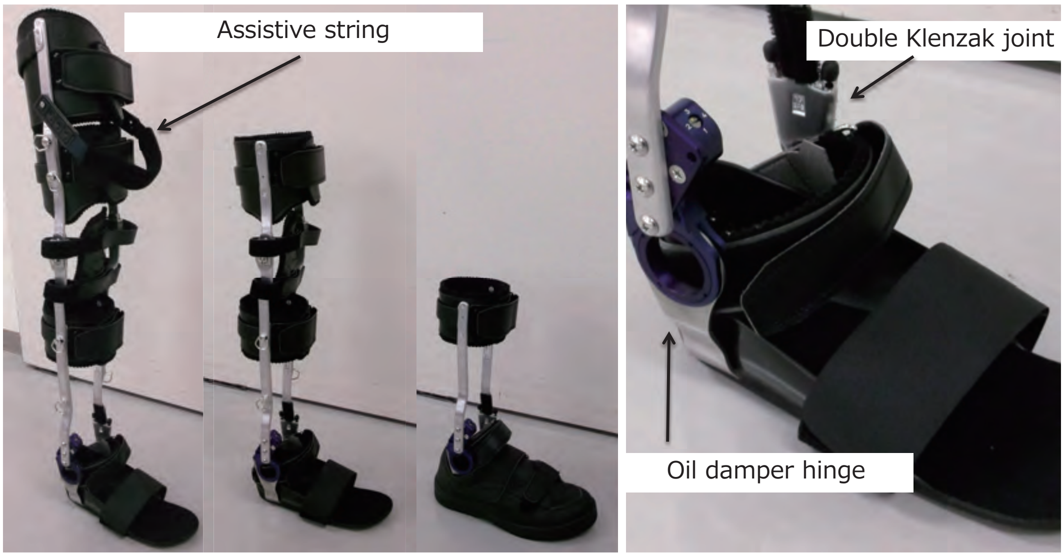

Fig. 1. A knee-ankle-foot orthosis with an oil damper ankle hinge.
The hinged oil damper can resist plantarflexion during swing and promote adequate plantarflexion after heel contact.

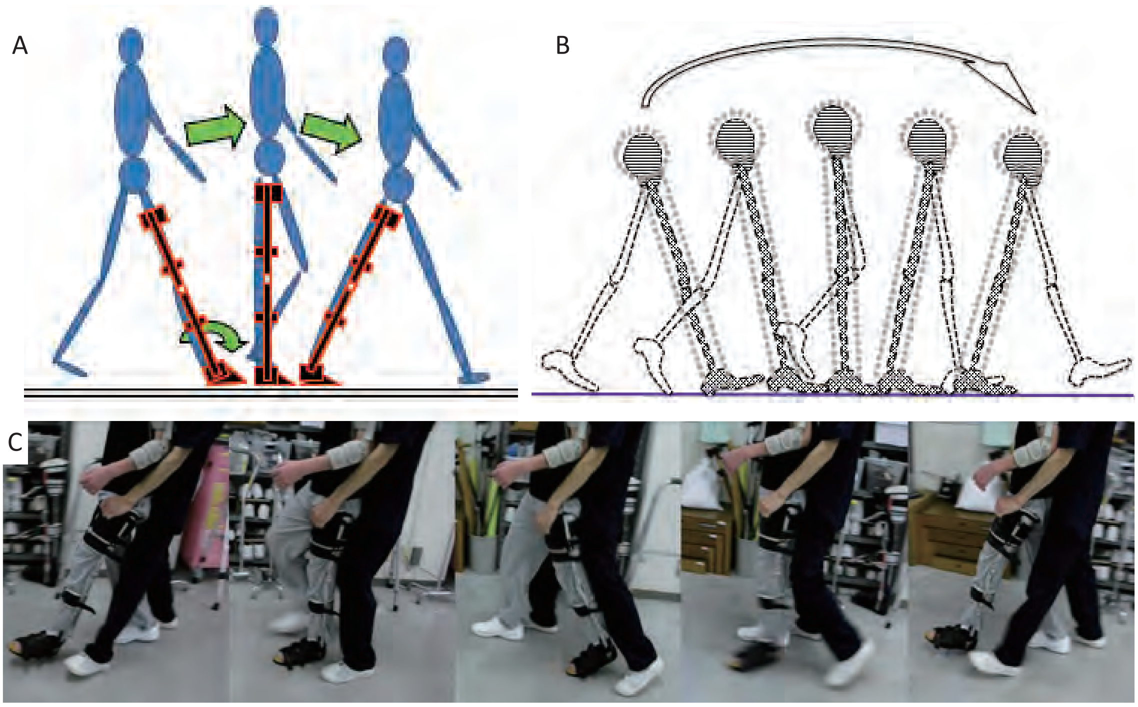

Fig. 2. Alternate gait pattern using knee-ankle-foot orthosis with an oil damper ankle hinge that matches the inverted pendulum model.
A: Alternate gait pattern using knee-ankle-foot orthosis with an oil damper ankle hinge
B: The inverted pendulum model
C: Alternate gait pattern using knee-ankle-foot orthosis with an oil damper ankle hinge with external assist by physiotherapist

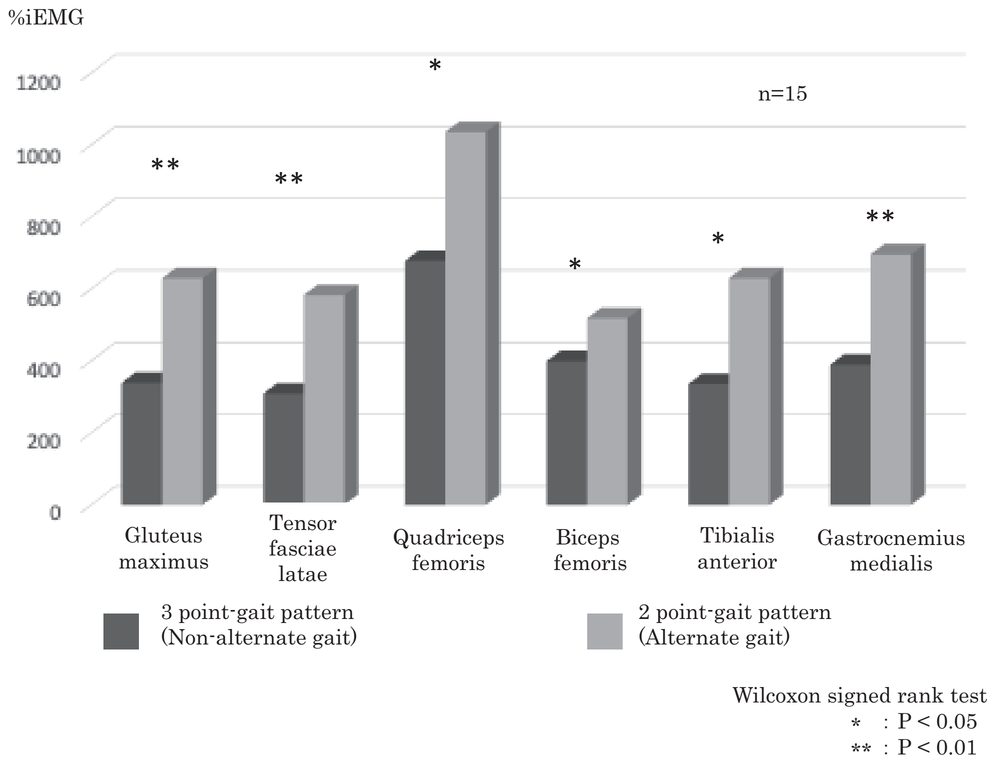

Fig. 3. Electromyography results

Integrated electromyography revealed that all six muscles had more increased muscle activity in the affected side lower limb during the stance phase of the 2-point gait pattern than of the 3-point gait pattern.

A Comparative Study of the Effect of AGT Using a KAFO

1) Muscle activity during AGT; the differences in lower leg muscle activity between 2-point gait (AGT pattern) and the conventional 3-point gait patterns (defined as walking with a stride length of the non-affected leg not exceeding that of the affected leg).

We have investigated[40] differences in lower limb muscle activity during two gait patterns—2-point gait without a cane and 3-point gait with a cane—in 12 stroke patients. All 12 patients required KAFOs due to severe hemiparesis when walking. When performing the 2-point gait training, the patients would step the unaffected foot in front of the affected foot with assistance provided by a physical therapist. In contrast, when carrying out the 3-point gait training, patients would step the unaffected foot to the lateral side of the affected foot using the cane with slight assistance by the physical therapist. The muscle activities were measured by electromyogram in the tibialis anterior, gastrocnemius medialis, biceps femoris, quadriceps femoris, gluteus maximus, and tensor fasciae latae muscles of the affected lower limb. Integrated electromyography revealed that all six muscles had increased muscle activity during the stance phase of the 2-point gait pattern than of the 3-point gait pattern (Fig. 3). In severe hemiparetic patients, 2-point gait training may be more effective in facilitating muscle activity of the paretic lower limb than 3-point gait training.

2) AGT with a KAFO to support earlier walking independence

We have previously reported[41] the effects of physical therapy with an early prescription of KAFO during the course of recovery of walking and stair climbing functions evaluated using Functional Independence Measures (FIM). Eight patients with post-stroke hemiparesis, who had been prescribed a KAFO and had received AGT during their acute hospital stays (the KAFO group), and 20 patients who had not been prescribed a KAFO (the non-KAFO group), were recruited. All patients in the non-KAFO group had similar characteristics to those in the KAFO group on admission; age, length of hospitalization, severity of hemiparesis, duration between stroke onset and admission to the convalescent rehabilitation ward, walking function, and stair climbing function. We compared the time course of recovery of walking and stair climbing functions between the KAFO and non-KAFO groups by using FIM at admission, midpoint of the hospital stay, and discharge from the rehabilitation ward. FIM for walking and stair climbing gradually improved in both groups. However, walking function improved earlier in the KAFO group than in the non-KAFO group (Fig. 4A). Furthermore, the stair climbing function at

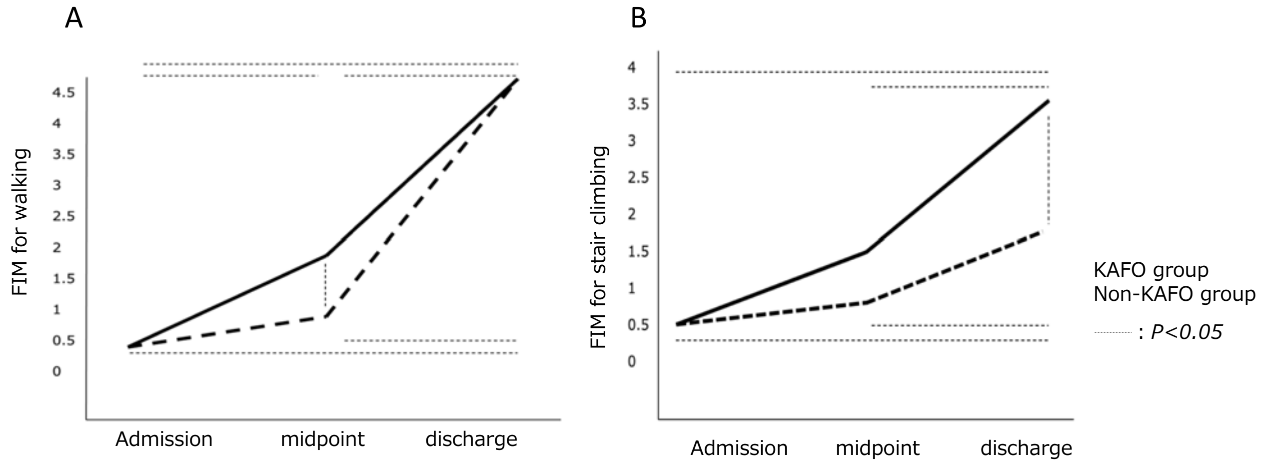

Fig. 4. The time course of recovery of walking and stair climbing functions in the KAFO and non-KAFO groups evaluated using FIM at admission, midpoint of hospital stay, and discharge.

discharge was significantly better in the KAFO group than in the non-KAFO group (Fig. 4B). Therefore, physical therapy using an early-prescribed KAFO might be effective for improving walking and stair climbing functions in post-stroke patients with severe hemiparesis.

Case Reports

1) Gait restoration in a patient who required full assistance to walk at 6 months after stroke onset

Kadowaki et al.[12] tried to restore the gait function in a patient with severe stroke hemiparesis who required full assistance to walk 6 months after stroke onset. This patient was a woman in her 50s who had suffered subarachnoid and intracerebral hemorrhages. Her Brunnstrom motor function was stage II in the upper limbs and fingers, and II-III in the lower limbs.

The patient underwent physical therapy in the Kaifukuki rehabilitation (convalescent) ward and received gait training using a soft knee brace and a soft bandage between 75 and 176 days of stroke onset. At six months post-stroke, any improvement in motor paralysis was unlikely. Nevertheless, we assumed that her gait function could be improved if lower limb muscle activity was induced by providing AGT.

Initially, we provided AGT using a soft knee orthosis and an AFO. However, the inverted pendulum movement could not be constructed because of the bent knee of the affected side during the stance phase. We therefore decided to make a KAFO for the patient. Figure 5A shows the gait pattern at 3 weeks after admission. Figure 5B shows a trial transition from the KAFO to the AFO. In this trial, the knee joint was observed as too bent in the AFO, we this continued gait training using the KAFO. Figure 5C shows the patient's gait at discharge, and Figure 5D shows the gait at home following hospital discharge. The patient achieved remarkable recovery with AGT; from being unable to walk at 6 months after stroke onset to eventually being able to walk independently.

2) Gait reconstruction in a patient with complete damage to the corticospinal tract.

We (Tsujimoto et al.[13]) previously reported a case of gait reconstruction in a young patient with large right frontal lobe cortical hemorrhage due to a ruptured arteriovenous malformation (AVM). The lesion extended from the central precentral gyrus to the subcortical region of the postcentral gyrus (Fig. 6A). It was not possible to visualize the corticospinal and sensory tracts on diffusion tensor tractography (Fig. 6B). The patient in fact showed severe hemiparesis and severe sensory disturbance. The patient's functional ambulation category (FAC) went from 5 (fully independent) before the AVM ruptured to FAC 0 (unable to walk).

The patient's knee was excessively bent and showed an extension thrust pattern (Fig. 7A). For restoration of his gait function, a KAFO with the oil damper ankle hinge was used, and AGT was provided. Initially, the patient was assisted by a physiotherapist (Fig. 7B), with the assistance gradually reduced (Fig. 7C). A previous report[9] stated that gait reconstruction is possible even when the corticospinal tract is completely damaged. In this young patient, physical therapy was started on Day 34 after the AVM rupture, and his walking ability gradually improved, reaching 58.8 m/min as a maximum walking speed on Day 113 (Fig. 7D). At the same time, the KAFO was switched over to an AFO, and his gait training continued. After transfer to a convalescent hospital, the patient was eventually able to walk independently both indoors and outdoors.

Conclusions

In the current narrative review, we introduced AGT

Fig. 5. The restoration of gait function in a stroke patient with severe hemiparesis who required external assistance for gait 6 months after stroke onset.
1. Initial contact; 2. Loading response; 3. Mid stance; 4. Terminal stance

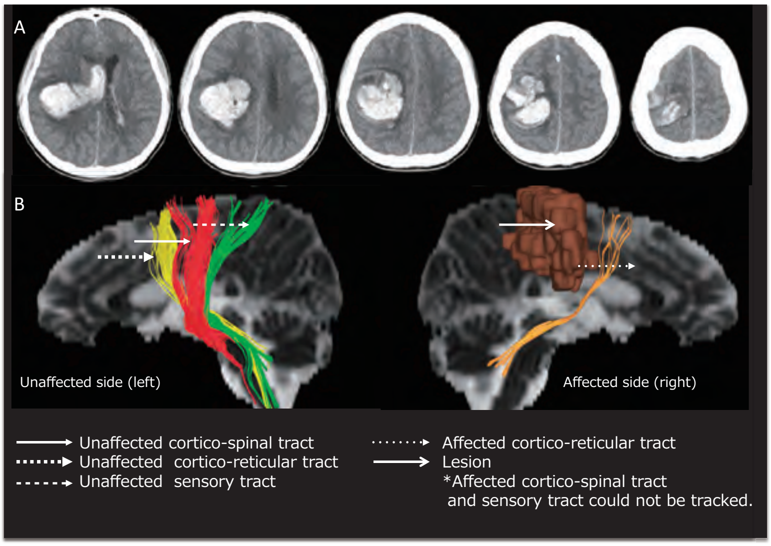

Fig. 6. Brain imaging of intracranial hemorrhage due to ruptured arteriovenous malformation.
A: Computed tomography
B: Diffusion tensor tractography

A
B
C
D

Fig. 7. The restoration of gait function in a stroke patient with severe hemiparesis with complete disconnection of the corticospinal tract and sensory tract on the affected side.

using a KAFO for restoration of gait function in stroke patients with severe hemiparesis. We believe that AGT with a KAFO can benefit stroke patients with severe hemiparesis as they may achieve earlier improvements in gait ability. Neurological physical therapists should be encouraged to use this approach for restoration of gait function in such patients. However, the effect of AGT is not fully elucidated, and there are very few reports on this subject, all of which are written in Japanese. Further study is required to validate the effect of AGT with a KAFO.

Conflict of Interest: The authors declare that there are no conflicts of interest.

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PHYSICAL THERAPY RESEARCH

SCIENTIFIC RESEARCH ARTICLE

Walking Attainment in Very Low Birth Weight Infants in Japan

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ABSTRACT. Objective: To clarify the corrected age of walking attainment in very low birth weight infants by birth weight and gestational age, and determine perinatal factors affecting the delay in walking attainment. Method: This was a longitudinal study. We investigated walking attainment and perinatal factors in 145 very low birth weight infants without neurological abnormalities (mean birth weight 1019.3 ± 299.7 g, gestational age 29.0 ± 2.9 weeks). The study infants were stratified by birth weight (group A: <1,000 g, group B: 1,000 g≤, <1,500 g) and gestational age (group I: <28 weeks, group II: 28 weeks≤, <37 weeks) and were compared using unpaired t-tests. Furthermore, we examined the perinatal factors that affect the delay in walking attainment using multiple regression analysis. Results: Of the walking attainment, infants in Group A were older than those in Group B (50th percentile, 15.8 vs. 14.7 months). Infants in Group I were older than those in Group II (50th percentile, 16.0 vs. 14.8 months). Using multiple regression analysis with walking attainment age as the dependent variable, the duration of mechanical ventilation was found to be significantly related. Conclusion: Very low birth weight infants with light weight and short gestational age have delayed walking attainment, and longer duration of mechanical ventilation increases the risk of delay.

Key words: Preterm infants, Very low birth weight, Motor milestone, Walking

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Due to advances in neonatal care, the mortality rate of newborns has decreased in recent years[1,2)]. On the other hand, the number of preterm births has been increasing[3,4)]. In particular, the number of very low birth weight (VLBW) infants, weighing less than 1,500 g, has remarkably increased, and these infants have poor neurological outcomes[5,6)]. Moreover, even if no neurological abnormality is observed, VLBW infants have delayed motor development relative to that in term infants[7-9)]; therefore, careful evaluation and observation are necessary.

In motor development, walking is the most significant motor milestone in terms of acquiring free locomotion and social participation in a wider area. Furthermore, walking is the most perceptible index of motor development for the guardians of infants. Several studies have shown the timing of walking attainment in preterm infants as well as term infants[10-13)]. The factors affecting walking attainment in preterm infants are low birth weight[14)] and the presence or absence of bronchopulmonary dysplasia (BPD)[13)].

Various studies have investigated the age of walking attainment in preterm infants; however, there are few reports on preterm infants in Japan. Therefore, it is important to report the walking attainment of Japanese VLBW infants. Furthermore, studies that have examined the influence of clinical data on the age of motor development are generally limited to relatively scarce medical conditions such as BPD[13)].

The purpose of this study was to reveal the corrected age of walking attainment in VLBW infants by birth weight and gestational age, and to determine the perinatal factors that affect the delay in walking attainment.

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Methods

Study design and population

This longitudinal study included all VLBW infants born at Tokyo Women's Medical University Hospital from April 2010 to March 2017. The inclusion criteria were as follows: (i) birth weight of <1500 g; and (ii) gestational age of <37 weeks. The exclusion criteria were as follows: (i) diagnosed with chromosomal abnormalities, neurological disorders, or malformation syndromes; (ii) diagnosed with cerebral palsy; (iii) died in the hospital; and (iv) infants who were not followed up as an outpatient due to hospital transfer or relocation. The diagnosis of cerebral palsy was made by a doctor based on the definition of cerebral palsy by the age of 2 years[15].

To reveal the age of walking attainment in VLBW infants by birth weight and gestational age, the infants were classified as follows: the study infants were divided into group A (birth weight < 1,000 g) or group B (1,000 g ≦ birth weight < 1,500 g). The infants were also divided into group I (gestational age < 28 weeks) or group II (28 weeks ≤ gestational age < 37 weeks).

Procedure

Perinatal factors during neonatal intensive care unit (NICU) hospitalization and walking attainment ages were investigated retrospectively from medical records. Perinatal data were collected and included maternal age, multiple pregnancy, sex, gestational age, birth weight, head circumference at birth, small for gestational age (SGA), Apgar scores, cranial ultrasound findings (grading of intraventricular hemorrhage (IVH)[16] and periventricular echo densities (PVE)[17]), presence or absence of periventricular leukomalacia (PVL), grading of retinopathy of prematurity (ROP)[18], laser photocoagulation, duration of mechanical ventilation, presence or absence of respiratory distress syndrome (RDS), presence or absence of chronic lung disease (CLD) 28 which is defined as requiring oxygen 28 days after birth, home oxygen therapy, presence or absence of septicemia, presence or absence of symptomatic patent ductus arteriosus, patent ductus arteriosus ligation, presence or absence of late-onset circulatory collapse, and length of hospital stay.

In our hospital, VLBW infants are followed up by a physical therapist in a regular development outpatient department until they can walk. Guardians of infants were asked in a developmental outpatient department to monitor and record the date when the infant began walking for ten successive steps without support in a mother and child health handbook. After that, at the next outpatient development session, the physical therapist, who engaged with the infants from the NICU to the outpatient department, confirmed the gait status, and the walking attainment date was converted to the corrected age. The definition of walking attainment was based on the description of Denver II[19] and was described to guardians as the day when the infant walked for 10 or more steps without support.

Statistical methods

We used unpaired t-tests to compare perinatal factors between the two groups, including gestational age, birth weight, head circumference at birth, duration of mechanical ventilation, and length of hospital stay. The chi-square test was used for multiple pregnancy, sex, SGA, PVL, laser photocoagulation, RDS, CLD 28, home oxygen therapy, septicemia, symptomatic patent ductus arteriosus, patent ductus arteriosus ligation, and late-onset circulatory collapse, while the Mann-Whitney U test was used to compare the Apgar scores, IVH, PVE, and ROP between the two groups. The Mann-Whitney U test was used to compare the timing of walking attainment age between the two groups by birth weight and gestational age. The distributions of the corrected age of walking attainment were estimated for each of the two groups using the Kaplan-Meier method and were compared using the log-rank test.

In addition, multiple regression analysis was used to reveal the perinatal factors that affect the delay of walking attainment in VLBW infants. First, Pearson's correlation coefficient or Spearman's rank correlation coefficient was used to determine the relationship between the walking attainment age and perinatal factors. In multiple regression analysis, the object variable was the walking attainment age, and the explanatory variables were the perinatal factors that significantly correlated with the walking attainment age according to the correlation analysis. The perinatal factors were entered simultaneously using the forced entry method.

All analyses were performed using IBM SPSS Statistics for Windows, version 23 (IBM Corp., Armonk, NY, USA). The significance level was set at $p<0.05$ for all analyses.

Ethics statement

This study was approved by the Tokyo Women's Medical University Ethics Committee (approval number: 5408). In addition, the disclosure of research information involved an opt-out system, and a veto right was guaranteed. For the management of personal information, we anonymized the data and ensured that individual patients could not be identified.

Results

Study population

There were 230 infants who weighed less than 1,500 g and had a gestational age of <37 weeks admitted during the study period from April 2010 to March 2017. Eleven infants were diagnosed with chromosomal abnormalities,

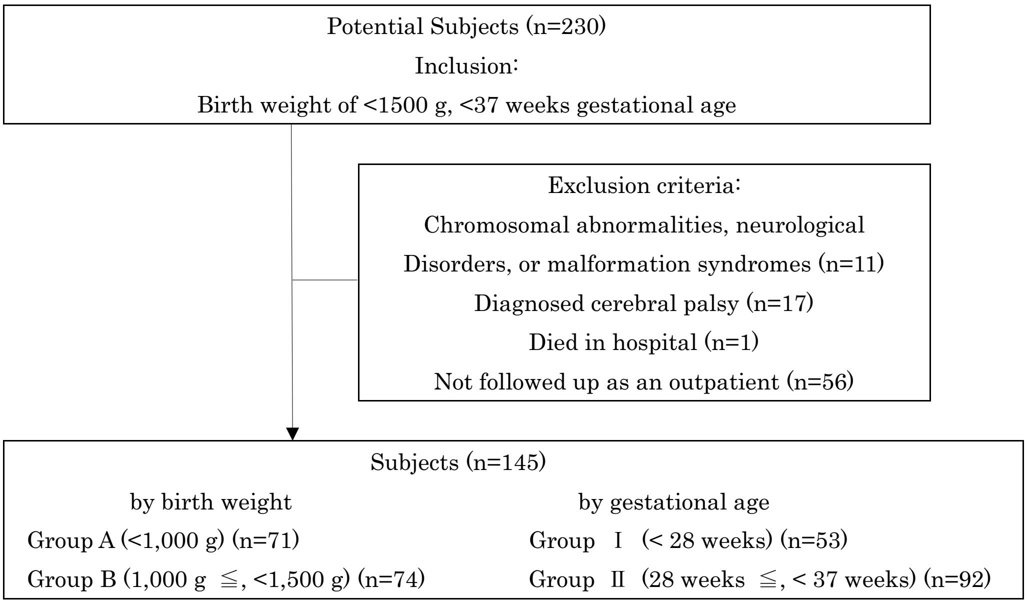

Fig. 1. Patient flow chart detailing the infants included in the study

neurological disorders, or malformation syndromes, 17 were diagnosed with cerebral palsy, 1 infant died in the hospital, and 56 infants were not followed-up as outpatients due to a hospital transfer or relocation. Thus, the analyzed population included 145 infants. The study infants were divided into group A (n=71) or group B (n=74) by birth weight. The infants were also divided into group I (n=53) or group II (n=92) by gestational age (Fig. 1). The perinatal factors of each group are shown in Table 1.

Corrected age of walking attainment in VLBW infants

Table 2 shows the percentile values at the time of walking attainment by birth weight and gestational age. The 50th percentile value by birth weight was 15.8 months for group A and 14.7 months for group B, showing a significant difference between the two groups (p=0.003). The 50 th percentile by gestational age was 16.0 months in group I and 14.8 months in group II, showing a significant difference between the two groups (p<0.001).

Figure 2 shows Kaplan-Meier function plots of walking attainment age distribution by birth weights and by gestational age. Figure 2 shows that group A, comprising infants with a lower birth weight, showed later walking attainment than did group B (p=0.002). Similarly, Group I, comprising infants with a shorter gestational age, showed later walking attainment than did group II (p<0.001).

Perinatal factors associated with delayed walking attainment age in VLBW infants

As a result of the correlation analysis, the perinatal factors that were found to have a significant correlation with the walking attainment age were birth weight (r =−0.364, p<0.001), gestational age (r=−0.346, p<0.001), head circumference at birth (r=−0.386, p<0.001), 1-minute Apgar score (r=−0.244, p=0.003), 5-minute Apgar score (r =−0.282, p=0.001), IVH (r=0.293, p<0.001), ROP (R= 0.271, p=0.028), laser photocoagulation (r=0.241, p= 0.004), duration of mechanical ventilation (r=0.422, p< 0.001), CLD28 (r=0.189, p=0.023), home oxygen therapy (r=0.194, p=0.02) and sepsis (r=0.198, p=0.017) (Table 3).

Using multiple regression analysis with walking attainment age as the dependent variable, the duration of mechanical ventilation was found to be significantly related (p =0.040) (Table 4). The variance inflation factor of all independent variables was less than 10, so no evidence of predictor multicollinearity was found.

Discussion

In this study, we examined the walking attainment age in VLBW infants in relation to birth weight and gestational age, and clarified the perinatal factors that delay walking attainment. The 50th percentile value for walking attainment age in VLBW infants was 14.7 months for group B (1,000 g ≤ birth weight < 1,500 g) and 14.8 months for group II (28 weeks ≤ gestational age < 37 weeks). On the other hand, the 50th percentile for walking attainment age was 15.8 months for group A (birth weight < 1,000 g) and 16.0 months for group I (gestational age < 28 weeks). Therefore, it was shown that walking attainment was more delayed with decreasing birth weight and gestational period. Our results support a previous study demonstrating that acquisition of gross motor skills in VLBW infants is more delayed as the birth weight and gestational period decrease[20,21].

Marín Gabriel et al.[20] reported that the 50th percentile value of walking attainment age for VLBW infants was 14-15 months at a birth weight less than 1000 g, and 13 months at a birth weight between 1,000 and 1,500 g. Bu-

Table 1. Perinatal factors of the subjects by birth weight and gestational age

		Birth weight			Gestational age		
	(n=145)	Group A (<1,000 g)	Group B (1,000 g ≦ , <1,500 g)	p value	Group I (< 28 weeks)	Group II (28 weeks ≦ , < 37 weeks)	p value
		(n=71)	(n=74)		(n=53)	(n=92)	
Multiple pregnancy, n (%)	26 (17.9)	14 (19.7)	12 (16.2)	0.58	11 (20.7)	15 (16.3)	0.50
Gender				0.65			0.13
Male, n (%)	81 (55.8)	41 (57.7)	40 (54)		34 (64.1)	47 (51)	
Female, n (%)	64 (44.1)	30 (42.2)	34 (45.9)		19 (35.8)	45 (48.9)	
Birth weight, g, mean (range, SD)	1019.3 (388-1496, 299.7)	756.5 (388-999, 165.7)	1271.5 (1006-1496, 139.1)	<0.001	754.3 (388-1149, 202.6)	1172 (612-1496, 233)	<0.001
Gestational age, weeks, mean (range, SD)	29 (22.5-36.5, 2.9)	27.1 (22.5-33.5, 2.5)	30.9 (26.8-36.5, 2)	<0.001	25.9 (22.5-27.8, 1.5)	30.9 (28-36.5, 1.8)	<0.001
Small for gestational age, n (%)	63 (43.4)	36 (50.7)	27 (36.4)	0.08	15 (28.3)	48 (52.1)	0.01
Head circumference at birth, cm, mean (range, SD)	25 (18.8-29.6, 2.7)	23 (18.8-26.6, 2)	27.2 (23-29.6, 1.3)	<0.001	22.5 (18.8-26, 1.9)	26.6 (22.9-29.6, 1.7)	<0.001
1-minute Apgar score, mean (range, SD)	5.1 (1-9, 2.3)	4 (1-9, 2.2)	6.1 (1-9, 2)	<0.001	3.6 (1-7, 1.9)	6 (1-9, 2.1)	<0.001
5-minute Apgar score, mean (range, SD)	6.8 (1-9, 1.8)	5.9 (1-9, 1.9)	7.6 (3-9, 1.4)	<0.001	5.5 (1-8, 1.7)	7.5 (3-9, 1.4)	<0.001
Intraventricular hemorrhage				0.004			0.001
normal, n (%)	121 (83.4)	52 (73.2)	69 (93.2)		37 (69.8)	84 (91.3)	
GradeI-II, n (%)	19 (13.1)	14 (19.7)	5 (6.7)		12 (22.6)	7 (7.6)	
GradeIII-IV, n (%)	3 (2)	3 (4.2)	0 (0)		3 (5.6)	0 (0)	
Periventricular echo densities				0.25			0.47
normal, n (%)	90 (62)	47 (66.1)	43 (58.1)		35 (66)	55 (59.7)	
GradeI, n (%)	37 (25.5)	14 (19.7)	23 (31)		11 (20.7)	26 (28.2)	
GradeII-III, n (%)	16 (11)	8 (11.2)	8 (10.8)		6 (11.3)	10 (10.8)	
Periventricular leukomalacia, n (%)	0 (0)	0 (0)	0 (0)	-	0 (0)	0 (0)	-
Retinopathy of prematurity				<0.001			<0.001
normal, n (%)	73 (50.3)	26 (36.6)	47 (63.5)		14 (26.4)	59 (64.1)	
GradeI-II, n (%)	47 (32.4)	24 (33.8)	23 (31)		18 (33.9)	29 (31.5)	
GradeIII-V, n (%)	25 (17.2)	21 (29.5)	4 (5.4)		21 (39.6)	4 (4.3)	
Laser photocoagulation, n (%)	35 (24.1)	31 (43.6)	4 (5.4)	<0.001	28 (52.8)	7 (7.6)	<0.001
Days of mechanical ventilation, mean (range, SD)	17.8 (0-90, 22.6)	31.2 (0-90, 25.3)	4.9 (0-34, 7.1)	<0.001	38.5 (1-90, 24.4)	5.9 (0-52, 8.6)	<0.001
Respiratory distress syndrome, n (%)	66 (45.5)	45 (63.3)	21 (28.3)	<0.001	40 (75.4)	26 (28.2)	<0.001
Chronic lung disease 28, n (%)	85 (58.6)	63 (88.7)	22 (29.7)	<0.001	52 (98.1)	33 (35.8)	<0.001
Home oxygen therapy, n (%)	2 (1.3)	1.3 (2)	2 (2.8)	0.15	2 (3.7)	0 (0)	0.06
Sepsis, n (%)	31 (21.3)	20 (28.1)	11 (14.8)	0.05	19 (35.8)	12 (13)	0.001
Symptomatic patent ductus arteriosus, n (%)	15 (10.3)	10 (14)	5 (6.7)	0.15	10 (18.8)	5 (5.4)	0.01
Patent ductus arteriosus ligation, n (%)	3 (2)	3 (4.2)	0 (0)	0.07	3 (5.6)	0 (0)	0.02
Late-onset circulatory collapse, n (%)	19 (13.1)	14 (19.7)	5 (6.7)	0.02	13 (24.5)	6 (6.5)	0.01
Length of hospital stay, mean (range, SD)	107.7 (41-484, 53)	137.2 (79-484, 55.8)	79.3 (41-218, 29.8)	<0.001	148.8 (83-484, 59.6)	84 (41-218, 29.3)	<0.001

SD: standard deviation

Table 2. Walking attainment time in very low birth weight infants by birth weight and gestational age (months)

	birth weight	n	10th percentile	50th percentile	90th percentile
Group A	<1,000 g	71	12.9	15.8	19.3
Group B	1,000 g ≦ , <1,500 g	74	12.5	14.7	17.9

	gestational age	n	10th percentile	50th percentile	90th percentile
Group I	< 28 weeks	53	13.7	16	19.5
Group II	28 weeks ≦ , < 37 weeks	92	12.5	14.8	17.3

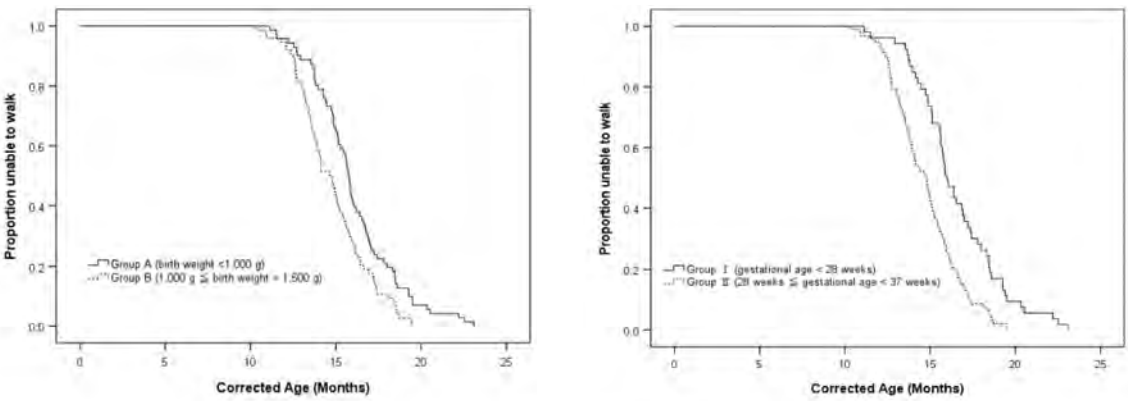

Fig. 2. Kaplan-Meier plots of corrected age of walking attainment for VLBW infants by birth weight and gestational age

Table 3. Correction analysis between walking attainment age and perinatal factors

	Correlation coefficient (r)	p value
Multiple pregnancy	-0.145	0.083
Gender	0.077	0.356
Birth weight	-0.364	<0.001
Gestational age	-0.346	<0.001
Small for gestational age	0.037	0.659
Head circumference at birth	-0.386	<0.001
1-minute Apgar score	-0.244	0.003
5-minute Apgar score	-0.282	0.001
Intraventricular hemorrhage	0.293	<0.001
Periventricular echo densities	-0.088	0.292
Periventricular leukomalacia	0	
Retinopathy of prematurity	0.271	0.028
Laser photocoagulation	0.241	0.004
Days of mechanical ventilation	0.422	<0.001
Respiratory distress syndrome	0.13	0.120
Chronic lung disease 28	0.189	0.023
Home oxygen therapy	0.194	0.020
Sepsis	0.198	0.017
Symptomatic patent ductus arteriosus	0.108	0.195
Patent ductus arteriosus ligation	0.128	0.125
Late-onset circulatory collapse	0.144	0.085
Length of hospital stay	-0.044	0.596

cher et al.[22] also investigated walking attainment ages in term infants and in preterm infants with a median birth weight of 1,200 g and a median gestational age of 29.7 weeks. It was reported that more than 95% of preterm and term infants attained the ability to walk at a corrected age of 18 months. According to the results of this study, the walking attainment rates at the modified 18 months were as follows: group A, 80.3%; group B, 90.5%; group I, 73.6%; group II, 92.2%, and it was found that the walking attainment rate in this study was lower than that in previous studies[12,22]. The reason for this is that Japanese infants have physiques different from those of infants in other Western countries, and the period of motor development may be delayed[23,24]. The results of this study provide useful information to the caregivers and medical staff of Japan's VLBW infants regarding the unique walking attainment age based on birth weight and gestational age in Japan.

In multiple regression analysis, the duration of mechanical ventilation was adopted as a factor affecting walking attainment. The reason that walking attainment is delayed in children requiring long-term artificial respiration management may be that they are forced to take long-term rest for preventive purposes such as unplanned extubation. Prolonged ventilator management may delay early gross motor development[25]. Since walking attainment age is related to the acquisition of initial gross motor skills such as the ability to support the head and stand upright, it is con-

Table 4. Multiple regression analysis with walking attainment age as the dependent variable

	Unstandardized coefficients B	95% Confidence interval for B	Standardized coefficients β	p value	VIF
Birth weight	-0.008	(-0.101~0.085)	-0.035	0.864	6.171
Gestational age	1.078	(-0.117~2.273)	0.312	0.077	4.647
Head circumference at birth	-6.796	(-18.55~4.959)	-0.267	0.254	8.28
1-minute Apgar score	-0.422	(-10.124~9.279)	-0.014	0.931	3.997
5-minute Apgar score	4.5	(-10.425~19.426)	0.113	0.551	5.496
Intraventricular hemorrhage	14.059	(-3.689~31.806)	0.141	0.119	1.227
Retinopathy of prematurity	8.612	(-3.724~20.948)	0.15	0.169	1.794
Laser photocoagulation	-1.638	(-38.041~34.765)	-0.01	0.929	2.005
Days of mechanical ventilation	1.004	(0.045~1.964)	0.325	0.04	3.734
Chronic lung disease 28	-1.909	(-33.87~30.052)	-0.013	0.906	1.903
Home oxygen therapy	73.2	(-64.385~210.785)	0.094	0.294	1.225
Sepsis	30.919	(-1.108~62.946)	0.176	0.058	1.293

Full model R=0.53, R^2=0.28, adjusted R^2=0.20

VIF: variance inflation factor

sidered that delays in initial gross motor development contribute to delayed walking. Low birth weight infants with mechanical ventilation had significantly delayed gross motor development at 8 to 12 months compared to that in infants without mechanical ventilation[26]. In addition, it has been reported that children who needed long-term mechanical ventilation show decreased adolescent motor function scores and low psychomotor development indices, even in the absence of neurological abnormalities[27,28]. Since artificial respiration management affects mental and motor development after walking attainment, it is necessary to carefully conduct long-term follow up of these children. BPD is also defined as requiring oxygen for >30 days or after 35 weeks postmenstrual age[13]. In our hospital, CLD 28, which required oxygen administration even beyond 28 days after birth, is recorded in the medical record as a factor of immature lungs. Therefore, CLD 28 was used instead of BPD in this study. The reason why CLD 28 was not adopted as a risk factor for delayed walking attainment is clinically considered to be that ventilator management, which requires more rest than oxygen administration, is involved in motor development.

Our study has some limitations. First, the study excluded infants who had a diagnosis of cerebral palsy by a corrected age of 2 years. Thus, infants included may have been diagnosed with cerebral palsy after 2 years, or with psychomotor retardation. Second, in the multiple regression analysis, the coefficient of determination (R^2 = 0.28), which is the contribution percentage of the independent variable, was low. It has been reported that locomotor activity in infancy is related to the timing of walking attainment[29]. In the future, in order to predict children with delayed walking attainment, it will be necessary to consider the evaluation of spontaneous movement in addition to perinatal factors. Third, the sample size was relatively small. A larger study population followed-up at multiple centers is needed.

Conclusion

The results of this study showed that VLBW infants with light weight and short gestational age have delayed walking attainment, and longer duration of mechanical ventilation increases the risk of delay. Therefore, intervention with developmental support from an early stage may lead to improvement of gross motor skills in such cases.

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PHYSICAL
THERAPY
RESEARCH

SCIENTIFIC RESEARCH ARTICLE

Stroke Patients Showed Improvements in Balance in Response to Visual Restriction Exercise

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ABSTRACT. Objective: Several strategies have been designed to improve balance after stroke. Although recent studies have suggested that the balance training in stroke should include exercises that are performed in different sensory conflict conditions, little attention has been paid to manipulation of visual input. This study aimed to compare effects of balance training on an unstable surface with balance training under visual deprivation conditions in persons with stroke. Method: Forty-five stroke patients were randomized into three groups: the visual deprivation- stable based training (VD-SBT); unstable based training (UBT); and control (C) groups. Subjects of the VD-SBT group performed balance training on a stable surface with closed eyes. The UBT group performed balance training on an unstable surface with open eyes. Patients were assessed before and after interventions for Timed Up and Go (TUG), Four Square Step (FSS) and Five Times Sit to Stand (FTSS) tests. Result: There was a significant difference in pre- post intervention time of TUG, FSS and FTSS tests in all three groups. In a comparison of three groups, the UBT and VD-SBT groups had a significant improvement in time of all tests but significant improvement in time of all tests was observed in the VD-SBT group in comparison with the UBT group. In the field of balance training, the manipulation of visual input was more effective than the manipulation of standing surface to reweighting the sensory information. Conclusion: We recommended balance rehabilitation programs after stroke performed under conditions to stimulate the use of underused sensory input.

Key words: Balance training, Stroke, Sensory integration, Visual deprivation

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Stroke is a condition that happens when blood circulation in some parts of the brain is interrupted as a results of blockage in blood stream or hemorrhage event[1]. Based on the World Health Organization (WHO) report, stroke has the second place among diseases causing death worldwide[2] and causing long-term disability for patients[3]. The majorities of people with stroke have some degree of balance and gait impairment. Balance impairment owing to paralysis and muscle weakness in lower limbs is one of the main determinants associated with falls and restricted activities of daily living after stroke.

Control of balance needs the involvement of different parts of the brain and spinal cord[4]. Sensory inputs from vestibular system and proprioceptors are necessary for postural control and balance which are used by different parts of the brain and spinal cord to provide a good balance[5]. In a neurologically normal participant, these systems act together to build a multisensory integration system for adjusting balance; as a result, when a sensory input from one of these systems decreases, the central integration resolves

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sensory conflict and selects an appropriate information from disparate sensory input to achieve the best result in controlling the balance[6]. Impaired somatosensory integration in stroke patients has been reported in several studies[7-9]. Several therapeutic strategies are designed to improve balance by manipulation of these three systems. Perturbation training[10], training on unstable surface[11] and weight shift training[12] are designed interventions for enhancing the balance ability in stroke patients to use the proprioception. Visual feedback and visual deprivation training are two different methods of visual input manipulation that are used as a therapeutic approach to improve balance reactions[13,14]. Visual feedback therapy is able to gain a symmetrical stance[15] and improve sitting balance and visual perception[13] after the stroke, but there are evidence that visual feedback therapy has no additional effect on the conventional therapy[16]. Previous studies showed that persons with stroke are significantly rely on their vision to compensate for the decreased function of the other involved sections for improving their balance[7,17]. Therefore, they suggest that the balance training for patients with chronic stroke should include practicing with different sensory conditions to make it challenging enough for nervous system to improve its ability to increase balance. Despite a great number of studies on the unstable base training and visual deprivation training by stroke patients, such programs have not been compared yet. Therefore, the aim of current study is to compare the effects of balance exercise on unstable base with balance exercise under visual deprivation conditions in stroke patients.

Methods

1 Participants

This was a randomized clinical trial with concealed allocation. Patients on the physiotherapy clinic of Loghman hospital, university of Shahid Beheshti medical sciences, Iran were approached for participation. Patients who expressed interest in participating in the study were screened for the following inclusion criteria: First ever stroke; at least 6 months after stroke; ability to walk at least 10 m without assistance. We excluded individuals with sever cognitive problems; neurological disease and musculoskeletal conditions preventing participation in rehabilitation program. The study protocol was approved by ethics committee of Shahid Beheshti University of medical sciences (No: IR.SBMU.RETECH.REC.1398.819). Participants provided written informed consent after receiving full information about the goals and process of study. Following consent, patients were randomized using a computer-generated block randomizer to 1 of 3 groups: The visual deprivation- stable based training (VD-SBT); unstable based training (UBT); and control (C) groups. Sealed envelopes opaque were used for allocation concealment. The sealed envelope was opened by the researcher exactly before the intervention. The assessor and data analyst did not know how the subjects were allocated. The sample size was calculated based on BBS data reported by Combs et al.[18] We used the effect size (0.53) of the BBS for calculation. A sample size of 15 participants in each of the 3 groups was needed to achieve a power of 0.80 at α level of 0.05. The study was registered at the Iranian Registry of Clinical Trials (IRCT) (http://www.irct.ir, registration reference: IRCT 20190812044516N1).

2 Intervention

All groups received general physical therapy exercise including muscle stretching and strengthening exercise that was specific for each patient by a train researcher. Participants in the VD-SBT group were instructed to perform balance training exercise on a firm floor while they are keeping their eyes closed. The balance training program consisted of Weight shifting; toe/heel rising; heel/toe standing and one leg standing exercise[19,20] (Table 1). The UBT group performed balance training on a firm foam (balance pad: Mambo balance pad 37, 22, 6 cm Europe bvba) with open eyes. Figure 1 summarize the balance exercises that performed by the UBT group. Subjects in the control group received general physiotherapy exercise. Each exercise session consisted of 4 sets in 30 minutes with one minute of rest interval between each set. The interventions were carried out for one month, 3 sessions per week in the stroke rehabilitation center.

3 Outcome Measures

Participants completed the Timed Up and Go (TUG), Four Square Step (FSS) and Five Times Sit to Stand (FTSS) tests at baseline and after completing their intervention. The dynamic balance during walking was assessed by TUG[21]. To do this test, patients were asked to stand up from a seat (using armrests, if necessary), walk towards a cone that is 3 meters far away from the seat, turn around, walk back to the seat and sit back down on the seat. Dynamic standing balance was assessed by the FSS test[22]. The Four Square Step Test is a valid clinical test of dynamic standing balance[23]. This test could show whether the patient is able to a step over an object in different directions or not (forward, sideways and backward). During FTSS test, patients instructed to stand up straight and sit down 5 times as quickly as they could. This ability relies on the lower extremity proprioception[24], dynamic balance and their general mobility[25].

4 Data analysis and statistics

The average time of all test trials were calculated. All the data were analyzed by SPSS18.0 for Windows (SPSS Inc., Chicago, IL, USA). Descriptive statistics and test of normality using the Shapiro-Wilk test was performed on all outcome variables. The means of subject characteristics

Table 1. Balance training protocol

Weight shifting exercise with feet parallel together a. Weight shift side to side b. Weight shift heel to toe
Toe raise a. Standing with feet hip-width apart slowly lift the front of feet b. Standing with feet hip-width apart slowly lower the front of feet
Weight shifting exercise with feet in half tandem a. Weight shift side to side b. Weight shift heel to toe
Heel raise a. Standing with feet hip-width apart slowly lift up the heel b. Standing with feet hip-width apart slowly lower the heel
Heel toe standing a. Standing with paretic foot in front of the sound foot for 10 -20 seconds b. Standing with paretic sound foot in front of the paretic foot for 10-20 seconds
One leg standing a. Standing on sound leg without holding onto the counter for 10 seconds b. Standing on the paretic legwithout holding onto the counter for 10 seconds

Fig. 1. Participant in the UBT group performing balance training on a balance pad: (a) Weight shift side to side. (b) Heel raises (c) Toe raises (d) One leg standing.

across groups were compared using 1-way analysis of variance (ANOVA). The paired t-test was used to examine the difference between pre and post-treatment in each group. The difference on the type of therapy among the 3 groups were assessed by using two-way repeated-measures analysis of variance (ANOVA) with time (pre, post intervention) and group (VD-SBT, UBT, control) as factors for each of post-training scores (TUG, FSS, TUG). The Tukey HSD was used as the post hoc analyses. For all analyses, statistical significance was set at $P < 0.05$.

Results

The study began with an initial screening of 60 individuals, 15 were excluded, and 45 were finally chosen on the basis of inclusion criteria and were enrolled in the study (Fig. 2). All participants completed the intervention and assessments. Of the 45 subjects in the study, 26(60%) had the right side of body affected. The time after the onset of stroke was a minimum of 6 months and a maximum of 2 years with average duration of 14.6 ±9.2 months. No significant difference was observed in time from stroke onset ($p = 0.72$), among the three groups. Table 2 presents general characteristics of all groups. No significant differences were found in terms of age, height, weight and side of stroke between all groups. Table 3 revealed the values of all outcome measures before and after intervention.

The results of two-way Repeated Measures (ANOVA)

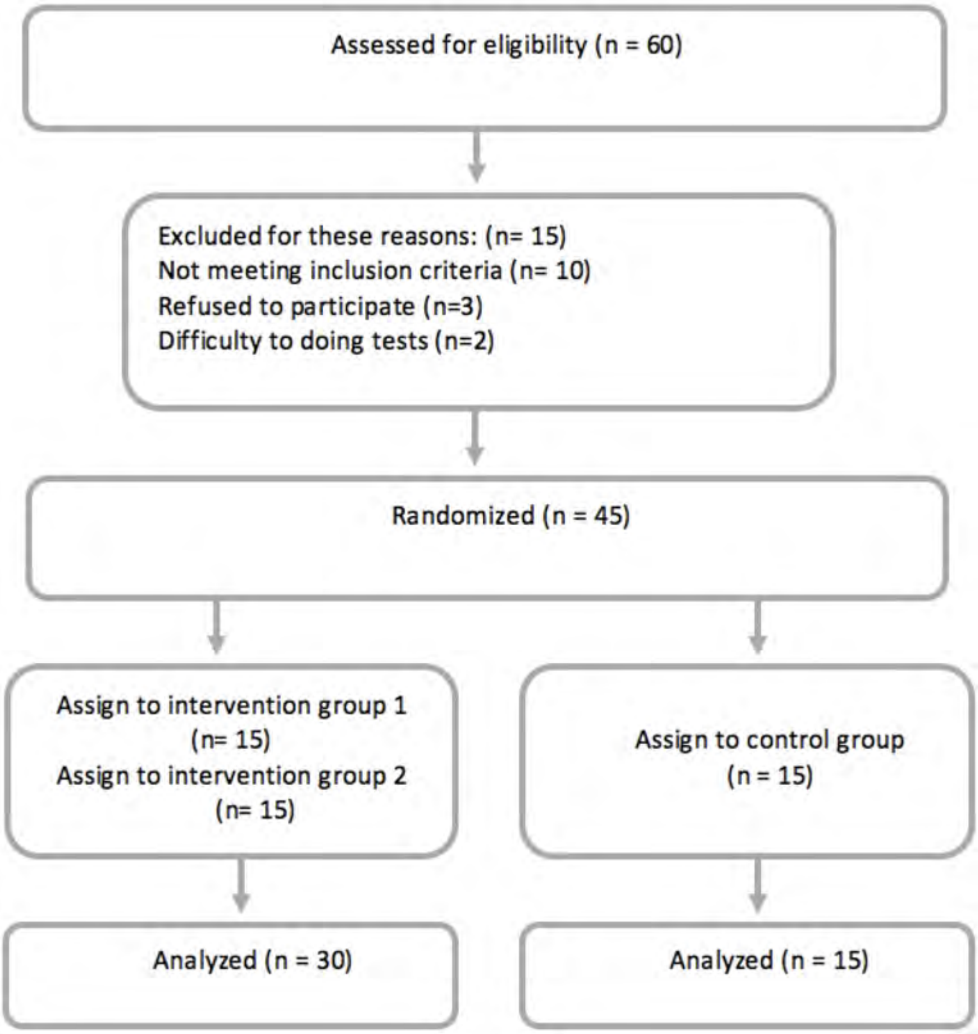

Fig. 2. Flow diagram of the study participants.

Table 2. The general characteristics of the study participants.

	VD-SBT (n=15)	UBT (n=15)	Control (n=15)	P
Gender (M/F)	7/8	9/6	8/7	0.88
Age (years)	67.2±9.6	68.8±8.9	67.5±9.9	0.69
Time since stroke onset (months)	15.4±4.7	14.4±4.5	14±6.3	0.72
Weight (Kg)	79.9±7.4	81.2±8.6	79.2±8.7	0.81
Height (cm)	167.9±8.7	170.0±10.4	164.2±7.4	0.33
Stroke type (schemic/hemorrhagic)	8/7	7/8	7/8	0.92
Involved side (Rt/lt)	9/6	8/7	10/5	0.00*

NOTE: Values are mean ± standard deviation (SD) or number.
M/F: Male/Female; VD-SBT: visual deprivation-stable based training; UBT: unstable base training; Rt/lt: Right/Left; P*≤0.05

showed that the main effect of the time is significant, meaning that the mean score of all outcome measures after the intervention is lower than before the intervention in all groups ($p < 0.001$). Also, the main effect of the group was significant for TUG ($p = 0.017$), 4SS ($p = 0.008$) and FTSS ($p < 0.001$). Multiple comparisons by Tukey HSD method showed that control and unstable groups had a higher mean of all outcome measures than the non-visual group, without significant differences compared to each other in meantime of TUG (0.960), 4SS(0.938) and FTSS (0.215). In addition, the interaction effect was significant ($p < 0.001$), which means that while the meantime of TUG, FFSS and FTSS

Table 3. Statistical analyses of outcomes of the study in each group.

Parameter	Group	Pre intervention	Post intervention	Pre-Post difference	Repeated-Measures ANOVA
TUG time (sec)	VD-SBT (15)	16.5±1.8	10.0±1.2	-6.4±2.4	Time* Group=0.017*
	UBT (15)	16.2±2.7	15.9±2.3	-0.7±1.4	
	Control (15)	16.1±2.6	15.4±3	0.7±1	
4SS time (sec)	VD-SBT (15)	20.5±2.3	12.0±1.2	-8.5±2.4	Time* Group= 0.008*
	UBT (15)	20.3±2.8	18.2±2.7	-2.8±3.0	
	Control (15)	20.3±3.0	19.6±3.7	-1.3±0.9	
FTSS time (sec)	VD-SBT (15)	18.4±3.6	10.9±2.0	-7.4±3	Time* Group <0.001*
	UBT (15)	21.2±3.0	20.1±3.4	-1.4±1.6	
	Control (15)	18.8±2.4	18.1±2.2	-0.7±1.6	

NOTE: Values are mean ± standard deviation (SD).
VD-SBT: visual deprivation- stable based training; UBT: unstable base training; TUG: Timed Up and Go; 4SS: Four Square Step; FTSS: Five Times Sit to Stand; P*≤0.05

tests after intervention was slightly lower than before intervention in both control and unstable groups, in the VD-SBT group this decrease was very significant (Fig. 3).

Discussion

In our study, we evaluated the effects of the 2 exercise training protocol (visual deprivation- stable based training and unstable based training) on the dynamic and static balance ability of post stroke patients. Despite the fact that the pre-post comparison within each group indicated that balance scores were significantly improved after 4 weeks of intervention, we found that all measures of treated balance by the visual deprivation- stable based training and unstable based training were significantly greater than the control group. Previous studies also indicated that performed training under different sensory conflict conditions in stroke subjects affected their balance ability[17,26]. The main finding of this study show that after balance training with visual deprivation in stable surface, patients had a significant improvement in their ability to control the static and dynamic balance compared to the unstable base training with open eyes group. It was assumed that the improvement in VD-SB balance training group could be due to the fact that the manipulation of visual input was more effective than the manipulation of standing surface to reweighting sensory information in the field of balance activity. Previous studies found that the exercise training with visual restriction by stroke patient affected their gait dynamic stability[27] knee joint proprioception[28], balance and concentration ability[29], gait velocity and balance[7]. Results of the present study extended previous results indicating that a training program with visual restrictions could improve the balance ability in persons with stroke more than training at free vision conditions[28,30].

Intrinsic and extrinsic feedback could enhance movement performance in healthy subjects. Intrinsic feedback could be mediated by vision, proprioception, touch, pressure and audition[31]. Extrinsic feedback, which is also known as augmented feedback, supplements an intrinsic feedback and cannot be elaborated without an external source. Both intrinsic and extrinsic feedback controls are affected after stroke[31]. Impairment in the intrinsic feedback system, especially proprioceptive feedback is common after stroke, and this impairment makes stroke survivors more dependent on an extrinsic feedback system(augmented visual input)and exhibits the excessive dependency on visual input[32]; hence, this system may be even more important than the intrinsic feedback system. Therefore, patients become unable to use vestibular and proprioceptive input correctly. We hypothesize that, in comparison with free vision conditions, the vestibular and proprioceptive inputs are weighted more heavily in the conditions that extrinsic feedback system is removed (visual deprivation condition). Therefore, we recommended that balance rehabilitation programs after stroke performed under conditions to stimulate the integration of underused sensory input and minimize the overuse of other afferent inputs.

Somewhat surprisingly, the present study found no difference between the training group on the unstable surface and the control group. Most other studies that have examined the training on the unstable surface have reported significance difference between stable and unstable base training[11]. However, it is worth noting that some studies suggested that older adult used a compensatory strategies of muscle co-contraction[33] which is associated with increasing joint stiffness and decreased postural steadiness, when exposed to changes in their base of support[34]. It is possible that during balance training on unstable surface the patients were using muscle co contraction strategy that made the training ineffective.

The present study had some limitations. First: we used only clinical tests to evaluate the balance ability. Future studies are necessary for further validation of our finding

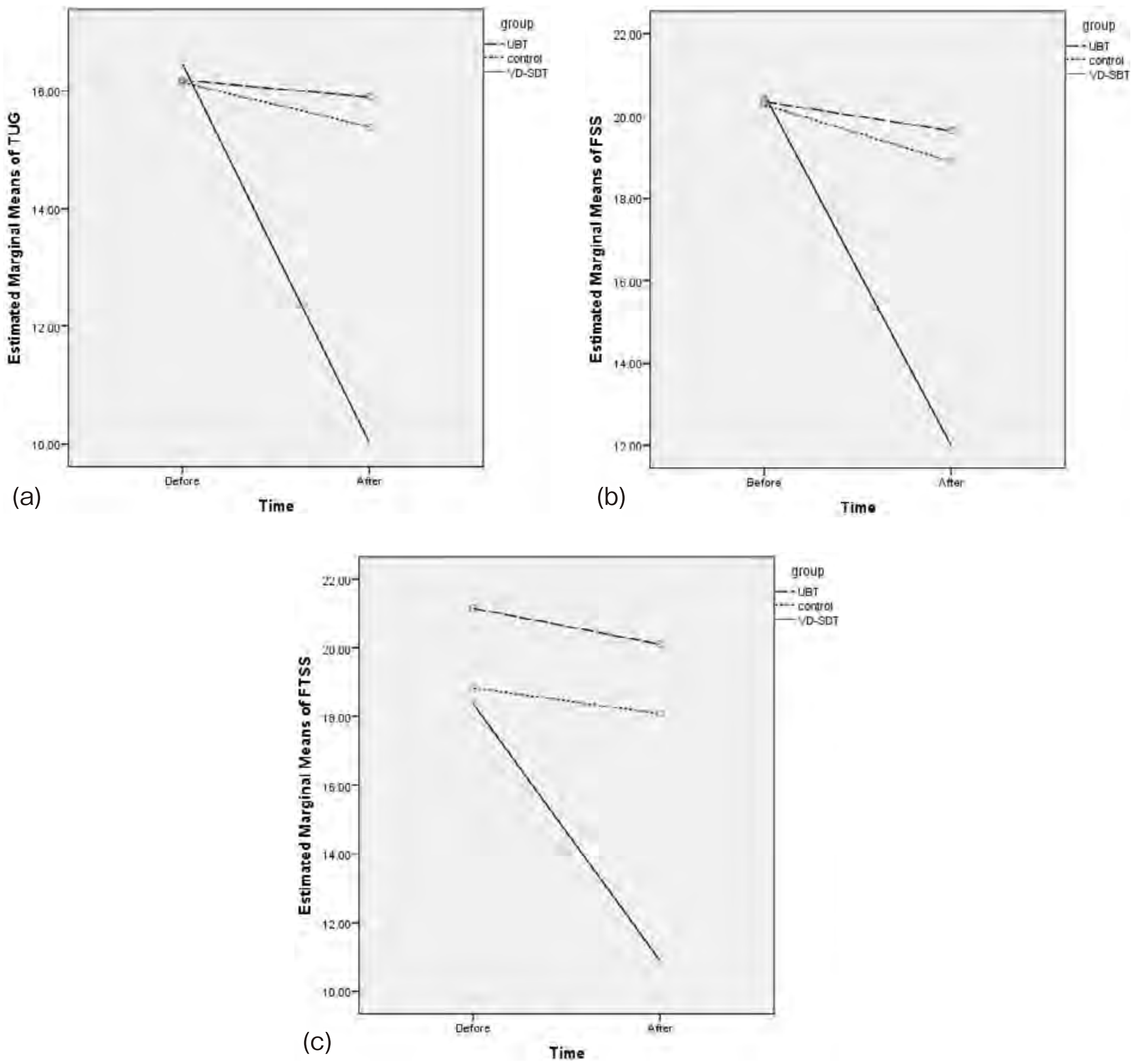

Fig. 3. Group*Time interaction effect on TUG (a), FSS (b) and FTSS (c). After intervention, VD-SBT group showed a significant decreased in TUG, FSS and FTSS times with respect to UBT and control groups.

by using quantitative measurements of balance scores. Second: we included male and female patients at later stages after stroke. Further studies should examine roles of sex and chronicity of lesion.

Conclusion

The result of our study suggested that stroke subjects who received balance training in vision restriction conditions could improve the balance more than training at free vision conditions. The reason for this finding may be that the balance training with blocking visual information more facilitated the use of the proprioceptive and vestibular senses. We recommended balance rehabilitation programs after stroke performed under conditions to stimulate the use of underused sensory input to minimize the overuse of other afferent inputs.

Conflict of Interest: There is no conflict of interest to disclose.

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PHYSICAL
THERAPY
RESEARCH

SCIENTIFIC RESEARCH ARTICLE

Electromyography Activity of Vastus Medialis Obliquus and Vastus Lateralis Muscles During Lower Limb Proprioceptive Neuromuscular Facilitation Patterns in Individuals with and without Patellofemoral Pain Syndrome

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ABSTRACT. Objective: Exercise therapy to strengthen quadriceps muscle is recommended in rehabilitation program for people with patellofemoral pain syndrome (PFPS). This study aimed to investigate the electromyography (EMG) activity of vastus medialis obliquus (VMO), vastus lateralis (VL) and VMO/VL ratio during PNF in individuals with and without PFPS. Methods: 26 persons with PFPS and 26 healthy subjects participated to study. All subjects performed PNF patterns (Flexion-Adduction-External Rotation (D_1FL), Extension-Adduction-External Rotation (D_2EX), D_1FL+ load, D_2EX+ load) and straight leg raise (SLR). The normalized EMG activity of VMO, VL and VMO/VL ratio were measured and analyzed using repeated measure ANOVA. Results: There were significant main effects of group and exercises for the both VMO and VL ($p<0.05$). It was found that except SLR and D_2EX, in the other motions PFPS group had lower VMO activity compared to healthy group ($p<0.05$). For VL except SLR, in the other motions PFPS group had lower VL activity too ($p<0.05$). The PNF patterns activated VMO more than SLR, however it was not significant ($p>0.05$). Also; there weren't any significant difference between the two groups in VMO/VL activation ratios. Also, performing the PNF patterns with load increased VMO and VL muscles activity significantly ($p<0.05$). It also found that in PFPS group the VMO/VL ratio values in PNF patterns were significantly more than SLR and the highest VMO/VL ratio value (0.96) was found during D_2EX. Conclusion: The PNF patterns due to provide optimal VMO/VL ratio value than SLR and proper balance between these two muscles can be recommended in rehabilitation of individuals with PFPS.

Key words: Patellafemoral pain syndrome, Physical therapy, Exercise therapy, Electromyography, Vastus medialis obliquus

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Patellofemoral pain syndrome (PFPS) is a common problem which has been reported mostly in young females and included 25% to 40% of knee injuries in athletes[1-4)]. People with PFPS experience dull pain around and behind the patella during movements such as climbing stairs, running, jumping, or keeping knees in positions such as kneeling or quad sitting for a long time[1)]. Normal patellar tracking on trochlea groove depends on coordination and balance of various structures including soft tissues, muscles, tendons, ligaments and the shape of articular surfaces around the knee joint[4,5)]. Impairment of any of these factors effect on the patella's normal biomechanics and resulted in the increased pressure on the articular surface and PFPS[1,6)].

Weakness of the Vastus Medialis Obliquus muscle (VMO) or the imbalance between VMO and Vastus Lateralis muscle (VL) activity are one of the most important fac-

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tors in increasing lateral force which can lead to PFPS[1,7,8]. VMO plays a critical role in maintaining patella in the trochlea groove. Therefore, the weakness or delay in VMO muscle activation which cause disturbance in the stabilization and function of the patella would lead to PFPS[1,9]. Previous studies demonstrated that proprioceptive neuromuscular facilitation (PNF) techniques can play an important role in reducing pain, increasing the range of motion, joints stabilization and facilitating the initiation of movement[10-12]. People with quadriceps muscle weakness are more likely at risk of PFPS, because it can lead to increase pressure on patellofemoral joint[13]. Therefore, exercise therapy to strengthen muscles is a part of the program for people with PFPS and studies showed muscle strengthening exercises can improve pain and biomechanics of the patellofemoral joint and these exercises are important part of PFPS treatment[14-17]. One of the important training methods in physical therapy exercises is PNF. In PNF diagonal motions, based on facilitation principles such as proprioceptors stimulation and overflow, a weak muscle can be strengthened with the help of strong components in the pattern[10,18,19].

The VMO is the first muscle that is atrophic and inhibited in the knee injuries[20]. Therefore, the focus of the exercises is to strengthen and increase its activity level and improve balance between VMO and VL activity. Some studies showed when the hip is externally rotated, VMO muscle contraction is at the highest level[21,22]. Also, the VMO originated from adductor magnus with tendons medially, so with hip external rotation and adduction, adductor muscles can provide a stable origin for VMO and increase VMO activity[1,23]. Previous studies showed that straight leg raise (SLR) with external rotation, and dorsiflexion, as well as adding hip adduction to open and close kinematic chain exercises are proper exercises to enhance VMO activation[1,8,24-26]. However, there is no consensus on this[27-30]. The PNF patterns are in different plane and contain different motions together. So, these patterns with combining motions simultaneously are functional and can activate the VMO and VL muscles well. Also, better results have been seen in improving the function of weak muscles by performing motor patterns in a group as compared to training a single muscle[18,19].

There is no study in PFPS to demonstrate the impact of PNF's diagonal patterns on the facilitation of VMO or balance between VMO and VL. Therefore, the aim of this study was to investigate the effect of PNF patterns on the activation of VMO and VL muscle in individuals with and without PFPS.

Methods

Subjects

Fifty two individuals (n= 26 PFPS, n=26 healthy) through an analytical design participated in the study. The inclusion criteria were: 1) reporting an anterior knee pain in the at least past 3 months during activities such as squatting, climbing, stepping, running, jumping, kneeling and quad sitting; 2) Having at least one positive PFPS clinical tests including, patellofemoral compression, patellofemoral gliding or resistive quadriceps setting[1,31]. The subjects were excluded from the study if they had history of knee surgery or injury, patellar dislocation or subluxation, any neurological or rheumatic disorders and pain intensity more than 5 (based on visual analogue scale). Subjects in healthy group should not have had any history of knee pain or other pathologies of knee in the past[1,7,31-33]. All participants signed an informed consent form to participate in this study that approved by the ethics committee of University of Social Welfare and Rehabilitation Sciences (Ethical number: IR. USWR.REC.1396.128)

Electromyography (EMG) assessment

In this study the EMG data of VMO and VL muscles were recorded during PNF patterns (Flexion-Adduction-External Rotation (D_1FL) in hip joint with knee extended, Extension -Adduction-External Rotation (D_2EX) in hip joint with knee extended, D_1FL+ load and D_2EX+ load) and SLR. The EMG data of VMO and VL were collected using MT8 EMG device manufactured by MIE in the UK. The participants lay supine on a bed and put their hands crossly on the chest. The electrodes were Ag/ AgCl, the diameter of the surface electrode was 10 mm and the electrode spacing was 20 mm. The sampling frequency was 1000 and the band pass filter was between 20-450 Hz[1,20]. Before the electrodes placement first, the skin of the area was prepared by shaving the hair and cleaning it with alcohol. A hypothetical line which connected anterior superior iliac spine to the center of the patella was considered as the reference line for electrodes placement. The VMO electrode was placed with an angle of 55° relative to the reference line, 4 cm above the superior border of the patella and 3 cm medially to the reference line. The VL electrode was placed with the angle was 15° relative to the reference line, 10 cm above the superior border of the patella and 7 cm laterally to the reference line. The ground electrode was placed on the patella[2,6,20].

Subjects first were trained on how to perform the movements. By using the goniometer and a designed device, we determined thirty degrees as target for elevation of lower limb during PNF patterns and SLR. The sequence of movements was random. To determine the sequence of movements, the participants selected random order sheets. To perform PNF patterns, the limb was first placed in an antagonistic pattern with a straight knee. By giving the verbal command, the subjects were asked to reach the lower limb to determined target point within 5 second according to their familiarization training. Between each exercise, there was 4 minutes of rest. The PNF patterns were also performed with weights. We used an adjustable weight cuff

Table 1. Comparison of normalized electromyographic activity of VMO, VL and VMO/VL ratio during PNF patterns and SLR between the PFPS and healthy groups

muscles	groups	exercises (The mean ±SD) (%MVIC)				
		D_1FL	D_2EX	SLR	D_1FL + load	D_2EX + load
VMO	PFPS	44.92 ± 15.44	45.87 ± 12.25	41.55 ± 13.22	58.01 ± 18.50	60.09 ± 13.96
	Healthy	56.52 ± 17.57	52.31 ± 12.47	49.57 ± 19.70	75.25 ± 15.45	67.95 ± 11.67
	p-value	0.01	0.06	0.09	0.001	0.03
VL	PFPS	49.15 ± 16.53	48.91 ± 13.47	51.05 ± 10.92	63.21 ± 19.48	63.98 ± 13.78
	Healthy	60.00 ± 11.38	56.80 ± 9.75	56.78 ± 15.84	80.77 ± 11.01	71.67 ± 9.93
	p-value	0.01	0.02	0.13	< 0.001	0.02
VMO/VL	PFPS	0.92 ± 0.17	0.96 ± 0.20	0.81 ± 0.18	0.93 ± 0.16	0.94 ± 0.16
	Healthy	0.93 ± 0.17	0.93 ± 0.19	0.84 ± 0.17	0.93 ± 0.12	0.95 ± 0.14
	p-value	0.90	0.57	0.58	0.96	0.91

PFPS, patellofemoral pain syndrome, VMO, vastus medialis oblique, VL, vastus lateralis, VMO/VL, ratio of vastus medialis oblique/vastus lateralis, SLR, straight leg raise, D_1FL, flexion, adduction, external rotation with knee straight, D_2EX, extension, adduction, external rotation with knee straight

that its weight could be changed. It was be fixed on ankle of subjects. The load which we added to exercise was determined according to the subjects' body mass index (BMI) as follows: 1 kg for those BMI less than 20, 1.4 kg for BMI of 20-22, 1.7 kg for BMI of 22-24 and 2 kg for those BMI more than 24[23,34]. To achieve the mean activity of VMO and VL muscles, the Raw data processed with the root mean square (RMS). Normalization was necessary to minimize variables between PFPS and healthy subjects. To compute the normalized data for VMO and VL muscles we also measured maximal voluntary isometric contraction (MVIC), so the participants were seated at the end of a bed to perform MVIC of the quadriceps muscle against manual resistance. The highest root mean square (RMS) value of the three MVICs was used for normalization purposes[35]. EMG data were collected during the patterns and SLR were normalized and expressed as a RMS processed percentage of MVIC. For assessing test-retest reliability, 10 subjects (5 healthy and 5 PFPS) were studied twice as the same mentioned methods with an interval of one day.

Statistical analyses

All data were analyzed using SPSS statistical software version 18. The repeated measures ANOVA were used to compare the mean of VMO and VL muscles activity separately and VMO/ VL ratios across exercises for each group and between the two groups. The post hoc test was also performed for pairwise comparison between the exercises. Multivariate analysis of variance (MANOVA) was used to compare the muscles activation level in each exercise between the two groups. ($p < 0.05$, indicating a significant difference)

Results

Twenty six PFPS subjects (18 women, 8 men) and 26 healthy subjects (18 women, 8 men) participated in this study. The mean ± SD of the age and BMI of participants in PFPS group were 22.92 ± 1.78 years, 22.97 ± 2.21 kg/m^2 and in healthy group were 23 ± 1.91 years, 23.08 ± 2.72 kg/m^2. There was no statistically significant difference in subject's age ($p = 0.98$) and BMI ($p = 0.88$) between the two groups. The intra-class correlation coefficients (ICC) values for assessing test-retest reliability was calculated. The results showed the reliability of EMG data of mean activity was greater than 0.86 in all exercises.

The results of repeated measures ANOVA for VL muscle activity revealed a significant effect of group × exercises ($F=2.90$, $p=0.04$) and significant effects of the exercises ($F=43.70$, $p<0.001$) and the group ($F=11.97$, $p=0.001$). This analysis for VMO muscle activity showed no significant interaction effect ($F=1.90$, $p=0.15$). However, significant main effects of exercises ($F=36.12$, $p<0.001$) and group ($F=10.49$, $p=0.002$) were observed. For VMO/ VL ratio the interaction effect of group × exercises was not significant ($F=0.47$, $p=0.68$). Also, main effect of group was not significant ($F= 0.001$, $p= 0.97$) however, significant main effects of exercises ($F= 10.07$, $p<0.001$) was observed.

The mean of EMG activity of VMO, VL and VMO/ VL ratio (as a percentage of MVIC) during PNF patterns and SLR in PFPS and Healthy groups have shown in Table 1. The result of MANOVA analysis of VMO activation level in each motion between the two groups showed that except SLR and D_2EX ($p>0.05$), in the other motions PFPS group had lower VMO activity ($p<0.05$). For VL except SLR, in the other motions PFPS group had lower VL activity too ($p<0.05$) (Table 1). Also, there weren't any signifi-

Table 2. Pairwise Comparisons of normalized EMG activity of muscles between exercises in PFPS and healthy groups

group	Exercises		VMO		VL		VMO/VL	
Healthy	(I)	(J)	Mean difference (I-J)	P value	Mean difference (I-J)	P value	Mean difference (I-J)	P value
	Comparison of D_1FL with	D_2EX	4.21	0.05	3.20	0.14	-0.001	0.96
		SLR	6.95	0.12	3.22	0.38	0.09	0.01
		D_1FL+ load	-18.73	< 0.001	-20.77	< 0.001	0.003	0.90
		D_2EX+ load	-11.43	< 0.001	-11.67	< 0.001	-0.02	0.40
	Comparison of D_2EX with	D_1FL	-4.21	0.05	-3.20	0.14	0.001	0.96
		SLR	2.74	0.49	0.02	0.99	0.09	0.05
		D_1FL+ load	-22.94	< 0.001	-23.97	< 0.001	0.004	0.89
		D_2EX+ load	-15.64	< 0.001	-14.87	< 0.001	-0.02	0.38
PFPS								
	Comparison of D_1FL with	D_2EX	-0.95	0.65	0.24	0.91	-0.04	0.17
		SLR	3.37	0.44	-1.90	0.60	0.11	0.001
		D_1FL+ load	-13.09	< 0.001	-14.06	< 0.001	-0.01	0.83
		D_2EX+ load	-15.17	< 0.001	-14.83	< 0.001	-0.02	0.37
	Comparison of D_2EX with	D_1FL	0.95	0.65	-0.24	0.91	0.04	0.17
		SLR	4.32	0.28	-2.14	0.46	0.15	0.002
		D_1FL+ load	-12.14	< 0.001	-14.30	< 0.001	0.03	0.27
		D_2EX+ load	-14.22	< 0.001	-15.07	< 0.001	0.02	0.59

cant difference between the two groups in VMO/VL activation ratios (p>0.05) (Table 1).

Pairwise Comparisons of the motions have shown in Table 2. As shown in Table 1 however, the mean of EMG activity of VMO in PFPS group during PNF patterns was more than SLR; there weren't any significant differences in VMO muscle activity between D_1FL, D_2EX and SLR (Table 2). Also, as shown in Table 1 however, the mean of EMG activity of VL in PFPS group during SLR was more than PNF patterns; there weren't any significant differences in VL muscle activity between D_1FL, D_2EX and SLR (Table 2). Adding weight to D_1FL and D_2EX increased VMO and VL muscles activity significantly in both groups (Table 2). The pairwise Comparisons showed that the VMO/VL ratios of the PNF patterns were significantly more than SLR too (p<0.01) (Table 2).

As shown in Table 1, the activation levels of VMO during the motions from the highest to the lowest in PFPS group were: D_2EX+ load, D_1FL+ load, D_2EX, D_1FL, SLR while, in healthy group were : D_1FL+ load, D_2EX+ load, D_1FL, D_2EX, and SLR. Also, the activation levels of VL during the motions from the highest to the lowest in PFPS group were: D_2EX+ load, D_1FL+ load, SLR, D_2EX and D_1FL while, in healthy group were: D_1FL+ load, D_2EX+ load, D_1FL, D_2EX and SLR (Table 1).

In addition, the Table 1 showed that the VMO/VL ratio during PNF patterns were significantly more than SLR and were near the ideal 1:1 ratio in two groups.

Discussion

The results of this study on comparison of VMO activation level in each exercises between the two groups showed that except SLR and D_2EX, in the other exercises PFPS group had lower VMO activity. In the other words SLR and D_2EX in PFPS group activated the VMO the same as healthy group. Also, pairwise comparisons of PNF patterns (without load) with SLR showed that the mean of EMG activity of VMO in PFPS and healthy groups during PNF patterns were more than SLR, however, these differences weren't significant. In PFPS group, the balance of internal and external forces on patellofemoral joint is disturbed and causing pressure on the joint and pain[1]. Due to pain the person with PFPS, reduces the motion of joint and it causes weakness of muscles and this weakness intensifies imbalance of forces on patellofemoral joint[7,8,13]. Therefore, this defective cycle is repeated. As our results, Hwang et al[36] showed that the EMG activity of muscle in PFPS group was less than healthy group. Also Giles et al[37] showed that atrophy of the quadriceps muscle was seen in person with PFPS. The quadriceps muscle strengthening program is one of the most important part of PFPS treatment and studies showed the effectiveness of these exercises on reduce pain and improvement of PFPS treatment[14,16,17].

SLR is one of the exercises that are often recommended for strengthening quadriceps muscle in patients with knee problems[24]. According to the results of this study, PNF patterns without load activated VMO muscle similar to the SLR. Mikaili et al[24] and Choi et al[1] showed that by adding external rotation and dorsiflexion to the SLR, the contraction force of VMO and VL muscles increases. Previous studies showed that, adding adduction to open and close kinematic chain exercises could increase VMO activity too[8,25,26,32,38]. Due to the origin of the VMO from adductor Magnus, contraction of adductor muscles can provide a stable origin for VMO and increase its activity[8,32]. The mentioned motions are similar to the D_1FL that used in this study, which simultaneously included flexion, adduction, external rotation and dorsiflexion. In fact, the PNF patterns by combining different components of motion together simultaneously and being functional can activate the VMO and VL muscles well. Based on the principle of Overflow (Irradiation) proposed in PNF, a muscle contraction in an area can affect the contraction of another muscle in the distant area and thus facilitates the activation of the weakened or inhibited muscle[10,18,19]. Also, according to another PNF facilitation principle (stretch reflex) starting the lower PNF patterns from the antagonist pattern, as it was used in this study, can improve weak muscle function[18]. Shimura et al[10] showed that facilitation position compared to normal position lead to increased muscle discharge and motor evoked potential, decreased muscles reaction time and latency, and improvement of joint functional movements.

The other results of the study were PNF patterns with load could significantly increase the VMO and VL activity. In agreement with our results, Sykes and Wong[21] found that adding external rotation to SLR was suitable for patients with PFPS, especially if this movement is done with a weight. In another study Wong[39] suggested that it is better to do exercises with weight to improve the neuromotor control in the vasti muscles. Also, Rhyu et al[19] showed the positive effect of PNF patterns using the Theraband resistance on the activation of the abductor muscles. In our study performing the PNF patterns with a low weight, increased VMO and VL activities significantly compared to weightless patterns. The basis of resistance used in PNF patterns is reinforcement of weak muscles by strong contractions of the other muscles[18]. Unfortunately because SLR with weight wasn't assessed in this study, the comparison of PNF patterns with weight and SLR with weight weren't included in this study.

Also, our results showed that the most activity of the muscles in PFPS group and healthy group were during D_2 EX+ load and D_1FL+ load respectively. The comparison of PNF patterns showed that in PFPS group D_2EX activated the muscles more than D_1FL, while in the healthy group, D_1 FL activated the muscles more than D_2EX.

In D_2EX quadriceps contracts eccentrically in the direction of gravity, while in D_1FL quadriceps contraction is concentric and against the gravity. In agreement with our results, Douglas et al[40], and Chen et al[41], showed that eccentric exercises are better than concentric for improving muscle performance, especially if they are accompanied by resistance. Also, one of the strategies used in PNF therapeutic methods is the use of eccentric motion to facilitate the agonist muscle[10].

The other result of this study was that the VMO/VL ratio values in PNF patterns were significantly more than SLR. Also, in the PFPS group VL showed more activity during SLR compared to PNF patterns while, the VMO had the least activation during SLR. The lower VMO/VL ratio value during SLR compared to PNF patterns ratios can be attributed to lower VMO activity and/or the higher VL activity which found in our study. In PFPS group the VMO/VL ratio values in PNF patterns (with and without load) were near to the ideal 1:1 ratio and the highest VMO/VL ratio value (0.96) was found during D_2EX[7].

It is possible that during SLR hip flexion would activate the rectus femoris more than VMO and VL muscles[23]. Also the selective activation of VL compared to VMO during SLR can be increased, because VL is a mobilizer muscle and has more fibers in perpendicular orientation[6]. In contrast, PNF patterns are functional and have different motion components in different planes, so they can activate both VMO and VL muscles.

Conclusion

In PFPS group the activity of VMO during PNF patterns (without load) were more than SLR, however, these differences weren't significant. The VMO had the least activation during SLR and the most in D_2EX, but the VL had the most activity during SLR. The VMO/VL ratio values in PNF patterns were significantly more than SLR and the highest VMO/VL ratio value (0.96) was found during D_2 EX. Also, adding weight to D_1FL and D_2EX increased VMO and VL muscles activity significantly. The imbalance between VMO and VL activity is one of the most important factors in person with PFPS which PNF patterns can provide appropriate VMO/VL ratio value than SLR. Thus, these patterns (especially D_2EX) due to higher activity of VMO and lower activity of VL and proper balance between VMO and VL muscles can be recommended in rehabilitation of individuals with PFPS. Also, adding a weight even a low weight, to these patterns can increased VMO and VL activities.

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PHYSICAL THERAPY RESEARCH

SCIENTIFIC RESEARCH ARTICLE

Effects of Early Physical Therapist-supervised Walking on Clinical Outcomes after Liver Resection: Propensity Score Matching Analysis

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ABSTRACT. Objective: The study aimed to demonstrate the significance of early postoperative physical therapy interventions on clinical outcomes by determining the influence of the distance walked under the supervision of a physical therapist in the early postoperative period after liver cancer. Methods: All consecutive patients who underwent surgery for liver cancer between April 2018 and March 2020 were eligible for enrollment in the study. The total walking distance during physical therapy till the third postoperative day was examined. The clinical outcomes comprised duration of postoperative hospital stay, time to independent walking, and occurrence of postoperative complications. For data analysis, the patients were divided into two groups: those who walked more than the median total distance (the long-distance group) and those who walked less than the median distance (the short-distance group). We used propensity score matching to match the background characteristics between the groups. Results: Of the 65 patients who were eligible, 14 patients were included in the two groups each, after matching. The long-distance walking group had a significantly shorter hospital stay (9.0 days vs. 11.0 days, p=0.008) and a shorter time to independent walking (3.5 days vs. 7.5 days, p=0.019) than the short-distance walking group. There were no significant differences in postoperative complications between the two groups (7.1% vs. 42.8%, p=0.08). Conclusion: In the early postoperative period after liver cancer surgery, increasing the walking distance under the supervision of a physical therapist is important for improving clinical outcomes. Further prospective studies are needed to confirm the findings of this study.

Key words: Early postoperative physical therapy, Longer walking distances, Postoperative hospital stay, Liver cancer

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In recent years, the concept of enhanced recovery after surgery (ERAS)[1)] has become widespread, especially in postoperative patients. It is effective in reducing hospital stay and postoperative complications and aids in the recovery of gastrointestinal function[2-4)] through appropriate management before and after surgery. The early mobilization of patients after gastrointestinal surgery has been reported to be effective in reducing hospital stays and preventing complications[5,6)]. It has recently been reported that early mobilization within 24 hours after partial hepatectomy positively affects the pain score and aids the recovery of gastrointestinal function[7)], making early mobilization essential.

While there are many papers on early postoperative mobilization[5-7)], few have examined early postoperative activity. It has been reported that the duration of ‘standing time’ in the first three days after abdominal surgery is related to the length of hospital stay[8)]. It is important to maintain physical activity in the early postoperative period. It has also been reported that the presence or absence of perioperative physical therapy influences the extent of activity

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until the third postoperative day[9], and the role of physical therapists in ensuring the same in the early postoperative period is significant. In contrast, it was reported that additional walking with volunteer staff during the stable period after abdominal surgery did not affect hospital stay or complications[10]. This suggests that increasing the frequency of walking during hospitalization alone may not be sufficient to improve clinical outcomes. However, the walking with the volunteer staff of college students started after the postoperative risks had been reduced. There is no study about increasing the walking distance during the early postoperative period under the supervision of a physical therapist when the risk is considered to be higher. Demonstrating the impact of physiotherapist-supervised ambulation on clinical outcomes in the early postoperative period after hepatic tumor resection is also important for planning physiotherapy programs.

Therefore, the purpose of the present study was to examine if the distance walked under the supervision of a physical therapist in the early postoperative period after partial hepatectomy for hepatocellular carcinoma could affect the duration of hospital stay, time to independent walking, and occurrence of postoperative complications.

Method

Eligibility

All consecutive patients who underwent hepatectomy for the diagnosis of primary hepatocellular carcinoma at our hospital between April 2018 and March 2020 were considered eligible for enrollment. The exclusion criteria comprised death during hospitalization and missing data. This study was conducted in accordance with the Declaration of Helsinki, with due care taken to protect the patients. It was approved by the Ethics Committee of Aso Iizuka Hospital (Approval No. R19172). Patients were granted the option to opt-out of the study.

Physical therapy program

Physical therapy was initiated according to the attending physician's prescription. The criteria for discontinuation included the "Anderson's criteria[11]" and "obvious deterioration of respiration or circulatory dynamics from the previous day". The physical therapy program conducted until the third postoperative day consisted of walking, coughing, deep breathing, pain-free standing exercises, and patient education. The interventions were carried out twice a day (in the morning and afternoon) for 20-40 minutes, until the third day after surgery. From the fourth day onwards, the physical therapy program included exercise therapy in the rehabilitation room where the patient could walk 300 meters. Exercise therapy included aerobic exercises, such as bicycle ergometer and treadmill walking, and resistance training. The interventions were performed every day, five to six times a week for 40-60 minutes.

Measurement items

The following items were extracted retrospectively from medical records. Walking distance was the primary factor, that was defined as the total distance walked during physical therapy until the third postoperative day. Walking distance was measured by the number of laps made around the 30, 100, and 110-meter circuits in the ward. The primary outcome of this study was the duration of postoperative hospital stay. The secondary outcomes were time to independent walking and occurrence of postoperative complications. Background factors included age, sex, body mass index (BMI), geriatric nutritional risk index (GNRI), Charlson Comorbidity Index (CCI), hepatocellular carcinoma stage, surgical procedure (laparoscopic or laparotomy) and intraoperative blood loss. The postoperative items measured comprised the duration of urinary catheterization, the deterioration in activities of daily living (ADL), whether the patient was transferred to a hospital for rehabilitation, and the presence of pain from postoperative days 1 to 7.

Postoperative complications

The Clavien-Dindo classification[12,13] was used to measure the postoperative complications. Postoperative complications were defined as grade II or higher in the Clavien-Dindo classification based on previous studies[14]. In addition, the presence or absence of the following: atelectasis due to pleural effusion within one week after surgery, delirium diagnosed by a psychiatrist, lower extremity thrombus, internal carotid artery thrombus, portal vein thrombus, bile leak, ileus, pseudomembranous enteritis, liver failure, and postoperative hemorrhage were noted during the postoperative period until discharge and were extracted from the medical records.

Measurement of ADLs

The Katz Index[15] is a highly reliable and valid assessment tool of ADL ability[16-18]. The definition of deterioration in ADL ability[19] was a decrease of 1 point or more between the preoperative period and the time of discharge from the hospital.

Measurement of pain

The numeric rating scale (NRS) is a reliable and valid assessment of postoperative pain[20,21]. In this study, the NRS scores were categorized into three categories according to the National Comprehensive Cancer Network guidelines[22]: 0-3 points for mild, 4-6 points for moderate, and 7-10 points for severe.

Statistical analysis

For statistical analysis, patients were divided into two groups based on the association of the walking distance: a

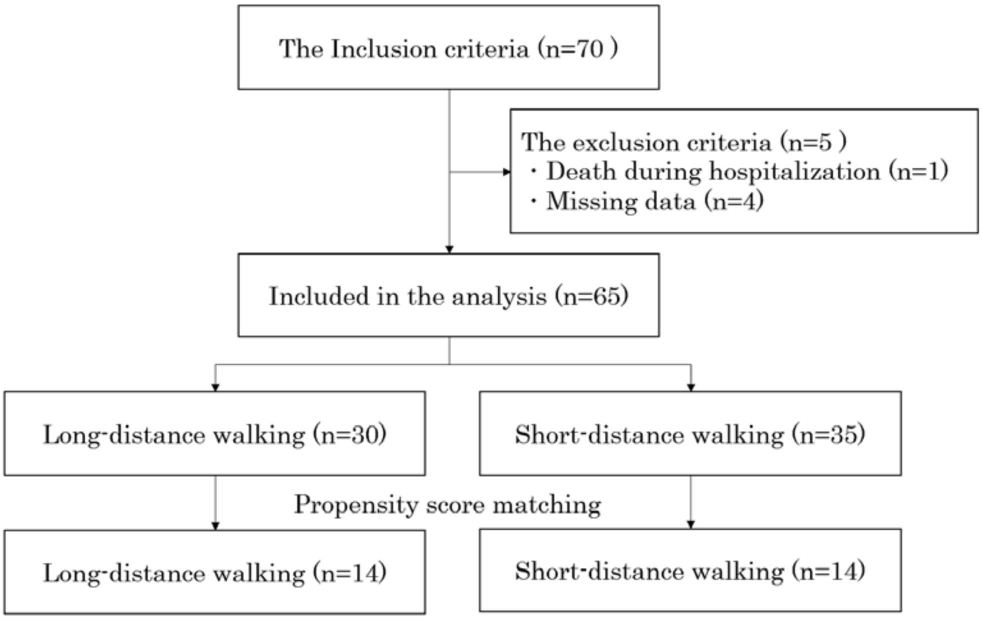

Fig. 1. Study flow chart in this study

long-distance walking group and short-distance walking group. Regarding the walking distance, we divided the patients into two groups using the median walking distance because there was no previous study with reports or results that could be used to divide them into two groups. For the continuous variables in each measurement item, the unpaired t-test was used for those with normality, and the Wilcoxon rank sum test was used for those without normality. Categorical variables were assessed using the χ^2 test.

To examine the effect of walking distance on the outcome, we calculated the probability of walking distance after adjusting for confounders. We matched long-distance walkers and short-distance walkers using the approximate probability approach, and we compared the two groups based on the outcomes using the propensity score method. The variables used to calculate the propensity score were age, sex, GNRI, CCI, intraoperative blood loss, and surgical procedure, which could affect walking distance and outcome. The optimal range of matching (caliper) was set to ±20% of the standard deviation for the propensity score, which is the standard value. After matching, the two groups were compared using the χ^2 test for categorical variables and the Wilcoxon rank sum test for continuous variables. The statistical analysis software used was Stata Statistical Software (Release 15. College Station, TX: StataCorp LLC), and the significance level was set at 5%.

Results

Background characteristics

Of the 70 patients who met the eligibility criteria, 65 patients were included in the analysis, four patients were excluded because they had some missing data and one patient died during hospitalization (Fig. 1). The median age (interquartile range) was 72.0 (69.0-78.0) years, and 45 patients (69%) were male. The median walking distance was 530 m. Thirty patients in the long-distance walking group and 35 patients in the short-distance walking group walked a total of 530 m, and the balance was adjusted, 14 and 14 patients in the long-distance and short-distance walking groups, respectively, were matched.

On comparing the background factors between the two groups before propensity score matching, the long-distance walking group had a significantly higher percentage of patients who underwent laparoscopic surgery (p=0.007) and had a less intraoperative blood loss (p=0.024), shorter operation time (p=0.04), and shorter anesthesia time (p=0.008). After propensity score matching, there was no significant difference between the groups, and the balance was adjusted (Table 1).

Comparison of outcomes

The median duration of postoperative hospital stay in the long-distance walking group was 9.0 days, while that in the short-distance walking group was 11.0 days (p=0.008). The median time taken to walk independently was 3.5 days in the long-distance walking group and 7.5 days in the short-distance walking group (p=0.019). Regarding postoperative complications, the percentage of complications classified as grade II or higher as per the Clavien-Dindo classification were inclined to be higher in the short-distance walking group (42.8%) when compared to the long-distance walking group (7.1%) (p=0.077) (Table 2).

Postoperative factors

There were no items that showed significant differ-

Table 1. Patient characteristics before and after propensity score matching

	All patients n=65			Propensity-matched patients n=28		
	Long-distance walking (n=30)	Short-distance walking (n=35)	p-value	Long-distance walking (n=14)	Short-distance walking (n=14)	p-value
Total gait distance, m	940.0 [726.3, 1187.5]	390.0 [270.0, 442.5]	<0.001	940.0 [728.8, 1175.0]	340.00 [272.5, 436.3]	<0.001
Age, year	72.0 [69.3, 76.8]	72.0 [69.0, 79.0]	0.490	73.0 [66.0, 76.8]	72.5 [71.0, 77.8]	0.490
Sex, male	22 (73.3)	23 (65.7)	0.595	9 (64.3)	10 (71.4)	1
BMI, kg/m²	24.0 [20.5, 25.8]	23.0 [21.0, 24.0]	0.133	24.0 [20.0, 25.0]	23.0 [19.8, 23.8]	0.200
GNRI	114.0 [110.0, 118.0]	111.0 [105.5, 113.5]	0.087	112.0 [103.0, 117.5]	106.5 [103.3, 112.0]	0.311
CCI, <3	23 (76.7)	32 (91.4)	0.167	14 (100.0)	12 (85.7)	0.481
Cancer stage			0.655			0.870
I	11 (36.7)	9 (25.7)		6 (42.9)	6 (42.9)	
II	15 (50.0)	19 (54.3)		7 (50.0)	5 (35.7)	
III	4 (13.3)	5 (14.3)		1 (7.1)	2 (14.3)	
IV	0 (0.0)	2 (5.7)		0 (0.0)	1 (7.1)	
Laparoscopy	15 (50.0)	6 (17.1)	0.007	5 (35.7)	3 (21.4)	0.678
Blood loss, ml	102.5 [50.0, 259.0]	250.0 [127.0, 465.0]	0.024	150.0 [51.5, 259.0]	240.0 [156.0, 380.0]	0.370
Operative time, min	184.50 [150.00, 234.50]	248.00 [211.50, 305.00]	0.004	212.50 [162.50, 238.25]	235.00 [209.50, 302.25]	0.148
Anesthesia time, min	278.50 [218.75, 320.75]	328.00 [288.00, 378.00]	0.008	302.50 [240.75, 331.50]	317.50 [278.75, 385.25]	0.26

BMI, body mass index; GNRI, geriatric nutritional risk index; CCI, Charlson Comorbidity Index.
n (%), median [25, 75%]

Table 2. The differences of hospital stay, the time to independent walking, and complications between long and short distance groups.

	All patients n=65			Propensity-matched patients n=28		
	Long-distance walking (n=30)	Short-distance walking (n=35)	p-value	Long-distance walking (n=14)	Short-distance walking (n=14)	p-value
Postoperative hospital stay, days	9.0 [8.0, 10.0]	11.0 [9.0, 13.0]	<0.001	9.0 [8.0, 9.8]	11.0 [9.0, 14.5]	0.008
The time to independent walking, day	4.0 [3.0, 5.0]	4.0 [4.0, 10.0]	0.013	3.5 [3.0, 4.8]	7.5 [4.0, 10.0]	0.019
The Clavien-Dindo Classification, ≥II	7 (23.3)	15 (42.9)	0.12	1 (7.1)	6 (42.8)	0.077

n (%), median [25, 75%]

ences in postoperative factors after matching (Table 3).

Discussion

This study showed that the distance walked by patients under the supervision of a physiotherapist during the early postoperative period after partial hepatectomy for hepatocellular carcinoma affected the duration of hospitalization. Furthermore, it influenced how quickly they could walk independently.

Association with the hospital stay

Long-distance walking under physiotherapist supervision in the early postoperative period after partial hepatectomy affected the length of hospital stays. Browing et al.[8] stated that the duration of standing in the early postoperative period was an important indicator for the length of hospital stay after upper abdominal surgery. The outcomes

Table 3. The differences of the duration of urinary catheterization, ADLs deterioration, hospital transfer, and types of complications and pain between long and short distance groups.

			All patients, n=65			Propensity-matched patients, n=28		
			Long-distance walking (n=30)	Short-distance walking (n=35)	p-value	Long-distance walking (n=14)	Short-distance walking (n=14)	p-value
The duration of urinary catheterization, day			3.0 [2.0, 3.0]	3.0 [3.0, 4.0]	0.002	3.0 [2.0, 4.0]	3.5 [3.0, 4.0]	0.084
ADLs deterioration		yes	3 (10.0)	8 (22.9)	0.201	2 (14.3)	5 (35.7)	0.685
Hospital transfer		yes	1 (3.3)	2 (5.7)	1	0 (0.0)	2 (14.3)	0.481
Types of complications	Atelectasis	yes	9 (30.0)	16 (45.7)	0.213	5 (35.7)	7 (50.0)	0.704
	Delirium	yes	1 (3.3)	4 (11.4)	0.363	1 (7.1)	3 (21.4)	0.596
	Lower extremity thrombus	yes	1 (3.3)	3 (8.6)	0.618	0 (0.0)	2 (14.3)	0.481
	Internal carotid artery thrombosis	yes	1 (3.3)	2 (5.7)	1	0 (0.0)	1 (7.1)	1
	Portal vein thrombosis	yes	4 (13.3)	6 (17.1)	0.742	1 (7.1)	1 (7.1)	1
	Bile leak	yes	0 (0.0)	0 (0.0)		0 (0.0)	0 (0.0)	
	Ileus	yes	1 (3.3)	1 (2.9)	1	0 (0.0)	1 (7.1)	1
	Enteritis	yes	2 (6.7)	0 (0.0)	0.209	0 (0.0)	0 (0.0)	
	Liver failure	yes	0 (0.0)	0 (0.0)		0 (0.0)	0 (0.0)	
	Postoperative hemorrhage	yes	0 (0.0)	2 (5.7)	0.495	0 (0.0)	0 (0.0)	
NRS	Day1	mild	20 (66.7)	24 (68.6)	1	9 (64.3)	10 (71.4)	1
		moderate	4 (13.3)	5 (14.3)		4 (28.6)	3 (21.4)	
		severe	6 (20.0)	6 (17.1)		1 (7.1)	1 (7.1)	
	Day2	mild	19 (63.3)	20 (57.1)	0.076	9 (64.3)	10 (71.4)	1
		moderate	6 (20.0)	14 (40.0)		4 (28.6)	4 (28.6)	
		severe	5 (16.7)	1 (2.9)		1 (7.1)	0 (0.0)	
	Day3	mild	19 (63.3)	23 (65.7)	0.549	8 (57.1)	9 (64.3)	1
		moderate	8 (26.7)	11 (31.4)		6 (42.9)	5 (35.7)	
		severe	3 (10.0)	1 (2.9)		0 (0.0)	0 (0.0)	
	Day4	mild	23 (76.7)	25 (71.4)	0.299	11 (78.6)	10 (71.4)	1
		moderate	4 (13.3)	9 (25.7)		3 (21.4)	4 (28.6)	
		severe	3 (10.0)	1 (2.9)		0 (0.0)	0 (0.0)	
	Day5	mild	23 (76.7)	28 (80.0)	0.904	11 (78.6)	11 (78.6)	1
		moderate	4 (13.3)	5 (14.3)		3 (21.4)	3 (21.4)	
		severe	3 (10.0)	2 (5.7)		0 (0.0)	0 (0.0)	
	Day6	mild	24 (80.0)	26 (74.3)	0.69	12 (85.7)	9 (64.3)	0.472
		moderate	2 (6.7)	5 (14.3)		1 (7.1)	3 (21.4)	
		severe	4 (13.3)	4 (11.4)		1 (7.1)	2 (14.3)	
	Day7	mild	26 (86.7)	29 (82.9)	0.222	13 (92.9)	11 (78.6)	0.596
		moderate	1 (3.3)	5 (14.3)		1 (7.1)	3 (21.4)	
		severe	3 (10.0)	1 (2.9)		0 (0.0)	0 (0.0)	

ADL, Activities of daily living; NRS, The numeric rating scale
n (%), median [25, 75%]

were similar to those in the present study, in which the factor under consideration was a longer walking distance under the supervision of a physical therapist. Hussey et al.[23] reported that in postoperative patients with esophageal cancer, 96% of the day is spent in a sitting or supine position until the fifth day after surgery. The early postoperative period after hepatic resection is also long, and it is likely that patients do not stand or walk except during physical therapy. In the early postoperative period after hepatocellular carcinoma surgery, it is imperative to provide an environment in which patients can stand and walk under the supervision of a physical therapist to improve their physical activity.

Association with independent walking

Long-distance walking under the supervision of a physical therapist in the early postoperative period after hepatocellular carcinoma surgery affected the time taken to walk independently. de Almeida et al.[24)] reported that the implementation of a discharge program that included early walking under the supervision of a physical therapist after abdominal tumor surgery was related to early recovery of physical function. Comparable results were obtained in the present study when the defined factor was a longer walking distance under the supervision of a physical therapist in the early postoperative period. Therefore, walking practice in the early postoperative period could be important in early discharge programs. Additionally, it has been reported that pain[25)] and postoperative complications[25,26)] affect the recovery of postoperative physical function. In this study, there was no significant difference in pain or postoperative complications between the two groups. However, the long-distance walking group tended to have fewer postoperative complications, which may have influenced the recovery in physical function. These results suggest that active walking practice in the early postoperative period may prevent postoperative complications and shorten the time to independent walking after surgery.

Association with postoperative complications

The long-distance walking group had a lower rate of postoperative complications than the short-distance walking group, but the difference was not significant. Ni et al.[3)] reported that early mobilization after hepatocellular carcinoma surgery did not show a significant reduction in complications, but there was a lower rate of pleural effusion and lower extremity thrombus. In this study, the long-distance walking group tended to have a lower rate of postoperative complications like lower extremity thrombus, atelectasis due to pleural effusion, and delirium, although the difference was not significant as well. Extending the walking distance in the early postoperative period after hepatic resection may be effective against some postoperative complications.

There are three important limitations of the present study. First, the sample size was small, and there were not enough events to adjust for confounders in the multivariate analysis[27)]. Therefore, the propensity score method was used for the analysis. It has been reported that when adjusted for the same variables, the results of both the propensity score and classical multivariate analysis are approximately the same[28)]. Therefore, in this study, we believe that the confounding factors were sufficiently accounted for despite a small sample size and fewer number of events. Second, because we collected information from medical records in a retrospective study, we were unable to obtain adequate items for measurement. Due to ethical issues, it was difficult to conduct an interventional study with a control group in which the walking distance is shortened. Therefore, it is necessary to examine the other unmeasured items prospectively in the future. Third, since this study was not a prospective interventional trial, the walking distance could have been shorter due to various factors, such as risk management and judgement of the therapist. In a retrospective study, it was difficult to identify factors that led to a reduction in the walking distance. Therefore, the investigation of the causes for shorter walking distances requires prospective studies and is a topic for future research.

Conclusion

This is the first study to demonstrate that a longer walking distance under the supervision of a physiotherapist in the early postoperative period after partial hepatectomy could affect the length of hospital stays and the time to independent walking. In the early postoperative period after partial hepatectomy surgery, it is important to extend the walking distance under the supervision of a physical therapist in an appropriate environment to improve the clinical outcomes. Further prospective studies with larger number of patients are needed to confirm this result.

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Conflict of Interest: The authors declare no conflicts of interest associated with this manuscript.

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PHYSICAL THERAPY RESEARCH

SCIENTIFIC RESEARCH ARTICLE

Relationship between Perceived Leg Length Discrepancy at One Month and Preoperative Hip Abductor Muscle Elasticity in Patients after Total Hip Arthroplasty

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ABSTRACT. Objective: Preoperative factors related to perceived leg length discrepancy (PLLD) after total hip arthroplasty (THA) are not well studied. This study aimed to examine the preoperative factors, including hip abductor modulus, related to PLLD one month after THA. Methods: The study included 73 patients diagnosed with osteoarthritis secondary to developmental dysplasia of the hip and a posterior approach to surgery. Multiple logistic regression analysis was performed using the presence or absence of PLLD as the dependent variable and preoperative hip abductor's modulus of elasticity, pain, hip abduction range of motion, hip abductor muscle strength and pelvic obliquity as the independent variable. Additionally, receiver operating characteristic curves were used for the extracted variables for calculating the cutoffs, sensitivity, specificity and area under the curve (AUC) to determine the presence or absence of PLLD. The significance level was set at p<0.05. Results: The hip abductor modulus (odds ratio=1.13; 95% confidence interval=1.06-1.21; p<0.001) was selected as a preoperative factor. The cutoff value to determine the presence or absence of a PLLD was 16.32 kPa. The sensitivity and specificity were 81.8% and 72.5%, respectively, and the AUC was 0.8137. Conclusion: The hip abductor muscle elastic modulus affected PLLD one month after THA. If the preoperative hip abductor elastic modulus is higher than the cutoff value, it may affect the appearance of PLLD at one month postoperatively.

Key words: Total hip arthroplasty, Perceived leg length discrepancy, Preoperative factors, Shear-wave elastography

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Total hip arthroplasty (THA) is one of the orthopedic treatments for osteoarthritis (OA), and the procedure has been reported to provide excellent pain relief and improve patients' range of motion (ROM) and walking ability[1)]. However, we frequently encounter cases wherein patients complain about a subjective leg length discrepancy, which is more significant than the leg length discrepancy seen on radiographic images (structural leg length discrepancy) after the surgery. Perceived leg length discrepancy (PLLD) is generally defined as the leg length discrepancy that the patient is aware of and is also referred to as functional leg length discrepancy[2,3)]. However, because these two terms are almost synonymous, PLLD is used throughout this paper.

Hofmann et al.[4)] reported that the leg length difference after THA is the main reason for postoperative lawsuits. Pakpianpairoj et al.[5)] reported that postoperative EuroQol 5 Dimension (EQ-5D) decreases in patients with leg length differences. The EQ-5D evaluates 5 dimensions of questions, including mobility, self-care, usual activities, pain/

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discomfort and anxiety/depression. EQ-5D is a standardized instrument for use as a measure of health outcome. Nakanowatari et al.[6] reported that PLLD is an important postoperative condition and decreases the patient's health-related quality of life. Furthermore, as a functional problem, PLLD after THA is associated with low back pain, decreased ability to walk, and decreased functional improvement[7,8]. In a previous report, Holtzman et al.[9] reported that patients with severe preoperative pain, reduced ability to walk, and who perform activities of daily living (ADL) had reduced postoperative function. Regarding the effects of preoperative physical therapy, Wang et al.[10] reported a slight decrease in pain and a significant effect on Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC), stair climbing, toilet use and chair start date at 6-8 and 12 weeks. As reported by Moyer et al.[11] a recent meta-analysis evaluating the effects of preoperative rehabilitation showed improvements in pain, function and hospital stay length. Furthermore, preoperative rehabilitation was reported to affect pain reduction, quality of life and overall satisfaction at one year postoperation[12]. On the contrary, Fujita et al.[13] reported that physical functions such as pain and ROM significantly improved up to six weeks after THA. We believe that preoperative rehabilitation plays an essential role in improving various functions in the early postoperative period.

The ROM of hip adduction pelvic obliquity and lateral mobility of the lumbar vertebrae are factors reported to affect PLLD[14,15]. Chi et al.[16] stated that shortening of the hip abductor muscles occurs with the displacement of the femoral head. Jasty et al.[17] reported that the degree of hip abductor stretch due to surgical leg extension and increased femoral offset length affects PLLD after THA. However, despite these reports, we could not find any study that objectively evaluated and examined soft tissues such as hip abductor muscles by shear wave elastography as preoperative factors affecting PLLD. In line, we believe that the identification of the preoperative factors involved in PLLD could facilitate the development of efficient preoperative physical therapy interventions. In the past, the stiffness (modulus) of the hip abductor muscles was qualitatively assessed by therapists through palpation and ROM measurements, for the lack of precise quantitative and non-invasive assessment techniques. However, the elastic modulus of a muscle can also be calculated using the recently developed shear wave elastography to indicate muscle stiffness. The technique makes it possible to compare the degree of elongation of the same muscle[18,19]. In this study, we objectively assessed the preoperative elastic modulus of the hip abductor muscles by shear wave elastography and investigated the preoperative factors associated with PLLD at one month after THA, including the hip abductor elastic modulus.

Materials and Methods

Experimental design

A longitudinal, observational study

Subjects

The study population included 116 patients who met the inclusion criteria among a total of 289 patients who underwent THA at our hospital between August 1, 2018, and March 31, 2019. The inclusion criteria were as follows: 1) preoperative diagnosis of secondary osteoarthritis of the hip due to developmental dysplasia of the hip, 2) the first THA for hip OA performed using the posterolateral approach, 3) patient consent to participate in this study. The exclusion criteria were as follows: 1) required postoperative exemption (4), 2) history of orthopedic disease affecting leg length discrepancy (13), 3) preoperative knee joint flexion contracture of 5° or more (5), 4) dislocated, neurological diseases and infectious diseases after surgery (0), and 5) incomplete preoperative records or incomplete records at one month postoperation (21). The final analysis was conducted on 73 patients (Fig. 1).

Regarding the measurement of structural leg length difference, the left-right difference was assessed using the distance between the teardrop and the lesser trochanter on a simple X-ray frontal image of both hips in the supine position. The difference between the left and right sides was measured using the distance between the teardrop and the lesser trochanter.[20] The measurements were made in units of 0.1 mm, with positive values for longer distances on the operative side and negative values for shorter distances on the operative side.

Ethical considerations

This study was conducted in accordance with the Declaration of Helsinki and the Ethical Guidelines for Clinical Research. The subjects were fully informed of the purpose of the study and their privacy protection. All of them provided written consent to participate in the study. This study was conducted following the review and approval by the Research Ethics Review Committee of the Medical Corporation Wajokai Eniwa Hospital and the Research Ethics Review Committee of the Hokkaido Bunkyo University (Wajokai Eniwa Hospital, Approval No. 77 and Hokkaido Bunkyo University Approval No. 01004).

Outcome Measures

Perceived leg length discrepancy

A block test was used for PLLD measurements. Specifically, a 5-mm plate was inserted under the sole in a spontaneous standing position with both upper limbs in a drooping position and the feet shoulder-width apart. The height at which the sensation of PLLD disappeared was

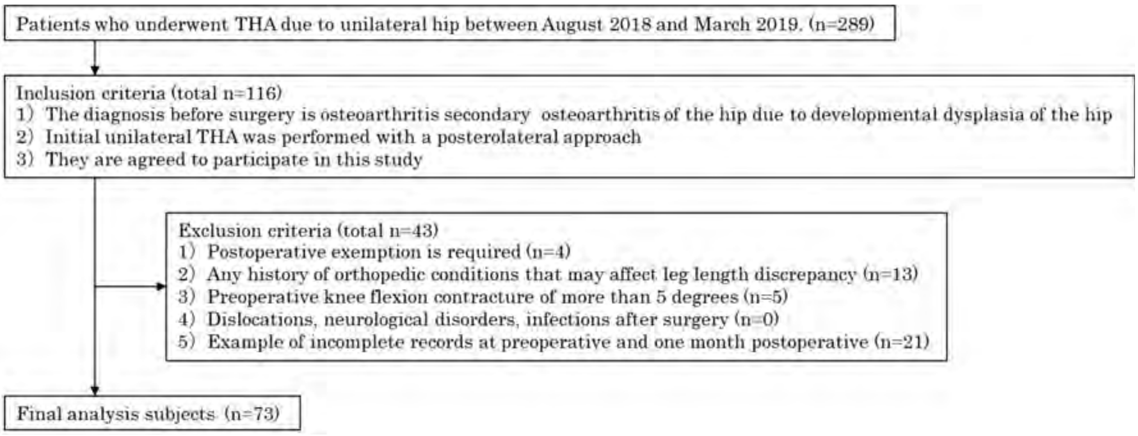

Fig. 1. Flow diagram of participant recruitment for THA in the present study.
THA: total hip arthroplasty

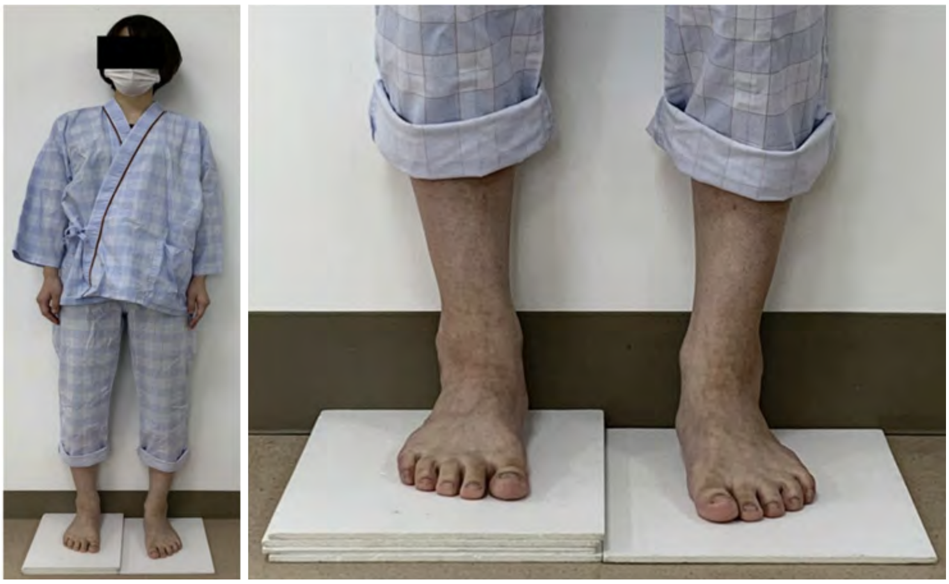

Fig. 2. A block test was used to measure the PLLD. A 5-mm plate was inserted into the sole of the foot with both upper limbs drooping and the legs shoulder-width apart. The height at which the feeling of leg length discrepancy was then measured.

then measured[21]. The postoperative subjective leg length discrepancy was divided into two groups, namely one with a leg length discrepancy of 5 mm or longer than the structural leg length discrepancy and one without a leg length discrepancy lower than 5 mm (Fig. 2).

Pain

Preoperative gait pain was assessed to the nearest 1 mm using the Visual Analog Scale.

Pelvic obliquity

The angle of supine pelvic obliquity in frontal images was used. The lateral pelvic tilt angle in the anterior forehead plane was measured as the line connecting the bilateral teardrop and the horizontal line[14]. Measurements were taken in 0.1° increments. The pelvic tilt angle was measured in 0.1° increments, with positive values for the downward pelvic tilt direction and negative values for the upward pelvic tilt direction.

Hip abductor muscle strength

The Hand-Held Dynamometer (HHD) utilized in this study was a Power Track IITM Commander (Nihon Medix, Matsudo, Japan). Each patient was placed in the supine position with intermediate hip abduction, secured with a belt such that the lower end of the sensory part of the HDD was at the level of the knee joint. The maximum isometric contraction of hip abduction was performed for 5 s[22]. The average values of three measurements were multiplied by the measured value (N) and the lever arm length (m) from the femoral trochanter to the knee joint cleft (Nm), divided by the body weight (Nm/kg).

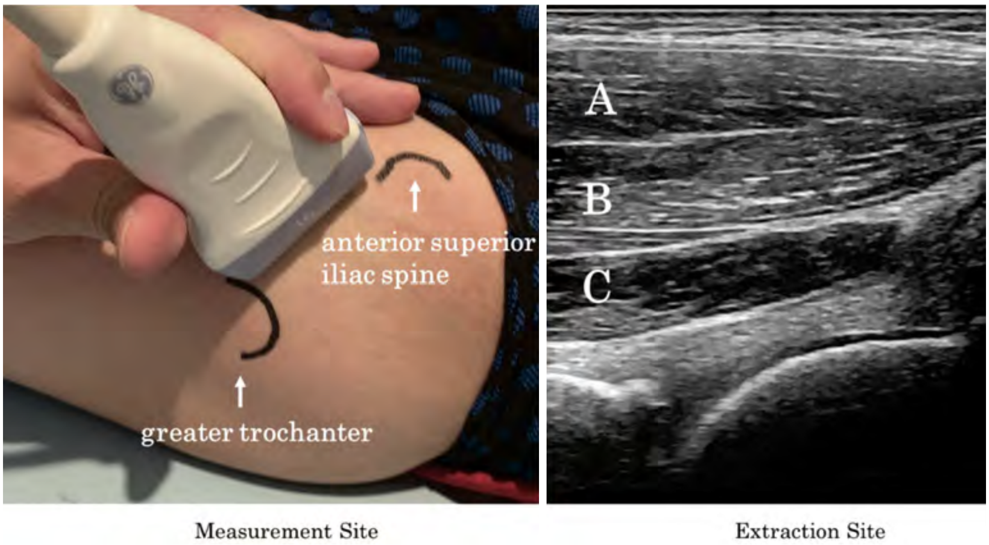

Fig. 3. Measurement site: the longitudinal section of the muscle at the midpoint between the operative superior anterior iliac spine and the superior end of the greater trochanter.
Extraction site: A. Tensor fasciae femoris, B. Gluteus medius, C. Gluteus minimus

ROM for hip adduction

The ROM for hip adduction was measured using an angle meter, according to the method established by the Japanese Society of Rehabilitation Medicine. The ROM was measured in 5° increments, considering compensatory movements such as the lateral pelvic tilt and lateral trunk flexion.

Hip abductor modulus of elasticity

The measurements were performed by physical therapists with over six years of clinical experience. The examiner was positioned on the operative side of the patient and was in a sitting position. The dominant hand (right hand) grasped the probe, and the muscle was palpated and captured on ultrasound images based on the muscle's anatomical structure. Each subject's hip was measured in the dorsal recumbent position with intermediate hip abduction and internal/external rotation with 10° of hip flexion to avoid the flexion contracture and postoperative pain. A rolled bath towel was used in the knee socket to fix the flexion position. Efforts were made to measure the hip flexion angle with a goniometer and to fix the limb position during the measurement.

The modulus of elasticity was calculated for the tensor fasciae femoris, the gluteus medius and the gluteus minimus together as the hip abductor muscle. The extracted area of the abductor muscle was the longitudinal section of the muscle of the superior anterior iliac spine and the greater trochanter as a landmark, with the probe tilt angle defined as the angle at which the greater trochanter showed the highest intensity[23]. The probe's position was determined by capturing the tensor fascia major, medius and gluteus medius muscles on ultrasound images. In addition to ensuring constant contact pressure of the probe, we specified manual contact using a gel without compressing the skin at the minimum pressure that allowed us to obtain an image (Fig. 3).

The hip abductor muscle's elastic modulus was calculated from the ultrasound images taken using a shear wave elastography ultrasound system (GE Healthcare Japan's LOGIQS8) and a linear probe (9 MHz center frequency). Shear wave elastography acquires the induced shear waves at an ultrafast frame rate and calculates their propagation velocity. Based on the shear wave propagation velocity, a quantitative color map image of the velocity distribution is created to obtain the shear modulus. The higher the value indicated as the elastic modulus, the stiffer the muscle, and the higher the chances of muscular limitation of the ROM. Each area was measured five times, and the average of the measurements was used for analysis.

Physical Therapy Protocol

In the postoperative protocol, the attending physician prescribed total loading for each patient in accordance with their pain levels. The patients walked with the help of a walker the day after surgery and with a cane on the third postoperative day. The patients were allowed to leave the hospital when they could walk with the help of a cane, climb stairs and perform their ADL. The postoperative stay duration was 14 days. The patients underwent regular checkups one month after the discharge. Exercise and lifestyle coaching were performed according to the patients' recovery status.

Statistical analyses

Statistical analyses were performed using two-sample

Table 1. Comparisons of the demographic characteristics of participants in the PLLD and no-PLLD groups.

Subject demographics	PLLD group (n=22)	No-PLLD group (n=51)	p Value
Age, year	66.6±3.61	67.3±3.92	0.676*
Female, % (n)	95.4 (21)	84.3 (43)	0.872#
Height, m	1.53±0.05	1.56±0.06	0.334*
Weight, kg	53.2±8.4	53.6±9.2	0.641*
Body mass index, kg/m^2	0.65±0.12	0.62±0.03	0.103*
Crowe class, type			
I, % (n)	86.3 (19)	90.1 (46)	0.432#
II, % (n)	9.2 (2)	7.9 (4)	0.532#
III, % (n)	4.5 (1)	2.0 (1)	0.321#
IV, % (n)	0 (0)	0 (0)	

Values are presented as mean±standard deviation
PLLD: perceived leg length discrepancy
Note: *t-test #χ^2 test

Table 2. Measurements items and differences between the PLLD and no-PLLD groups.

	PLLD group (n=22)	No-PLLD group (n=51)	p Value
PLLD, mm	11.14±3.61	2.52±3.92	<0.001*
Structural leg length discrepancy, mm	2.32±2.51	2.61±2.21	0.633*
VAS, mm	44.35±14.07	49.34±19.02	0.432*
Pelvic obliquity, °	0.32±2.43	1.33±2.31	0.642*
Hip abductor muscle strength, Nm/kg	0.65±0.12	0.62±0.03	0.921*
Range of motion for hip adduction, °	2.53±8.41	3.22±7.52	0.271*
Hip abductor's modulus of elasticity, kPa	20.62±6.97	11.74±8.23	<0.001*

Values are presented as mean±standard deviation
PLLD: perceived leg length discrepancy
VAS: Visual Analog Scale
Pelvic obliquity: +tactical underhand, −tactical overhand
Note: *t-test

Table 3. Preoperative factors affecting PLLD at one month.

	Odds Ratio	95%CI	p Value
Hip abductor's modulus of elasticity	1.13	1.06-1.21	0.004

PLLD: perceived leg length discrepancy
χ^2 test: p=0.012
Hosmer-Lemeshow test: p=0.064

t- or Mann-Whitney test to assess the difference between the two groups after confirming the normality by Shapiro-Wilk tests. To identify the preoperative factors affecting PLLD at one month after THA, stepwise multiple logistic regression analysis was performed using the presence or absence of PLLD at one month after THA as the dependent variable and each preoperative examination as the independent variable.

Also, the PLLD at one month postoperatively was classified into two groups based on the presence or absence of PLLD. Receiver operating characteristic (ROC) curves were used for the variables extracted by multiple logistic regression analysis to calculate the cutoff value, sensitivity, specificity and area under the curve (AUC) to determine the presence or absence of PLLD using R2.8.1 (CRAN: freeware; http://www.r-project.org/and accompanying software packages) with a significance level of p<0.05.

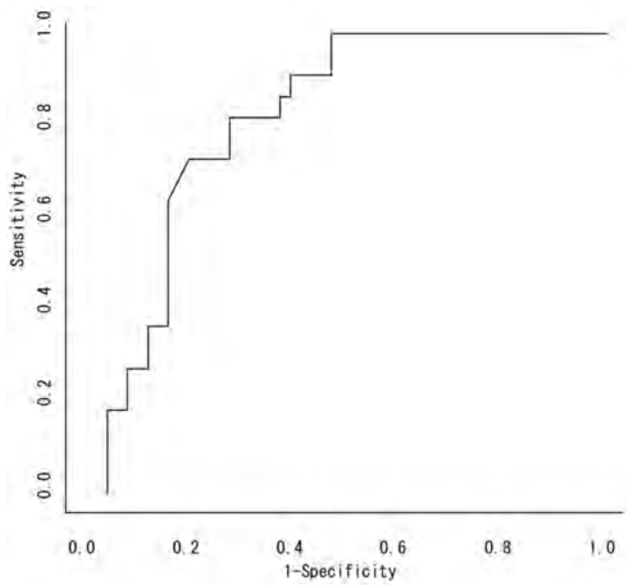

Fig. 4. ROC curve of preoperative hip abductor modulus to determine the presence of PLLD.

Results

Patient selection in the THA group is shown in Figure 1. Finally, 73 patients were included in the analysis. PLLD assessed at one month after surgery revealed 22 (30%) and 51 (70%) patients with and without PLLD, respectively. Preoperative hip abductor muscle elasticity was significantly higher in the PLLD group ($p<0.001$). Details of the two groups are shown in Table 1, 2.

A multiple logistic regression analysis showed that the model $\chi 2$ test was significant and identified hip abductor modulus as a preoperative factor affecting PLLD at one month postoperatively (odds ratio = 1.13; 95% confidence interval = 1.06-1.21; $p<0.004$). The result of the Hosmer-Lemeshow test was not significant. (Table 3).

Using the presence or absence of PLLD at one month postoperatively as the dependent variable, ROC curves were drawn to examine the cutoff value of hip abductor modulus, as the preoperative factor identified by the multiple logistic regression analysis. The cutoff value for the presence or absence of PLLD was 16.32 kPa. The sensitivity and specificity were 81.8% and 72.5%, respectively, with an AUC of 0.8137 (Fig. 4).

Discussion

The novelty of our study lies in the addition of hip abductor muscle elasticity to the preoperative factors affecting PLLD after THA. Our results showed that the hip abductor modulus is a preoperative factor affecting PLLD after THA.

When the femur is displaced proximally in patients with hip OA, the soft tissues around the affected hip joint contract, causing leg length discrepancy and hip instability[24)]. A computed tomography imaging study in patients with THA revealed significant shortening of the gluteus medius muscle on the affected side[25)]. In contrast, a magnetic resonance imaging study investigating the association between hip OA and muscle atrophy reported that the medius muscle is atrophic as the hip OA becomes more severe[26)]. These findings suggest that the preoperative shortening of the hip abductor muscle may continue after THA.

The evaluation of the hip abductor modulus by shear wave elastography in this study captured the changes in modulus due to muscle shortening associated with preoperative structural changes. It has been reported that the reproducibility of the conventional assessment of qualitative muscle stiffness by palpation is low[27)]. Therefore, objective and non-invasive evaluation methods are needed. Shear wave elastography acquires evoked shear wave signals at a very high frame rate and calculates their propagation speed. Based on the velocity of these shear waves, the shear modulus is determined by quantitative color-mapping of the velocity distribution. Shear wave elastography is highly valid and reliable for muscle tissue assessments[28,29)]. Niitsu et al.[30)] evaluated muscle stiffness and recovery after exercise using shear wave elastography. They reported that muscle stiffness continued to increase immediately after exercise, peaked on the second day after the exercise, and then was decreasing until the fourth day. Guo et al.[31)] evaluated the preoperative case of gluteal contracture using shear wave elastography and reported that the hip abductor muscle's elastic modulus was higher than that of healthy subjects and reported its usefulness in preoperative evaluation. This study's results indicate that the assessment of muscle function and disability may be helpful in clinical practice.

Because THA involves placing a cup in the primordial position, the postoperative hip abductor is expected to be stretched[32)]. A high preoperative hip abductor modulus of elasticity may affect the severity of PLLD after THA. These results suggest that the relaxation and stretching of the hip joint's abductor muscle as preoperative physical therapy may help improve PLLD after surgery. However, the effects of exercise therapy and stretching methods in patients with hip OA require further study.

This study has some limitations. Because the study was conducted in a single institution, a selection bias in patient selection may have occurred. It is therefore necessary to conduct a multicenter collaborative study in the future. Moreover, we did not assess the lateral lumbar mobility related to PLLD, as previous studies have reported an association between PLLD and lumbar lateral mobility[33)]. Total spine alignment was difficult to assess due to simple X-ray bilateral hip frontal views used in this study. Second, the lateral pelvic tilt and hip abductor modulus were evaluated in the supine position only. Although standing radiographs are commonly used to measure pelvic obliquity, we used dorsal radiographs in this study. The measurement of pelvic obliquity from standing radiographs is more likely to be affected by postural deviation due to pain. However, it is essential to examine the difference in pelvic obliquity between non-weighted and weighted positions to clarify the factors affecting PLLD. Dorsal assessment was also used to assess the hip abductor modulus in the supine position.

In line, we utilized the dorsal supine position to avoid muscle weakness and postural deviation related to pain occurring in the standing position. However, we could not deduce how the hip abductor modulus affected dynamic situations such as standing and walking. Hence, future studies should evaluate the hip abductor modulus in the standing position. The present study defined the midpoint of the superior anterior iliac spine and the midpoint of the greater trochanter as the measure points of the hip abductor's modulus. However, this is a localized assessment of the abductor hip muscle which does not represent the entire muscle. Therefore, separate evaluations of the anterior, middle and posterior regions of the hip abductor muscle are required in future studies. Finally, this study examined only preoperative factors. Therefore, it did not consider the effects of offset length, leg extension, surgical technique and implants, which are thought to be related to PLLD after THA. In the future, it would be beneficial to define all the factors that affect PLLD, including postoperative factors.

Conclusion

This study shows that hip abductor modulus was a preoperative factor affecting PLLD one month after THA. to determine the presence of PLLD, we calculated a cutoff value for preoperative hip abductor modulus. If the preoperative hip abductor elastic modulus was higher than the cutoff value, PLLD might remain one month after THA.

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Conflict of Interest: None of the authors has any conflict of interest to disclose.

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PHYSICAL THERAPY RESEARCH

SCIENTIFIC RESEARCH ARTICLE

Effect of Interventions for Improving Lumbar Motor Control on Low Back Pain in Sedentary Office Workers: A Randomized Controlled Trials

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ABSTRACT. Objective: To clarify the effect of intervention with dynamic motor control exercise (DMCE) for the lumbar region on low back pain in sedentary office workers (SOWs). Methods: The participants comprised 32 SOWs with low back pain who were randomly categorized into two groups: the DMCE group and the normal trunk exercise (NTE) group. Both groups performed each exercise for three days per week for 8 weeks. The primary endpoints were evaluated for the lumbar and hip flexion angles during trunk forward bending, effect of low back pain on activities of daily living (using the Oswestry Disability Index), and intensity of low back pain (using the Visual Analog Scale) pre- and post-intervention. The extent of changes was calculated by subtracting the pre-intervention value from the post-intervention value and was compared between the two groups using an unpaired *t*-test. Results: The extent of changes in the lumbar flexion and hip flexion angles at 10° of trunk forward bending were significantly greater in the DMCE group than in the NTE group, and no significant differences were noted between the two groups at other angles of trunk forward bending. The extent of changes in the Oswestry Disability Index and the Visual Analog Scale scores were significantly greater in the DMCE group than in the NTE group. Conclusion: DMCE is effective in improving motor control in the lumbar region and hip joints, thereby ameliorating low back pain in SOWs.

Key words: Low back pain, Dynamic motor control exercise, Sedentary office workers

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The lifetime prevalence of low back pain in Japan is approximately 83%[1)]. Low back pain is one of the most common occupational diseases[2)] and has significant social and economic impacts such as decreased labor productivity[3)]. In recent years, the number of sedentary office workers (SOWs) who work in a seated position for prolonged periods has increased with the development of the information technology industry[4)]. Subsequently, the prevalence of low back pain in SOWs has increased each year[5)]. Therefore, establishing a strategy to prevent back pain in SOWs has become socioeconomically important.

Impairment of the lumbar motor control, which controls movement of the lumbar region, is considered to be one of the causes of low back pain[6)]. Individuals with low back pain reportedly exhibit excessive lumbar region movement during the early stages of trunk and lower extremity movements[6)]. Sahrmann et al.[7)] reported that repetitive or sustained loading due to habitual movement patterns in daily life can cause microdamage to tissues. To summarize, individuals with low back pain are habituated to a movement pattern in which the lumbar region moves excessively during the early stages of trunk and lower extremity movements; this lumbar motor control impairment is thought to cause low back pain[6)].

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SOWs are forced to sit for long periods of time because of the nature of their work[4]. The sitting posture of SOWs tends to include trunk forward bending[8]. Due to the flexion-relaxation phenomenon of the erector spinae, support from passive tissues (such as the posterior spinal ligament) in the final stages of trunk forward bending predominates over support from lumbar erector spinae in the middle region of the trunk[9]. Therefore, SOWs are habituated to posture maintenance using passive support mechanisms such as ligaments instead of active support mechanisms from lumbar muscle groups, and it is assumed that they have a low ability to control excessive lumbar region movements during trunk movement. Lumbar motor control impairment in SOWs may be one of the factors that cause low back pain. One treatment for lumbar motor control impairment that has been attracting attention is dynamic motor control exercise (DMCE), which helps control the lumbar region movement during trunk and lower extremity movements[7,10,11]. Van Dillen et al.[11] reported that DMCE for the lumbar region reduced low back pain in participants with reduced lumbar motor control ability. Therefore, DMCE for low back pain in SOWs may improve low back pain by improving lumbar motor control. However, there is insufficient evidence on the effect of DMCE on low back pain in SOWs. Thus, this study aimed to clarify the effect of DMCE of the lumbar region on low back pain in SOWs and to find an effective treatment strategy for the same. This study was based on the hypothesis that compared to normal trunk exercise (NTE), DMCE of the lumbar region allows for a greater improvement in lumbar motor control and low back pain.

Method

1. Participants

This study was approved by the ethics committee of the Nanto City Home-Visit Nursing Station (approval number: 2020.NHS.1). The purpose of the study was explained to all participants verbally and in writing, and written consent was obtained from them before inclusion in this study. This trial was registered with the University Hospital Medical Information Network (UMIN; registration number UMIN000041318).

SOWs with low back pain living in Toyama and Ishikawa prefectures, Japan, were recruited between July and August 2020. The number of recruits was determined using a previous study for guidance[12]. The eligibility criteria for this study were as follows: (1) low back pain without organic factors[13], (2) low back pain lasting for more than 3 months[14], and (3) SOWs who spent more than 80% of their working hours in a sitting posture[15]. A physiotherapist confirmed that there was no disease caused by low back pain for each participant. Participants with a history of lumbar vertebrae or hip surgery and those with severe spinal deformities (such as kyphosis) were excluded.

2. Study design

This study was a double-blinded randomized controlled trial. Randomization was achieved by stratified random allocation and permuted block method using a random number table in Microsoft Excel 2016 to ensure equal proportions of males and females in each group. The participants were blinded by providing exercise instructions to each study group separately; this ensured that they remained unaware of the group to which they were assigned for the entirety of the study period. A physiotherapist performed the measurements, and the measurement data were processed so that the group to which the participants belonged was not known to the data analyst. The processed data were then analyzed by a different person to ensure blinding of the data analysis.

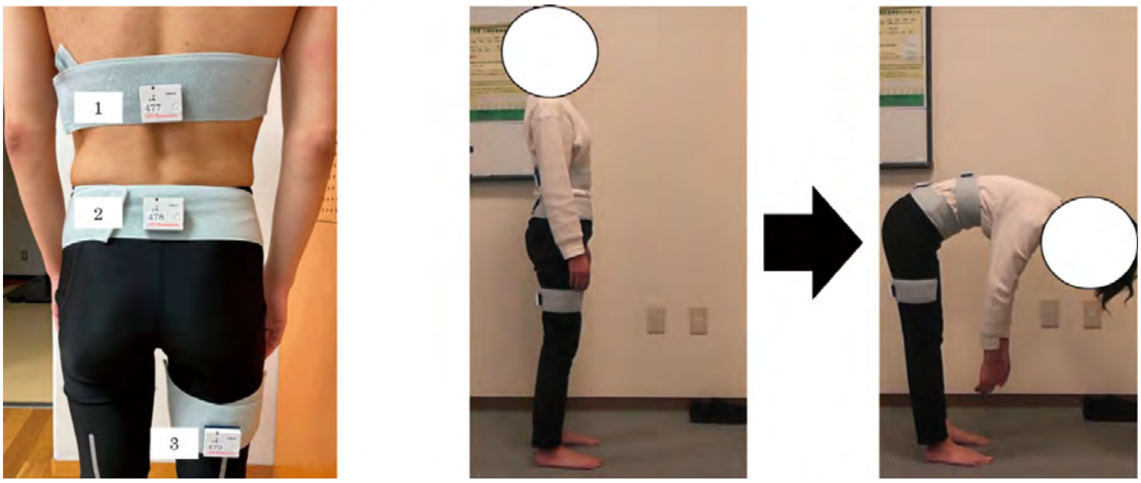
3. Process

This study was conducted between September and December of 2020. The participants were randomly divided into two groups: the DMCE group (n=16; lumbar region movements were controlled during trunk and lower extremity movements) and the NTE group (n=16; trunk movements were performed without lumbar region movements). The examiners provided individual exercise instructions to participants after baseline measurement. To ensure the level and consistency of the instructional content, a physical therapist with sufficient clinical experience (11 years) provided instructions to the participants. All measurements were conducted at local community centers and at the participants' workplaces. The exercise instructions were relayed to the participants using instruction sheets and exercise videos. The examiner instructed the participants to continue exercising for three days a week for eight weeks. Furthermore, the examiner distributed exercise record sheets to the participants and instructed them to return the updated sheets by mail or e-mail once every two weeks. The examiner confirmed the exercise record table and exercise implementation status of the participants. Only participants who were able to complete the 8-week exercise schedule were included in the final evaluation.

4. Intervention

The DMCE group

In accordance with the McGill method[10], the participants exercised while maintaining awareness of the hip joint movement and without moving the lumbar region. Three types of exercises were performed: quadruped rock back, squats, and hip extension in the prone position[10,16,17]. In the quadruped rock back, participants started in the quadruped position with the shoulder, hip, and knee joints in 90° flexion; from there the buttocks were moved backward. The participant stayed conscious of this hip flexion



a b c

Fig. 1. Location of the inertial sensor (a) and trunk forward bending (b, c)
a-1: The top edge of the sensor was placed at the top edge of the first lumbar vertebra
a-2: The top edge of the sensor was placed at the top edge of the first sacral vertebra.
a-3: Midpoint of the sciatic tuberosity and the popliteal fossa.
b: Starting position
c: Maximum trunk forward bending position

while maintaining the lumbar region in neutral position[10,16]. The squat was performed in a standing position with both lower extremities placed shoulder-width apart and the neutral position of the lumbar region maintained, and the participants focused their awareness on the hip flexion movements. The range of movement for hip flexion was limited to approximately 45°[10]. The participants were instructed to maintain awareness of the hip joint during the hip hinge movement, in which the torso is flexed forward at the hip joint, with the spine kept in neutral position[10]. During the prone hip extension exercise, bilateral hip/knee extension at 0° was set as the starting posture. Then, unilateral hip joint extension exercises were performed while maintaining knee joint extension at 0°[17]. All three exercises were performed 30 times a day (three sets of 10 reps), three times a week. In the case of the prone hip extension exercises, three sets of 10 reps were performed on both sides daily.

The NTE group

The participants performed abdominal bracing in the supine, sitting, and standing positions[10,18]. Abdominal bracing was based on the method of Tayashiki et al.[18], which consists of applying force to the abdomen using one's own fingers and pushing them back for 2-s followed by a 2-s relaxation. Ten sets of five contractions and relaxations were performed in each posture, with a 30-s rest interval between sets. In the supine position, the participants performed the exercise with both knee joints in slight flexion, and both soles placed on the ground. In the seated position, the participants performed the exercise with the hip and knee joints in 90° flexion while maintaining the lumbar region in a neutral position. In the standing position, the participants performed the exercise with both lower extremities spread apart and the lumbar region in neutral position.

5. Primary endpoint

The primary endpoints were the lumbar/hip joint angle during trunk forward bending, intensity of low back pain (evaluated using the Visual Analog Scale [VAS])[19], and effect of low back pain on activities of daily living (evaluated using the Oswestry Disability Index [ODI])[20]. Receiving software (Sensor Controller, ATR-Promotions, Sagara, Japan) and intrinsic motion sensors (TSND 151, ATR-Promotions, Sagara, Japan) were used to measure the lumbar and hip joint angles. The sensors were placed at three locations: the thoracolumbar vertebral transition, the lumbosacral vertebral transition, and the right thigh. At the thoracolumbar transition, the top edge of the sensor was placed at the top edge of the first lumbar vertebra. At the lumbosacral transition, the top edge of the sensor was also placed at the top edge of the first sacral vertebra. The thigh sensor was placed on the posterior surface of the thigh at the midpoint of the sciatic tuberosity and popliteal fossa (Fig. 1a). Finally, the sensors at the thoracolumbar and lumbosacral vertebral transitions were positioned at the midline on the frontal plane of the body, and the thigh sensor was positioned at the midline on the frontal plane of the right thigh. The acceleration range, angular velocity range, and sampling interval of the sensors were ±8 G, ±1.000 dps, and 10 ms, respectively. The measurements were taken as follows: after 5 s of starting position, maximum trunk forward bending was performed for 3 seconds, and the final position in trunk forward bending was held for 3 seconds

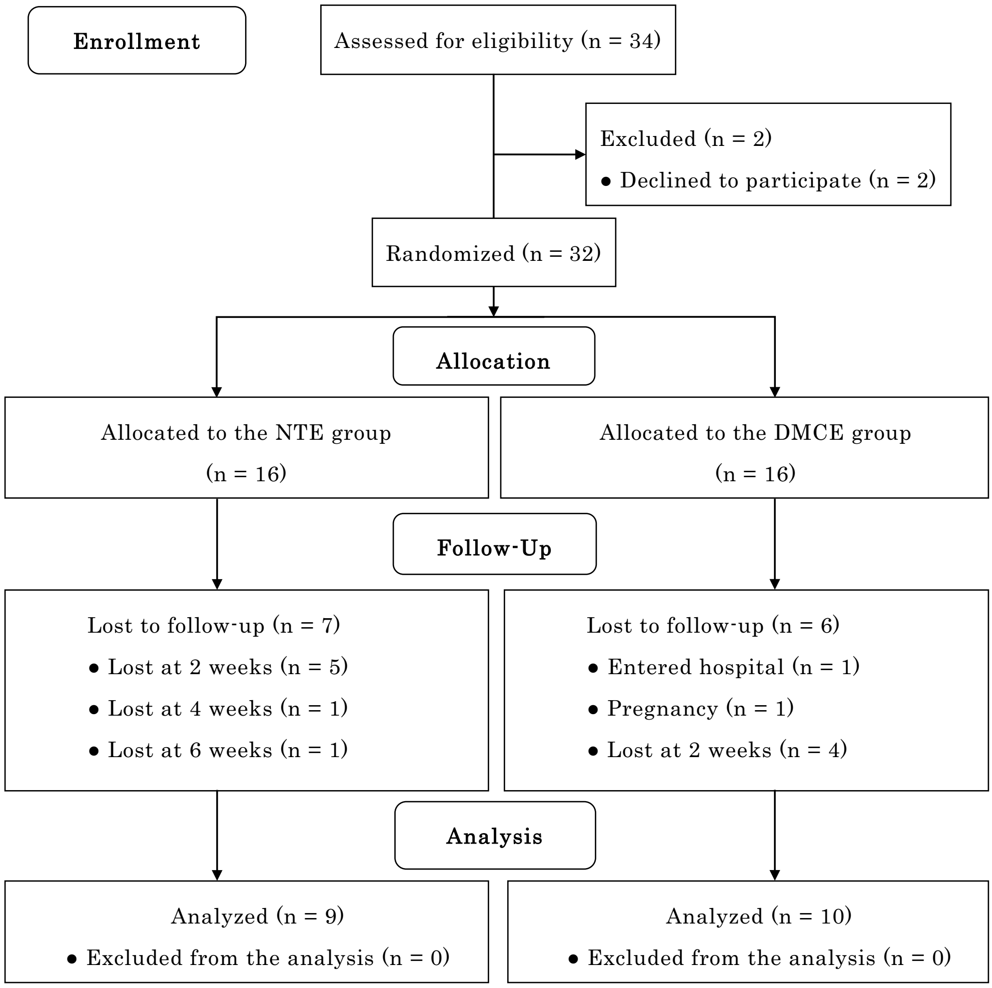


Fig. 2. The consolidated standards of reporting trials 2010 flow diagram for this study.

(Fig. 1b, c). This was performed in three trials, and the participants practiced once before measurements were taken. Prior to the study, we confirmed the reproducibility of the trunk forward bending measurement in 20 participants without low back pain, and evaluated the measurement reproducibility with the Intraclass Correlation Coefficient (ICC). The intra-rater reliability ICC (1.3) was calculated from the average value of the three trials performed by one examiner. The data measured included the lumbar region, hip flexion angles at 10°, 30°, 50°, 70°, and maximum trunk forward bending. The angle of trunk forward bending was defined as the tilt angle of the sensor at the thoracolumbar transition during trunk forward bending. Because the ICC was 0.8 or more at all trunk forward bending angles, the reproducibility of trunk forward bending measurement was confirmed.

6. Secondary endpoint

The secondary endpoints were unilateral hip flexion/extension, muscle strength, and the range of motion of bilateral passive hip flexion/extension. A hand-held dynamometer (HHD; μ Tas F-1, ANIMA, Chofu, Japan) was used to measure the hip muscle strength. The dominant leg was used for lower extremity measurements, which was defined as the leg that kicked a ball more readily. The hip flexion muscle strength was measured in the seated position, with both lower extremities raised off the floor and the hip and knee joints in 90° flexion, with the HHD placed on the anterior surface of the thigh, 10 cm proximal to the upper edge of the patella. During measurement of hip extension muscle strength, one knee joint was at 90° flexion on one side and the other was at 0° extension on the opposite side in the prone position, with the HDD placed on the posterior surface of the thigh, 10 cm proximal to the center of the popliteal fossa with the knee joint in 90° flexion. For reproducible measurements of muscle strength, a traction belt (Traction belt 270 cm, Erler Zimmer GmbH & Co. KG, Deutschland, Germany) was wrapped around the measurement bed to secure the HHD to the distal thigh of the participant. The examiner instructed the participant to avoid performing compensatory movement, such as trunk extension, during muscle strength measurement. The measurement procedure was as follows: two rounds of maximum isometric muscle contraction performed for 5 s, separated by a 30-second rest period. Passive hip joint range of motion was measured using a goniometer (plastic angle meter,

Table 1. Comparison of the baseline characteristics between the DMCE and NTE groups

Endpoint variables		Total (n=19)	DMCE group (n=10)	NTE group (n=9)	95% CI
Age (years)		48.2±9.5	46.5±9.3	50.0±10.0	-5.8 to 12.8
Male, n (%)		5 (26.3)	3 (30.0)	2 (22.2)	
Female, n (%)		14 (73.7)	7 (70.0)	7 (77.8)	
BMI, (kg/m^2)		23.5±3.6	24.7±4.4	22.1±1.6	-5.8 to 0.8
LF angle, (°)	10°	4.1±1.6	4.2±1.6	3.9±1.7	-1.9 to 1.3
	30°	12.3±4.6	12.9±5.4	11.7±3.9	-5.8 to 3.4
	50°	21.6±7.6	22.4±9.0	20.6±6.1	-9.3 to 5.7
	70°	30.9±10.1	31.8±11.7	29.9±8.6	-11.9 to 8.1
	Max	51.1±14.4	52.1±18.6	49.9±8.9	-16.6 to 12.1
HF angle, (°)	10°	6.3±2.0	5.8±1.5	6.8±2.4	-0.9 to 2.9
	30°	20.2±3.9	18.7±3.2	21.9±4.1	-0.3 to 6.7
	50°	35.5±8.3	35.1±8.8	35.9±8.2	-7.5 to 9.0
	70°	48.5±11.3	48.3±12.3	48.8±10.8	-10.8 to 11.8
	Max	79.1±20.7	79.0±19.7	79.3±23.0	-20.3 to 21.0
LHR	10°	0.8±0.6	0.9±0.7	0.7±0.4	-0.8 to 0.4
	30°	0.7±0.4	0.8±0.5	0.6±0.3	-0.6 to 0.2
	50°	0.7±0.5	0.8±0.6	0.7±0.4	-0.6 to 0.4
	70°	0.7±0.5	0.8±0.6	0.7±0.4	-0.6 to 0.4
	Max	0.7±0.4	0.8±0.5	0.7±0.4	-0.4 to 0.6
ODI, (%)		17.2±9.1	17.3±8.9	17.1±9.8	-9.3 to 8.9
VAS for LBP, (mm)		25.2±13.6	26.3±11.7	24.0±16.0	-15.8 to 11.2
Muscle Strength,	Hip Flexion	1.0±0.4	1.0±0.4	1.0±0.4	-0.3 to 0.4
(Nm/kg)	Hip Extension	0.7±0.4	0.7±0.4	0.7±0.4	-0.3 to 0.4
ROM, (°)	Hip Flexion, (Rt)	109.7±7.0	110.0±5.6	109.5±8.3	-6.4 to 7.4
	Hip Flexion, (Lt)	109.5±7.2	110.0±5.6	109.0±8.8	-6.2 to 8.2
	Hip Extension, (Rt)	16.3±3.7	15.5±3.7	17.2±3.6	-1.8 to 5.3
	Hip Extension, (Lt)	16.3±4.0	16.0±3.9	16.7±4.3	-3.3 to 4.7

Values are expressed as mean±standard deviation.

DMCE: dynamic motor control exercise; NTE: normal trunk exercise; CI: confidence interval; BMI: body mass index; LF: lumbar flexion; HF: hip flexion; LHR: lumbar hip ratio = lumbar flexion angle/hip flexion angle; ODI: Oswestry Disability Index; VAS: Visual Analog Scale; LBP: low back pain; ROM: range of motion

ÖSSUR Japan G.K.,Tokyo, Japan). During the measurement of the range of hip flexion, participants were supine on the bed, with the basic axis set as the line parallel to the trunk, and the translation axis as the line connecting the greater trochanter and the lateral epicondyle of the femur. The hip flexion range of motion was defined as the range of motion of the translation axis relative to the basic axis with the knee joint in maximum flexion. For the measurement of the range of hip extension, the participants were prone, with the same basic and translation axes as those considered for hip flexion. The knee joint was fully extended.

7. Data analysis

Flexion angles of the lumbar and hip joints during 10°, 30°, 50°, 70°, and maximum trunk forward bending were calculated. The lumbar flexion angle was defined as the difference between the sensor tilt angles at the thoracolumbar and lumbosacral transitions at each trunk forward bending angle. The hip flexion angle was defined as the difference between the sensor tilt angles at the lumbosacral transition and the thigh at each trunk forward bending angle. For each participant, the average value of the three trials was calculated and used as the representative value. The lumbar hip ratio (LHR; lumbar flexion angle/hip flexion angle) was calculated from the measured lumbar and hip flexion angles. The VAS score was calculated as the intensity of the current low back pain (range, 0-100 mm). For ODI, the total score of each section was divided by 50 and multiplied by 100; this was used as the representative value of the participant. For unanswered sections, the number of sections was multiplied by five, and the resulting value was subtracted from 50. The total score was then divided by this value and multiplied by 100 for use as the representative value for the participant. For hip flexion and extension

Table 2. Comparison of the primary and secondary endpoints pre- and post-intervention in each group

Endpoint variables		DMCE group (n=10)		95% CI	NTE group (n=9)		95% CI
		pre	post		pre	post	
LF angle, (°)	10°	4.2±1.6	3.0±1.7*	0.5 to 2.0	3.9±1.7	4.2±1.7	-1.4 to 0.9
	30°	12.8±5.4	9.9±5.2*	0.7 to 5.4	11.7±3.9	10.5±4.2	-1.3 to 3.8
	50°	22.4±9.0	18.3±7.9*	0.3 to 8.0	20.6±6.1	17.9±6.3*	0.1 to 5.3
	70°	31.8±11.7	27.5±9.1	-0.5 to 9.0	29.9±8.6	25.4±7.2*	2.0 to 7.0
	Max	52.1±18.5	47.3±10.8	-3.2 to 12.8	49.9±8.9	42.5±5.5*	2.9 to 11.9
HF angle, (°)	10°	5.8±1.5	6.7±1.5*	-1.6 to -0.2	6.8±2.4	6.0±1.6	-0.3 to 1.9
	30°	18.7±3.2	24.0±4.7*	-7.5 to -3.3	21.9±4.1	24.2±5.3	-5.1 to 0.4
	50°	35.1±8.8	39.3±7.4*	-7.9 to -0.5	35.9±8.2	40.0±7.1*	-7.2 to -1.0
	70°	48.3±12.3	52.4±8.9	-9.2 to 0.9	48.8±10.8	55.1±7.8*	-10.0 to -2.6
	Max	79.0±19.7	81.8±12.0	-12.8 to 7.2	79.3±23.0	86.0±15.1	-15.7 to 2.3
LHR	10°	0.9±0.7	0.6±0.7*	0.1 to 0.4	0.7±0.4	0.8±0.6	-0.5 to 0.2
	30°	0.8±0.5	0.5±0.5*	0.1 to 0.5	0.6±0.3	0.5±0.3	-0.1 to 0.3
	50°	0.8±0.6	0.5±0.4	-0.1 to 0.5	0.6±0.4	0.5±0.3	-0.1 to 0.3
	70°	0.8±0.6	0.6±0.4	-0.1 to 0.4	0.7±0.4	0.5±0.2*	0.1 to 0.4
	Max	0.8±0.5	0.6±0.2	-0.1 to 0.4	0.7±0.4	0.5±0.1	-0.1 to 0.5
ODI, (%)		17.3±8.9	6.6±7.4*	7.4 to 15.5	17.1±9.8	12.7±12.7	-1.8 to 10.7
VAS for LBP, (mm)		26.3±11.7	4.9±6.2*	16.5 to 26.2	24.0±16.0	18.0±19.5	-8.3 to 20.3
Muscle Strength,	Hip Flexion	1.0±0.4	1.4±0.5*	-0.6 to -0.2	1.0±0.4	1.4±0.4*	-0.6 to -0.2
(Nm/kg)	Hip Extension	0.7±0.4	1.2±0.5*	-0.7 to -0.2	0.7±0.4	1.2±0.3*	-0.6 to -0.3
ROM, (°)	Hip Flexion, (Rt)	109.5±8.3	114.0±7.3*	-7.6 to -1.4	110.5±5.6	110.0±4.3	-1.9 to 1.9
	Hip Flexion, (Lt)	109.0±8.7	114.0±7.4*	-7.9 to -2.0	110.0±5.6	110.0±4.3	-1.9 to 1.9
	Hip Extension, (Rt)	15.5±3.7	20.5±2.8*	-7.4 to -2.6	17.2±3.6	18.3±2.5	-2.8 to 0.6
	Hip Extension, (Lt)	16.0±3.9	20.5±2.8*	-7.1 to -1.9	16.7±4.3	17.7±3.6	-2.8 to 0.6

Values are expressed as mean±standard deviation.

DMCE: dynamic motor control exercise; NTE: normal trunk exercise; CI: confidence interval; LF: lumbar flexion; HF: hip flexion; LHR: lumbar hip ratio = lumbar flexion angle/hip flexion angle; ODI: Oswestry Disability Index; VAS: Visual Analog Scale; LBP: low back pain; ROM: range of motion

* Significant difference pre-and post-intervention, $p<0.05$

muscle strength, the maximum value of the two trials was used as the representative value for each participant. The torque value (Nm) was calculated by multiplying the measured muscle force value (N) by the thigh length (distance from the greater trochanter to the lateral epicondyle of the femur). The torque value was then normalized by the body weight, and the torque to body weight ratio was calculated, which was used as the muscle strength value for the participant (Nm/kg). The range of motion of the bilateral hip joints was measured once for each side, and the values were used as representative values for the participants. All measurements were calculated as the extent of the change by subtracting the pre-intervention values from the post-intervention values.

8. Statistical analysis

Statistical analyses were performed using SPSS version 22 (IBM SPSS Statistics, Japan IBM, Tokyo, Japan). Fisher's exact test and unpaired *t*-test were used to compare baseline data between the DMCE and NTE groups. The paired *t*-test was used to compare the primary and secondary endpoints between pre- and post-intervention in each group. The unpaired *t*-test was used to compare the extent of changes in the primary and secondary endpoints between the two groups. The significance level was set at 0.05, and all values are presented as mean ± standard deviation.

Result

The CONSORT flowchart for this study is shown in Figure 2. In this study, 19 participants (DMCE group = 10, NTE group = 9) were included in the analysis. The baseline characteristics of both groups are shown in Table 1. No significant differences in any characteristics were observed between the two groups. The pre- and post-intervention results for the primary and secondary endpoints are shown in Table 2, and inter-group comparisons of the extent of the changes in the primary and secondary endpoints pre- and post-intervention are shown in Table 3. The extent of the changes in the lumbar flexion angle, hip flexion angle, and LHR at 10° of trunk forward bending in the DMCE group were significantly greater than those in the NTE group. In

Table 3. Comparison of the extent of changes in the primary and secondary endpoints pre- and post-intervention between the two groups

Endpoint variables		DMCE group (n=10)	NTE group (n=9)	95% CI
LF angle, (°)	10°	-1.2±1.0*	0.2±1.5	0.2 to 2.7
	30°	-3.0±3.3	-1.2±3.3	-1.4 to 5.5
	50°	-4.2±5.4	-2.7±3.5	-3.0 to 5.9
	70°	-4.2±6.6	-4.5±3.2	-5.4 to 4.9
	Max	-4.8±11.2	-7.4±5.9	-11.4 to 6.2
HF angle, (°)	10°	0.9±0.9*	-0.8±1.4	-2.8 to -0.5
	30°	5.4±3.0	2.3±3.6	-6.2 to 0.1
	50°	4.2±5.1	4.1±4.0	-4.6 to 4.5
	70°	4.1±7.1	6.3±4.8	-3.7 to 8.2
	Max	2.8±14.0	6.7±11.7	-8.6 to 16.5
LHR	10°	-0.3±0.2*	0.1±0.4	0.1 to 0.7
	30°	-0.3±0.3	-0.1±0.2	-0.1 to 0.5
	50°	-0.3±0.3	-0.2±0.2	-0.2 to 0.4
	70°	-0.2±0.4	-0.2±0.2	-0.3 to 0.4
	Max	-0.1±0.3	-0.2±0.3	-0.4 to 0.2
ODI, (%)		-11.5±5.7*	-4.4±8.1	0.3 to 13.7
VAS for LBP, (mm)		-21.4±6.8*	-6.0±18.6	2.1 to 28.7
Muscle Strength, (Nm/kg)	Hip Flexion	0.5±0.3	0.4±0.3	-0.3 to 0.2
	Hip Extension	0.5±0.3	0.4±0.2	-0.3 to 0.2
ROM, (°)	Hip Flexion, (Rt)	4.5±4.4*	0.0±2.5	-8.0 to -1.0
	Hip Flexion, (Lt)	5.0±4.1*	0.0±2.5	-8.3 to -1.7
	Hip Extension, (Rt)	5.0±3.3*	1.1±2.2	-6.7 to -1.1
	Hip Extension, (Lt)	4.5±3.7*	1.1±2.2	-6.4 to -0.4

Values are expressed as mean±standard deviation.

DMCE: dynamic motor control exercise; NTE: normal trunk exercise; CI: confidence interval; LF: lumbar flexion; HF: hip flexion; LHR: lumbar hip ratio = lumbar flexion angle/hip flexion angle, ODI: Oswestry Disability Index; VAS: Visual Analog Scale; LBP: low back pain; ROM: range of motion

* Significant difference between the two groups ($p<0.05$)

the lumbar flexion angle and LHR of the DMCE group, the post-intervention values significantly decreased from the pre-intervention, and the hip flexion angle significantly increased. There were no significant differences in these parameters at the other angles of trunk forward bending between the two groups. The extent of change in ODI and VAS score was significantly greater in the DMCE group than the NTE group. In the ODI and VAS of the DMCE group, there was a significant decrease in post-intervention compared to pre-intervention. There were no significant differences in the extent of change in muscle strength of hip flexion and extension between the two groups. The extent of change in passive hip range of motion was significantly greater in the DMCE group for flexion and extension than the NTE group. In the passive hip range of motion of the DMCE group, there was a significant increase in post-intervention values compared to pre-intervention.

Discussion

The purpose of this study was to clarify the effect of DMCE of the lumbar region on low back pain in SOWs and to evaluate its efficacy as a treatment. Our findings revealed that in the early stage of trunk forward bending, the lumbar flexion angle decreased and the hip flexion angle increased in the DMCE group as opposed to the NTE group. The VAS score and ODI were also decreased in the DMCE group than in the NTE group. Therefore, it is suggested that DMCE of the lumbar region is an effective means of improving low back pain in SOWs.

It has been reported that trunk forward bending in a person with low back pain causes excessive movement of the lumbar region in the early stage of the movement and relatively decreased hip joint movement[6]. The lumbar ligaments contain a number of free nerve endings that act as pain receptors[21]. Excessive lumbar region movement in the early stages of lower extremity and trunk movements causes stress accumulation in the lumbar tissue and promotes tissue degeneration[7]. In this study, DMCE was used to suppress the movement of the lumbar region and movement of the hip joint. Therefore, unlike in the NTE group, it is possible that in the DMCE group, the stimulation of pain receptors (and consequently, the low back pain) decreased due to a decrease in the lumbar region movement and an increase in the hip joint movement in the early stage of trunk forward bending. The minimal clinically important differences for the VAS score and the ODI are reported to be 15 mm and 10 points, respectively[22], and the corresponding values in this study were higher than these values. Therefore, DMCE is suggested as an effective treatment strategy for low back pain in SOWs. It has also been reported that low back pain is associated with decreased hip range of motion and muscle strength[23]. In this study, DMCE promoted hip joint muscle group activity in the desired direction of the hip joint movement; simultaneously, the extensibility of the antagonist muscle increased due to reciprocal innervation[24]. This may have improved muscle strength and hip flexion/extension range of motion.

This study has some limitations. First, the number of participants who were able to perform the final analysis was only 19 due to attrition, and it was difficult to verify the intervention effect of DMCE by intention-to-treat analysis. Therefore, it is necessary to increase the number of participants in the future to verify the effect of DMCE intervention on low back pain in SOWs. Moreover, since the number of required participants in this study was calculated by referring to previous studies, it is necessary to calculate the number of required participants using G*Power.

Conclusion

This study examined the effect of DMCE of the lumbar region on low back pain in SOWs. Low back pain was reduced with improvements in the motor control ability of the lumbar region. Therefore, intervention by DMCE for the lumbar region is effective in improving motor control in the lumbar region and hip joints and in decreasing low back pain in SOWs and should be further explored as a treatment.

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Conflict of Interest: The authors declare no conflicts of interest.

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PHYSICAL THERAPY RESEARCH

SCIENTIFIC RESEARCH ARTICLE

Examination of Changes in 6-minute Walk Distance and Related Factors in Patients with Perioperative Peripheral Arterial Disease

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ABSTRACT. Objective: This study aimed to clarify the effects of pre- and postoperative physical function on the 6-minute walking distance (6MWD) in patients with peripheral arterial disease (PAD). Method: Forty-two elderly patients with PAD who were hospitalized for revascularization and able to walk independently were included in the study. The 6MWD, ankle brachial index (ABI), weight-bearing index (WBI), gait, and intermittent claudication distance (ICD) were measured before and after the surgery, and skeletal muscle index was measured only before surgery. Analyses were performed by comparing the pre- and postoperative values of each factor using a paired t-test. In addition, multiple regression analysis was performed with 6MWD as the dependent variable before and after surgery. Results: Postoperatively, pain disappeared in 22 patients, and ABI, ICD, 6MWD, and stride length improved significantly. ICD and stride length were extracted as factors related to 6MWD before and after surgery, and ABI, WBI, and stride length were extracted as factors related to 6MWD after surgery. Conclusion: The improvement of intermittent claudication associated with revascularization suggests a stronger influence of functional aspects on postoperative 6 MWD.

Key words: Peripheral arterial disease, 6-minute walk distance, Revascularization

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Peripheral arterial disease (PAD) is a chronic disease that causes atherosclerotic lesions in the blood vessels of the lower extremities, resulting in various disabling symptoms, including numbness, pain, ulceration, and necrosis of the legs. It has been reported that many patients with PAD experience ischemic symptoms in the lower legs, and typical intermittent claudication (IC) occurs in approximately one-third of patients[1)]. Many patients with PAD are reported to exhibit functional weakness associated with limitations in daily activities due to pain in the lower extremities[2)]. PAD has also been shown to cause decreased lower extremity muscle strength[3)] and exercise tolerance compared with non-diseased patients[4)]. The International Guideline for the Diagnosis and Treatment of PAD (TASC II) advocates revascularization, pharmacotherapy, and exercise therapy as treatment methods for PAD, and recommends supervised exercise therapy as part of the initial treatment for all patients with IC (evidence level A). Exercise therapy is included in physical therapy; in this study, exercise for the purpose of treating and preventing diseases is defined as exercise therapy. Exercise therapy has been reported to improve vascular endothelial function[5)] and maximum walking distance[6)], with continued therapy showing improvements in patient prognosis[7)]. Therefore, it is desirable to provide exercise therapy to patients with PAD, even during the postoperative period. A randomized controlled trial of revascularization alone versus revascularization with exercise therapy reported an effect of increased walking distance in

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the combined treatment group[8]. However, although previous studies have confirmed the utility of postoperative exercise therapy for increasing walking distance and improving long-term prognosis, there is a significant financial burden on patients associated with supervised exercise therapy. Moreover, a considerable burden is placed on medical personnel and the limited number of facilities that can provide continuous exercise therapy[9]. Therefore, it is necessary for medical practitioners to evaluate patients shortly before and after surgery to identify functional problems and predict prognosis.

The treadmill graded exercise test according to the Gardner protocol is a commonly used method to evaluate functional impairment and exercise capacity in patients with PAD[10]. However, the Gardner protocol is time-consuming, costly, and difficult to perform in ill-equipped environments. In contrast the 6-min walk test (6MWT) is a highly versatile measure that is also used to evaluate exercise capacity in conditions such as congestive heart failure and respiratory diseases[11,12]. The 6MWT can be performed in an environment with inadequate equipment, has a wide range of indications for older adults, and is easy to perform even in frail individuals. Its reliability and validity in patients with PAD have also been examined[13], and it is considered to be a useful index for evaluating the long-term prognosis of patients[14,15]. Exercise tolerance in the 6MWT was evaluated by the 6-min walking distance (6MWD), the results of which are strongly influenced by the severity of claudication in patients with PAD. Conversely, since claudication symptoms improve after surgery, the effect of physical function on walking distance may become more apparent, especially in older adults. However, the differences in the factors that affect 6MWD before and after surgery have not yet been clarified. To provide more effective physical therapy, it is necessary to clarify these factors and provide interventions tailored to the characteristics of each patient. In this study, we hypothesized that the severity of claudication symptoms had a significant impact on walking distance in older adult patients with PAD before surgery, and that when pain during ischemia improved after revascularization, the influencing factors would shift toward functional aspects. The purpose of this study was to clarify the relationship between each factor and 6MWD in order to individualize postoperative physical therapy interventions.

Methods

I. Study Participants

Among 62 patients with PAD admitted to the International University of Health and Welfare Hospital from June 2019 to September 2020 for endovascular treatment and bypass surgery of peripheral blood vessels, 51 patients aged 65 years or older were included in the study. Considering the indications for physical therapy and the influence of walking disabilities other than IC, we excluded (1) those with rest pain, (2) those with unstable angina, (3) those with walking limitations for reasons other than IC, and (4) those who developed postoperative complications (e.g., aspiration pneumonia or acute arterial occlusion), for a total of eight excluded patients. In addition, a patient with missing data (n = 1) was excluded from the analysis, resulting in 42 subjects in the final analysis (Fig. 1). The mean (± standard deviation) age of the participants was 75.24 ± 5.6 years, and the mean preoperative ankle brachial index (ABI) values were 0.89 ± 0.2 and 0.81 ± 0.3 for the right and left lower extremities, respectively.

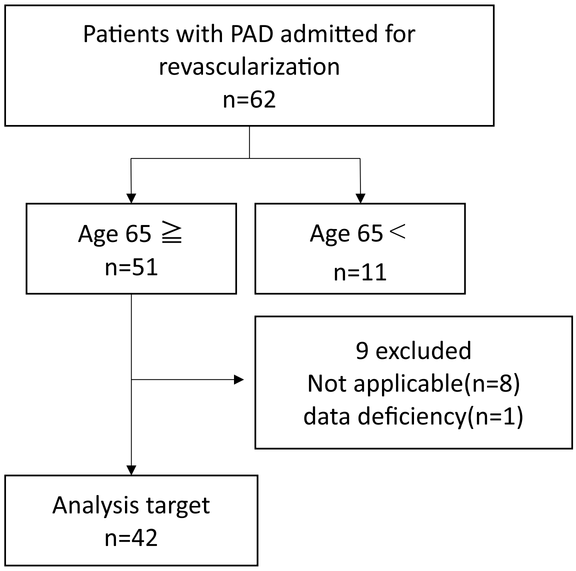

Fig. 1. Diagram of study flow

This study was approved by the International University of Health and Welfare Hospital Ethics Review Board (approval number 20-Io-8). All patients provided written informed consent before their inclusion in the study.

II. Measurement Method

The primary endpoint was 6MWD, which was used as an index of exercise tolerance. Secondary endpoints included intermittent claudication distance (ICD), which represents the severity of claudication symptoms and is related to the decrease in physical activity; weight-bearing index (WBI), which is an index of lower limb muscle strength; skeletal muscle index (SMI), which is an index of total body muscle mass; gait, which is reported to be affected by IC; and ABI, which is used as an index of lower limb blood flow. Physical functions other than SMI were measured preoperatively and after the fifth postoperative day.

The measurement method of the 6MWD was based on the guidelines of the American Thoracic Society[16]. The 6MWT was performed once at the maximum speed of the patient, walking a 40-m straight, flat course in the rehabilitation room. All patients were instructed to walk as fast and as long as possible within 6 min. The 6MWT was stopped if the patient experienced dyspnea, chest pain, or onset of pallor. It was explained to the patients in advance that a break could be taken if they experienced strong dyspnea or pain in the lower limbs and that the time would not be stopped. Measurements were taken preoperatively and after the fifth postoperative day.

ICD measurements were performed simultaneously with the 6MWT. During the 6MWT, patients were told to self-report when numbness or pain in the lower limbs occurred, and the distance of the appearance of subjective pain was recorded as ICD. Patients who did not experience pain within 6 min of walking were instructed to continue walking. The distance at which pain occurred was evaluated by measuring up to 500 m. If no lower limb pain occurred at 500 m, the pain was considered to have disappeared, and the presence or absence of residual pain was evaluated before and after surgery.

For WBI, based on a study by Hirasawa et al[17], the isometric maximum muscle strength of the quadriceps femoris muscle was measured using a hand-held dynamometer (Sakai Medical, Tokyo, Japan). The measurement was performed with the subject in an upright seated position with the knee joint flexed to 90°. The patient was instructed to maintain the trunk in a vertical position during the measurement, and both upper limbs were folded in front of the trunk. The sensor pad was fixed to the distal lower leg using a belt, and the patient performed isometric knee extension movements with maximal effort for approximately 3-5 s twice on each side; the maximal values were recorded. The mean value of each maximal value divided by body weight was used as the WBI.

To clarify customary gait, it was measured at a comfortable speed on 10-m and 3-m walking paths at both ends. The measurements were performed twice, and the walking speed and stride length were evaluated for each measurement. Stride length was calculated by dividing the stride length, which was calculated from the number of steps required to walk a distance of 10 m, by height, and it was used to calculate the stride-to-height ratio.

ABI was measured using a non-invasive vascular screening device (BP-203RPE III, Omron, Kyoto, Japan). The measurement procedure and prohibited maneuvers are described in the instruction manual for the device. The patients rested for approximately 5 min, and the measurement was started when the device detected a normal heartbeat signal. The lowest value of the measured ABI was used as the representative value.

SMI was measured using a multi-frequency body composition analyzer (MC-780A, Tanita Corporation, Tokyo, Japan). After confirming that the subjects had been in the resting position for at least 5 min, they were instructed to assume the measurement posture according to the instruction manual and not to move or speak during the measurement[18]. Since it has been reported that postoperative inflammatory edema affects muscle mass[19], SMI was only measured preoperatively.

III. Postoperative physical therapy

The patients' postoperative physical therapy started with treadmill gait training (12% gradient, 2.4 km/h) in accordance with the TASC II medical guidelines after the in-hospital gait and wound pain evaluations were conducted on the first postoperative day. For cases in which it is difficult to use a treadmill due to, for example, strong walking instability, we prescribed flat-ground walking at the maximum walking speed. Physical therapy was performed for 40 min/day from Monday to Saturday. All patients were discharged from the hospital 6-15 days postoperatively.

IV. Sample Size

Approximately 50 patients with PAD are admitted to the International University of Health and Welfare Hospital for surgery every year. The sample size was calculated using GPower3[20]. For the calculation of the sample size, α of 0.05, power of 80%, and a large effect size of 0.35 were set, which were selected based on a previous study[21] that examined the factors associated with 6MWD with gait, ABI, and clinical information as explanatory variables. As a result, the total sample size in this study was 43 patients.

For statistical processing, SPSS Statistics Ver.24 (IBM Corp., Armonk, NY, US) was used to compare the disease background of the patients and the changes in their physical functions before and after surgery using corresponding t-tests. To clarify the relationship between the factors and the amount of change before and after surgery, a partial correlation analysis was conducted using age and sex as covariates. Based on the results, ICD, ABI, WBI, SMI, and stride-to-height ratio were selected as explanatory variables for factors related to 6MWD before surgery, and ICD improvement, ABI, WBI, SMI, stride-to-height ratio were selected as explanatory variables after surgery. Stepwise multiple regression analysis was performed with the 6MWD before and after surgery as the dependent variable. The significance level of all the variables was set at 5%. To clarify the severity of the disease and complications, the site of stenosis and complications were obtained from medical records.

Results

From the physical function and disease background of PAD patients (Table 1), the mean preoperative 6MWD was 321.6 ± 107.8 m, and the ICD was 173.0 ± 116.0 m. Of these patients, 33% were able to continue the preoperative 6MWT without interruption, and the main reason for interruption was pain in the lower extremities in all patients. The mean postoperative 6MWD was 364.5 ± 94.6 m, which was significantly improved compared with the preoperative period. ICD improved in 22 subjects and the prevalence of

Table 1. Baseline characteristics

Characteristic		Total cohort
Sample size, n		42
Gender (Male/Female)		33/9
Age, mean±SD (year)		75.2±5.6
BMI, mean±SD (kg/cm^2)		23.1±3.0
SMI, mean±SD (kg/m^2)		7.4±1.5
medical history (case)	Diabetes mellitus	28
	Hypertension	27
	Hyperlipidemia	16
	Chronic kidney disease	6
Stenotic vessel area (case)	Common Iliac Artery	3
	External Iliac Artery	13
	Superficial Femoral Artery	20
	Below the popliteal artery	6
Drug therapies (case)	BB	8
	Ca channel blocker	16
	Statin	12
	Antiplatelet agents	39
	Heparin	36
	Warfarin	9
	NOAC	3
	Alprostadil	34

BMI, Body mass index; SMI, Skeletal muscle index; BB Beta-blocker; NOAC, Novel oral anticoagulant

Table 2. Pre- and post-operative comparisons

Characteristic	Preoperative	Postoperative
ABI, mean±SD*	0.7±0.2	0.9±0.2
WBI, mean±SD (kgf/kg)	0.4±0.1	0.4±0.1
stride-to-height ratio, mean±SD (%)*	0.3±0.1	0.4±0.1
Gait velocity, mean±SD (m/sec)	1.1±0.2	1.1±0.3
6MWD, mean±SD (m)*	321.6±107.8	364.5±94.5
Preoperative ICD, mean±SD (m)	173.0±116.0	
Postoperative Leg symptoms		Not remained: 22 remained: 20

ABI, Ankle-brachial index; WBI, Weight bearing Index; 6MWD, 6 min walk distance; ICD, Initial claudication distance
*: paired t-test <0.05

complications was as follows: diabetes mellitus (n = 28), hypertension (n = 27), hyperlipidemia (n = 16), and chronic kidney disease (n = 6), all of whom had undergone percutaneous vasodilation. A comparison of physical functions before and after surgery showed significant improvement in ABI and stride-to-height ratio, and no significant changes in WBI and walking speed (Table 2). Partial correlation analysis revealed a significant correlation between 6MWD and the stride-to-height ratio ($r = 0.43$, $p < 0.05$), WBI ($r = 0.43$, $p < 0.05$), and stride-to-height ratio ($r = 0.52$, $p < 0.01$). There was also a significant correlation between the change in 6MWD and the change in stride length ($r = 0.33$, $p < 0.05$) (Table 3). Based on these results, we decided to substitute only the stride-to-height ratio and walking speed, which showed a significant difference by t-test, as explanatory variables in the multiple regression analysis. A multiple regression analysis was performed with 6MWD as the dependent variable before and after the surgery, and the stride-to-height ratio and ICD were extracted before surgery (X1: stride-to-height ratio $\beta = 0.31$, X2: ICD $\beta =$

Table 3. Correlation between 6MWD and each factor, between the amount of change in 6MWD and the amount of change in each factor

	WBI	Gait velocity	stride-to-height ratio	SMI	ABI
I. Preoperative 6MWD	0.24	0.34	0.43*	-0.01	0.11
II. Postoperative 6MWD	0.43*	0.33	0.52*	-0.14	0.20
III. Amount of change of 6MWD	0.11	-0.08	0.33*	-	-0.19

WBI, Weight bearing Index; SMI, Skeletal muscle mass Index; ABI, Ankle-brachial index
6MWD, 6 min walk distance
*p<0.05 (two-tailed).
comment
I. Preoperative 6MWD×Preoperative factors
II. Postoperative 6MWD×Postoperative factors
III. Amount of change of 6MWD×Amount of change in each factor (preoperative-postoperative)

Table 4. Multiple regression analysis

	factor	β	P-value	r	VIF
Preoperative 6MWD	WBI	0.12	0.407	0.13	1.26
	stride-to-height ratio	0.31	0.023	0.36	1.14
	ABI	-0.08	0.540	-0.10	1.07
	ICD	0.50	0.000	0.53	1.14
	Adjusted R^2	0.42			
	factor	β	P-value	r	VIF
Postoperative 6MWD	WBI	0.31	0.010	0.41	1.30
	stride-to-height ratio	0.41	0.001	0.50	1.26
	ABI	0.23	0.046	0.32	1.19
	IC	-0.28	0.015	-0.39	1.17
	Adjusted R^2	0.58			

WBI, Weight bearing Index; ABI, Ankle-brachial index; ICD, Initial claudication distance
VIF: Variance inflation factor
IC (Intermittent claudication): ‘1’ if there is postoperative IC, ‘0’ if there is no IC

0.50). In the postoperative period, the stride-to-height ratio, ABI, WBI, and ICD improvement were extracted, and the multiple correlation coefficient (R = 0.62), adjusted coefficient of determination (R^2 = 0.58), and calculation model were significant (p < 0.01). Y = 733.5X1 − 108.0X2 + 247.8X3 − 52.4X4 − 71.1 (X1: stride-to-height ratio β = 0.41, X2: ABI β = 0.23, X3: WBI β = 0.31, X4: presence of ICD improvement β = −0.28) (Table 4). The variance inflation factor ranged from 1.07 to 1.26 preoperatively and 1.17 to 1.30 postoperatively, which was less than 10, and no multicollinearity was observed.

Discussion

Regarding the changes in physical function before and after surgery, there was no improvement in lower limb muscle strength, but significant improvement in stride length. As for the unchanged lower limb muscle strength, the results support the previous study by Kamiizumi et al[19]. When the gait of PAD patients was compared with that of older adults living in the community, it was found that the PAD group experienced a decrease in walking speed and stride length regardless of lower extremity pain[22]. It can be inferred that the change in gait in patients with PAD is the result of the establishment of a pain-avoidant walking strategy as a customary gait. Therefore, it is unlikely that the improvement of lower limb pain by revascularization affects gait independently and in the short term. In the present study, 22 patients underwent physical therapy for improvement in lower limb pain after surgery. Because the physical therapy included gait training at a speed of 2.4 km/h on a treadmill and at the maximum walking speed, the conventional gait was enforced, which may have resulted in an improvement in stride length[23]. The significant correlation between the change in stride length and the change in 6MWD suggests that the effect of stride length on walking distance is strong. However, it is necessary to investigate the independent effect of stride length on the change in walking distance by conducting a comparative study of patients who underwent revascularization alone versus those who underwent physical therapy.

The results of multiple regression analysis showed that the 6MWD was related to ICD and stride length in the preoperative period, and stride length, WBI, ABI, and the presence of pain improvement in the postoperative period. These results suggest that factors related to 6MWD in the perioperative period include pathological aspects, such as pain during lower limb ischemia, and functional aspects, such as stride length and lower limb muscle strength. The influence of the functional aspect became stronger with the improvement of pain in the determinants of postoperative 6MWD. In terms of factors related to continuous walking distance in patients with PAD, previous studies have reported that lower limb pain and muscle strength are related[24,25]. Many previous studies on changes in walking distance in the perioperative period have reported improvements in maximum walking distance with reduction of IC[26]. Conversely, it has been reported that muscle weakness and exercise tolerance, which were unnoticed due to activity limitations caused by IC, are limiting factors for continuous walking after surgery[1]. Thus, the improvement of walking distance in patients with PAD is affected not only by lower extremity pain but also by physical function, which may remain after surgery. In the present study, the relationship between 6MWD and WBI became stronger in the postoperative period, and in the multiple regression analysis, WBI was extracted as a related factor only in the postoperative period. This suggests that the postoperative 6MWD in patients with PAD is affected by lower limb muscle strength and that postoperative lower limb muscle strength training may contribute to the improvement of walking performance. When evaluating the exercise tolerance of patients with PAD, it is necessary to consider the pre- and postoperative lower limb ischemic pain severity when conducting the 6MWT. Furthermore, our results highlight the importance of considering the functional changes specific to PAD, such as muscle weakness and gait changes, in the interpretation of these results.

Conclusion

This study revealed that IC and stride length were related to the preoperative walking distance of patients with PAD and that the influence of gait and lower limb muscle strength became stronger after surgery. In contrast, the limitations of this study include the fact that unilateral and bilateral lesions were not separated in the selection of patients and that the interrelationship among 6MWD, lower limb muscle strength, and gait was only discussed in the literature. In the future, it will be necessary to conduct intervention studies on the mechanisms of temporal changes in gait and their interrelationships.

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Conflict of Interest: The authors have no conflicts of interest to disclose.

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PHYSICAL THERAPY RESEARCH

Scientific Research Article

Preoperative Physical Inactivity Affects the Postoperative Course of Surgical Patients with Lung Cancer

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ABSTRACT. Objective: Preoperative performance status is an important factor in thoracic surgery, but little is known about the effect of preoperative physical activity (PA) on the postoperative course. This study investigated the associations between preoperative PA and postoperative complications and clinical outcomes of lung cancer surgery. Methods: This prospective observational study included patients who underwent surgery for lung cancer at a single institution. PA was measured before hospitalization for 5 consecutive days and then after surgery until hospital discharge. The daily step count and time spent performing moderate intensity activity (> 3 metabolic equivalents) were measured with an accelerometer. We examined the correlations between PA and preoperative pulmonary function and physical fitness, and examined the relationship between postoperative complication and PA. Finally, a multivariate analysis was performed with pre-hospital PA as the dependent variable. Results: Forty-two patients were analyzed. Univariate analysis found no correlation between pre-hospital PA and preoperative pulmonary function, but found significant positive correlations between pre-hospital PA and time spent performing moderate intensity activity, in-hospital PA, preoperative 6-minute walk distance, and maximum gait speed ($r > 0.5$, $p < 0.01$). The nine patients who developed postoperative complications had significantly lower pre-hospital and postoperative step count than the patients with no complication ($p = 0.04$). Multiple regression analysis showed that pre-hospital PA was significantly associated with time spent performing moderate intensity activity, maximum gait speed, and postoperative complication. Conclusions: Evaluation of pre-hospital PA is useful in predicting the postoperative course after lung cancer surgery.

Key words: Lung cancer, Surgical treatment, Preoperative physical activity, Postoperative complication, Accelerometer

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Performance status (PS) is an important prognostic factor for lung cancer and a clinical indicator for surgical treatment[1-3]. Eastern Cooperative Oncology Group / World Health Organization PS is an indicator of general health and activity status on a scale of 0 to 4[4]. The lower the PS, the higher the activity, which is associated with the survival rate of non-small-cell lung cancer patients[4]. However, the PS is a simple measurement and does not fully reflect the activity level of each individual. A previous study found that physical activity (PA), mainly based on the average number of steps per day, is a strong prognostic factor in the outcome of chronic obstructive pulmonary disease[5]. Lung cancer is the leading cause of cancer death in Japan and is strongly associated with smoking[6]. The data of the cancer registry of Japan showed that the incidence of lung cancer is increasing[7], and surgical treatment is becoming increasingly frequent[8]. Perioperative pulmonary physical therapy for patients with lung cancer is a promising strategy to optimize physical fitness, and may yield improved outcomes such as reduced length of stay or fewer postoperative complications[9,10]. Although several studies have assessed in-hospital PA and postoperative complications in patients with lung cancer[11,12], no study has evaluated the relationship between pre-hospital PA (activity at home) and the postop-

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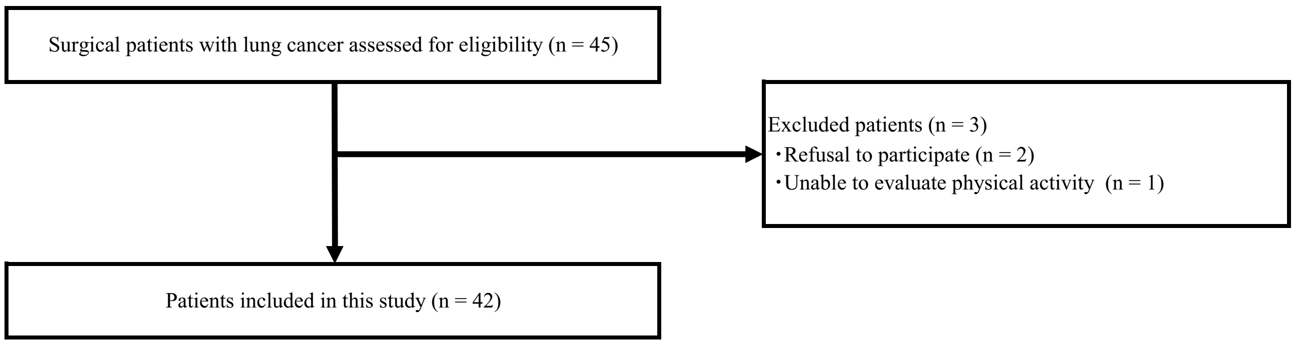

Fig. 1 Flowchart of patient inclusion and exclusion.

erative course. The aim of this study was to examine the relationship between PA and physical function and postoperative complications and to identify the clinical variables related to pre-hospital PA in surgical patients with lung cancer.

Methods

Study design and subjects

This prospective study was conducted from September 2016 to April 2017 in a single institution in Japan. The study was approved by the Human Research Ethics Review Committees of Showa General Hospital (approval number REC-112), and all patients provided informed consent for study participation. All surgical patients were assessed for physical and pulmonary function prior to surgery. Eligible patients had a diagnosis of lung cancer (non-small cell lung cancer), were aged > 18 years, and were scheduled for lung resection. Exclusion criteria were comorbid conditions affecting exercise performance (specifically, musculoskeletal or neurological impairment and cardiac disease) or refusal to participate. During the recruitment period, 45 individuals underwent surgery; however, data from three patients were not included (two who did not provide consent and one whose physical activity was not evaluated) (Fig. 1). Postoperative complications were defined as any postoperative event such as prolonged mechanical ventilation > 48 hours, atelectasis, bacterial pneumonia, cardiac arrhythmia, delirium or prolonged air leak requiring > 5 days of chest tube drainage (Clavien-Dindo grade ≤ IVa)[13]. PS was evaluated during the preoperative physical therapy. As a measure of overall health status, the attending anesthesiologist determined the American Society of Anesthesiologists physical status for each patient prior to surgery[14].

Physical function measures

The peripheral muscle strength was assessed on the basis of the quadriceps force (QF), defined as the peak force during maximal isometric knee extension measured using a hand-held dynamometer (μ-TusF-1; Anima Corporation, Tokyo, Japan). The QF of the dominant side was tested in the sitting position with the hip and knee joint flexed at approximately 90°. The highest value of three satisfactory measurements was recorded. The QF was expressed as a percentage of body weight. Grip strength (kg) was measured with a hand dynamometer (T.K.K.5401; Takei Scientific Instruments Corporation, Niigata, Japan). Measurements were made on the dominant side and the highest value of three technically correct attempts was used in the analysis.

The 6-minute walk test was performed in accordance with published guidelines[15] and the 6-minute walk distance (6MWD) was calculated. Mobility was evaluated using the perceived maximal (fastest) walking speed over 10 meters measured with a stopwatch, with the fastest of two measurements used in the analysis (m/seconds). The maximum inspiratory pressure (MIP) and maximum expiratory pressure (MEP) were measured as indicators of respiratory muscle strength using a respiratory dynamometer (MicroRPM, Micro Medical/CareFusion, Kent, UK) following the method recommended by the American Thoracic Society/European Respiratory Society[16]. For the MIP measurement, the patient was asked to exhale as much as possible (to residual volume) and then inhale maximally for more than 1 second against the resistance. For the MEP measurement, the patient was asked to inhale as much as possible and then exhale maximally for more than 1 second against the resistance. The measurements were repeated at least three times, and the highest measurements for both MIP and MEP were used in the analysis. Preoperative physical functional assessment was performed 1-2 days prior to surgery, while postoperative assessments were performed as needed with the removal of devices.

Physical activity

PA was determined with an accelerometer (Lifecorder EX, Suzuken Co. Ltd., Nagoya, Japan), which collected data during waking hours in 2-minute epochs. The mean step count and time spent engaged in PA (minutes per day) were evaluated. PA was classified as moderate to vigorous intensity activity (> 3 metabolic equivalents (METs)). We used a PA analysis software package (Liferiser 05 Coach, Suzuken Co. Ltd.) and Microsoft Excel (Microsoft Corp., Redmond, WA, USA) to analyze the activities measured via the accelerometer[17,18]. Preoperative PA was assessed on 5 consecutive weekdays before hospitalization, while in-hospital PA was assessed during the last 5-7 days of hospitalization. On each assessment day, PA was recorded for at least 8 hours from the time of waking, on the basis of methods used in previous studies[19-21].

Physical therapy

As part of standard perioperative care, all patients received an in-hospital physical therapy consultation 1-2 days prior to surgery. Patients were encouraged to meet the rigorous postoperative early mobilization recommendations for the prevention of postoperative complications and were given instructions on deep breathing and coughing exercises for airway clearance. Postoperative management comprised thoracic drains (all patients were managed with a water seal on the day after surgery), epidural catheters, urethral catheters, oxygen therapy, and intravenous drips. The thoracic tube was removed as early as possible on the basis of the absence of air leaks and drainage status assessed with daily chest x-rays and physical examinations performed by the attending medical doctor. In accordance with the American Thoracic Society/European Respiratory Society guidelines, the attending physical therapist instructed all patients to begin ambulating (i.e., leave their bed) from the day after surgery, if possible[22]. Patients were instructed to at least sit in a chair for 30 minutes and walk 30-50 meters on postoperative day 1. From postoperative day 2 onwards, patients who were able to walk on their own were encouraged to leave the bed as often as possible outside of rehabilitation. In addition, under the supervision of a physical therapist who monitored the pain severity and vital signs, each patient performed 20-40 minutes/day of resistance training and bicycling until discharge from the hospital. During hospitalization, no intervention was implemented on the basis of the activity recorded with the accelerometer.

Statistical methods

Data were expressed as means with standard deviation or medians with interquartile ranges for continuous variables, and as counts with percentages for categorical variables. The Shapiro-Wilk test was used to examine the distribution of the data. The relationship between variables was examined using Pearson's or Spearman's correlation coefficients in accordance with the distribution of the data. Multiple regression analysis was performed to determine the variables associated with the preoperative PA, after correcting for risk factors that were shown to be significant at $p < 0.05$ on univariate analysis. Stepwise multiple regression analysis was undertaken to identify whether the pulmonary function, physical function, step count, total duration of moderate to vigorous activity (> 3 METs) preoperatively, and presence of postoperative complications were dependent variables. A p value < 0.05 was considered significant. Analyses were performed using a statistical software package (IBM SPSS Statistics for Windows, Version 24.0 (IBM Corp., Armonk, NY, USA)).

Results

Patient characteristics

Characteristics of the 42 candidates for lung resection are summarized in Table 1. The PS was 0 and 1 for about 90% of the participants, and the preoperative activity based on the American Society of Anesthesiologists physical status was ≤ 2 in about 90% of patients. All patients were scheduled to undergo video-assisted thoracoscopic surgery or open surgery and had relatively good preoperative respiratory function. Nine patients developed postoperative complications. No patients had more than one complication. All patients were ambulating with or without a gait aid in the intensive care unit as early as the first postoperative day and were discharged from the intensive care unit on postoperative day 2 or 3. All patients had an uneventful postoperative course and were discharged home.

Clinical characteristics of patients with versus without postoperative complications

The group of patients with postoperative complications was significantly older than the group without complications. There were no significant differences between the two groups regarding the history of smoking or alcohol consumption, preoperative pulmonary function, or surgical outcome. The group with postoperative complications had significantly lower preoperative exercise capacity (6MWD) and in-hospital step count than the group without complications (data not shown). Patients with postoperative complications also had a significantly lower pre-hospital step count than those without complications (Fig. 2).

Relationships between clinical variables and pre-hospital PA

Preoperative pulmonary function was only weakly related to participation in daily pre-hospital PA (Table 2). The variables significantly related to pre-hospital PA were preoperative physical function and exercise capacity, step count during the hospitalization period, and duration of activity time before hospitalization.

Factors related to pre-hospital PA in surgical patients with lung cancer

The following variables with significant results in the univariate correlation analyses were entered into the multivariate model: age, sex, preoperative pulmonary function, physical fitness, 6MWD, pre-hospital activity level (daily minutes of activity > 3 METs), and the absence of postop-

Table 1. Characteristics of the 42 patients who underwent lung resection

Age	68.9 ± 10.1
Male, sex	31 (74)
BMI (kg/m^2)	22.7 ± 2.9
Smoking status	
Current or former smoker	34 (81)
Non-smoker	8 (19)
Alcohol history, yes	14 (33)
Underlying disease	25 (59)
Hypertension	17 (40)
Diabetes mellitus	6 (14)
Hyperlipidemia	6 (14)
Bronchial asthma	3 (7)
Preoperative pulmonary function tests	
VC (L)	3.3 ± 0.8
VC % predicted	106 ± 19.5
FEV_1 (L)	2.3 ± 0.6
FEV_1 % predicted	105 ± 25.2
Performance status (< 1)	38 (90)
ASA-PS (< 2)	36 (86)
Preoperative variables	
Grip strength (kg)	27.6 ± 7.8
QF (kgf/body weight)	0.49 ± 0.1
MIP (cmH_2O)	57.7 ± 22.1
MEP (cmH_2O)	59.8 ± 20.0
6MWD (m)	481.4 ± 98.4
Maximum gait speed (m/s)	1.7 ± 0.3
Physical activity	
Pre-hospital step count	5093.5 (2542.3 - 8613.3)
In-hospital step count	2410.5 (1652.8 - 3604.3)
Pre-hospital activity level (> 3METs, min)	57.1 (12.8 - 129.5)
Operative modes	
Wedge resection	7
Segmentectomy + wedge resection	10
Lobectomy	18
Lobectomy + lobectomy	4
Pneumonectomy	3
Operation time (min)	134.0 ± 62.3
Intraoperative bleeding loss (ml)	20.0 (10 - 47.3)
Postoperative events	9 (21%)
Prolonged mechanical ventilation (> 48 h)	-
Atelectasis	-
Pneumonia	1
Arrhythmia	3
Delirium	3
Prolonged air leak (> 5 days)	2
Length of stay (days)	9.5 ± 3.6

Data are reported as mean ± standard deviation, n (%), and median (interquartile range). BMI: body mass index; FEV_1: forced expired at one second; VC: vital capacity; ASA-PS: American Society of Anesthesiologists physical status; QF: quadriceps force; MIP: maximum inspiratory pressure; MEP: maximum expiratory pressure; 6MWD: 6-minute walk distance; METs: metabolic equivalents.

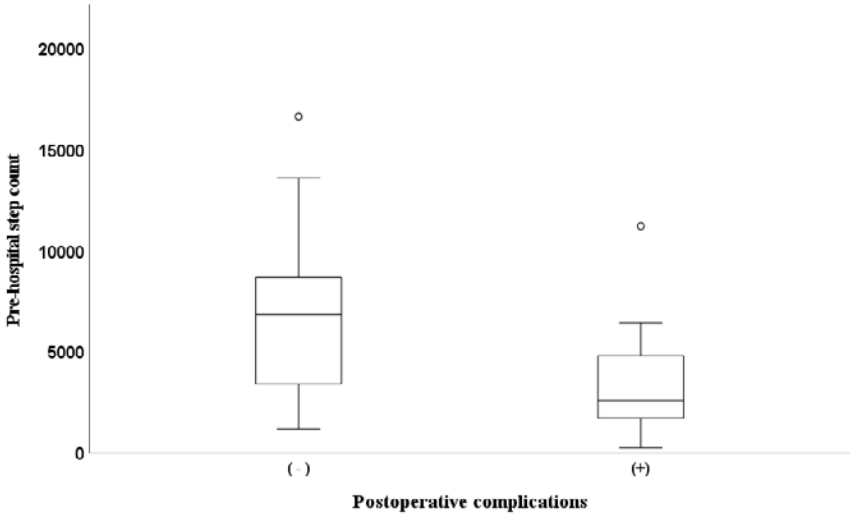

Fig. 2 Comparison of the preoperative physical activity level (step count) of patients with (+) versus without (-) postoperative complications. Data are reported as median (interquartile range) and evaluated using the Mann–Whitney U test. The preoperative step count was significantly lower in the group with postoperative complications than in the group without complications ($p < 0.05$).

Table 2. Univariate correlations between pre-hospital step count and other variables

	Effect size (r)	p value
Age	-0.46	< 0.01
BMI (kg/m^2)	0.12	0.46
Preoperative pulmonary function tests		
FEV_1 (L)	0.15	0.36
FEV_1 % predicted	-0.26	0.1
VC (L)	0.21	0.2
VC % predicted	0.001	0.9
Length of stay (days)	-0.17	0.27
Preoperative variables		
Grip strength (kg)	0.36	< 0.05
QF (kgf/body weight)	0.44	< 0.01
MIP (cmH_2O)	0.3	0.61
MEP (cmH_2O)	0.35	< 0.05
6MWD (m)	0.62	< 0.001
Maximum gait speed (m/s)	0.55	< 0.001
Physical activity		
In-hospital step count	0.65	< 0.001
Pre-hospital activity level (>3METs, min)	0.9	< 0.001

BMI: body mass index; FEV_1: forced expiratory volume at 1 second; VC: vital capacity; QF: quadriceps force; MIP: maximum inspiratory pressure; MEP: maximum expiratory pressure; 6MWD: 6-minute walk distance; METs: metabolic equivalents.

erative complications.

Multivariate regression analysis revealed a significant positive relationship between pre-hospital step count and pre-hospital activity level (daily duration of activity > 3 METs) ($p < 0.001$), between pre-hospital step count and preoperative maximum gait speed ($p < 0.001$), and between pre-hospital step count and the absence of postoperative complications ($p = 0.03$); these three variables explained 92% of the variance (Table 3).

Table 3. Clinical variables correlated with pre-hospital step count in multivariate regression analysis

Predictor	Pre-hospital step count		
	β	p value	R^2 (%)
Intercept			92
Duration of pre-hospital activity > 3 METs (min)	0.83	< 0.001	
Maximum gait speed (m/s)	0.27	< 0.001	
Postoperative complication (+)	-0.11	0.03	

ANOVA $p < 0.01$, β: regression coefficient, METs: metabolic equivalents.

Discussion

This study demonstrated that patients with lung cancer with postoperative complications had significantly lower preoperative PA levels than those without postoperative complications, and that preoperative PA was more strongly related to preoperative physical function than to preoperative pulmonary function.

A previous study reported that the duration of hospitalization after lung cancer surgery is increased in patients with lower levels of postoperative PA[11]. This is consistent with our finding that the postoperative PA was significantly lower in the group with postoperative complications than in the group without complications. However, all patients in the present series had an uneventful postoperative course and were discharged home, which was likely related to the efficacy of perioperative physical therapy. Marike et al. showed that the amount of activity during hospitalization is strongly associated with physical function at discharge in patients who have undergone lung cancer resection[23]. Our findings suggest that increasing the PA not only during but even before hospitalization may contribute to the improvement of physical function and the prevention of postoperative complications related to physical inactivity (such as atelectasis and delirium).

Many studies have investigated the association between preoperative pulmonary function and postoperative complications and outcomes[24-26]. Patients with low pulmonary function are at higher risk of postoperative complications and have a poorer prognosis. All patients in our study had relatively good pulmonary function, which suggests that the postoperative complications were related to other factors. Exercise capacity assessment is as essential as pulmonary function testing in predicting postoperative complications after lung resection[27,28]. In our study, there was a significant association between the preoperative 6 MWD and postoperative complications. We suggest that patients with relatively good preoperative pulmonary function should undergo multifaceted evaluation, including physical fitness assessment. Furthermore, we consider it extremely important to assess the at-home physical function and PA levels of patients whose lung function is borderline for surgical treatment.

Several reports have studied the relationship between postoperative complications after lung resection and respiratory muscle strength[29,30]. In the present study, the presence of complications was not associated with respiratory muscle strength but was moderately associated with preoperative PA. Future research is needed to determine whether respiratory muscle training is related to improved general activity levels.

In our survey, the factors significantly related to the pre-hospital PA were the 10 meters maximum walking speed, a high pre-hospital activity level (daily duration of activity > 3 METs), and the presence of postoperative complications. Izawa et al. reported an association between 10 meters maximum walking speed and hospital PA in older patients with coronary artery disease[19], which suggests the importance of physical therapy intervention to improve exercise function. Another important finding of our study was that pre-hospital PA was associated with the time spent performing moderate to vigorous intensity activity (> 3 METs) before surgery. The preoperative activity level (> 2 METs) of lung transplant recipients is reportedly lower than that of healthy subjects, and does not return to the level of healthy subjects after surgery[2].

Our findings suggest that walking speed and exercise intensity are also involved in the overall activity level of patients with lung cancer. Recent studies have demonstrated the importance of PA in patients with lung cancer[1,2], and of cooperating with local governments to encourage improvement in PA[2]. Additionally, low activity and depression are associated in patients with lung cancer[31], and PA assessment is an important indicator in postoperative follow-up[32].

Recently, telemedicine (telehealth) with a smartphone and an accelerometer has been increasingly used for perioperative patients with lung cancer; however, it is difficult to conduct telemedicine follow-up for patients with low activity[32]. In Japan, it is important to provide comprehensive physical therapy for low-activity patients not only in the acute phase, but also while in hospital and in the community to improve their activity levels.

Some limitations of the current study should be acknowledged. First, relatively few subjects were recruited because the study was conducted in a single center that only performs a limited number of surgical procedures for lung cancer annually. Second, this study included subjects with relatively good preoperative respiratory function and there was no standardization of treatment, such as the inclusion of only patients with anatomical lung resections. Finally, the preoperative activity assessment did not cover all yearly seasons. Future multicenter studies with larger cohorts that include patients with impaired pulmonary function are needed to determine how preoperative PA affects the outcomes of lung cancer surgery.

Conclusions

The present study demonstrated that assessing preoperative PA may be useful in predicting postoperative complications in patients with lung cancer. Preoperative activity correlates with physical function but not with preoperative pulmonary function. The use of an accelerometer to assess preoperative activity levels may be useful as an indicator to determine the need for preoperative physical therapy to prevent complications.

Conflict of Interest: The authors have no conflicts of interest to declare.

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PHYSICAL THERAPY RESEARCH

SCIENTIFIC RESEARCH ARTICLE

Effects of Lower-limb Muscle Fatigue, Cardiopulmonary Fatigue, and Brain FatigueTasks on One-legged Landing Motion

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ABSTRACT. Objective: Anterior cruciate ligament (ACL) injury is one of the most frequent sportsinjuries, and previous studies have shown that fatigue is a risk factor for sports injuries.This study aimed to inform prevention of ACL injury by investigating how exercise and desk tasks affect trunk and lower limb alignment and ground reaction force (GRF) during one-legged landing movements. Methods: The study subjects were 12 men who performed a one-legged landing movement from a 30-cm platform before and after fatigue tasks, including lower-limb muscle fatigue, cardiopulmonary fatigue, and brain fatigue tasks. For the measurement of joint angles and moments and GRF, a three-dimensional motion analysis device and a floor reaction-force meter were used. Statistics were performed using Wilcoxon's signed rank sum test as a multiple comparison test with Bonferroni adjustment to compare the difference in effects. Results: The maximum trunk flexion angle during landing on one leg was significantly lower in the brain fatigue group than in the control group. The time to peak vertical GRF (pGRF) was significantly shorter in the leg-muscle fatigue group than in the control group. Conclusion: Brain fatigue may have altered the postural strategy before and after landing, resulting in a decrease in trunk flexion angle. Time to pVGRF was shortened in the leg muscle fatigue group, suggesting that there may be an increased risk of ACL injury. Time to pVGRF during lower extremity muscle fatigue and trunk flexion angle during brain fatigue may be more pronounced during actual sports activities.

Key words: ACL injury, Jump-landing motion, Fatigue, Prevention

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Anterior cruciate ligament (ACL) injury is one of the most common sports injuries. ACL injury requires ligament reconstruction surgery for athletes to continue sporting activities[1] and may reduce athletic performance and activity. Among athletes and the general public, ACL injury has been associated with early-onset knee osteoarthritis, damage to the meniscus and cartilage surface, and economic loss due to difficulty in working[2].

Although the mechanism of ACL injury varies by sport, 70% result from non-contact injuries[3]. The injury is commonly caused when changing direction, landing, or decelerating/stopping. The landing position during injury is often a result of loss of balance, backward center of gravity, insufficient knee flexion, and valgus stress of the knee joint[3]. Recent findings regarding ACL injury mechanisms and dynamic alignment have informed ACL injury prevention strategies. Of non-contact injuries, 58-61% occur during a jump-landing motion[4], and athletes with ACL injury had approximately 20% higher vertical ground reaction force (VGRF) on landing than non-injured athletes[5]. The posterior GRF (PGRF) was significantly positively correlated with VGRF and the anterior withdrawal force of the proximal tibia during landing[6], suggesting that increased VGRF and PGRF in sports activities are risk factors for ACL injury. Landing with a flexed trunk and lower limbs is recommended to improve VGRF and PGRF control[7]. In this landing posture with an extended trunk, the center of

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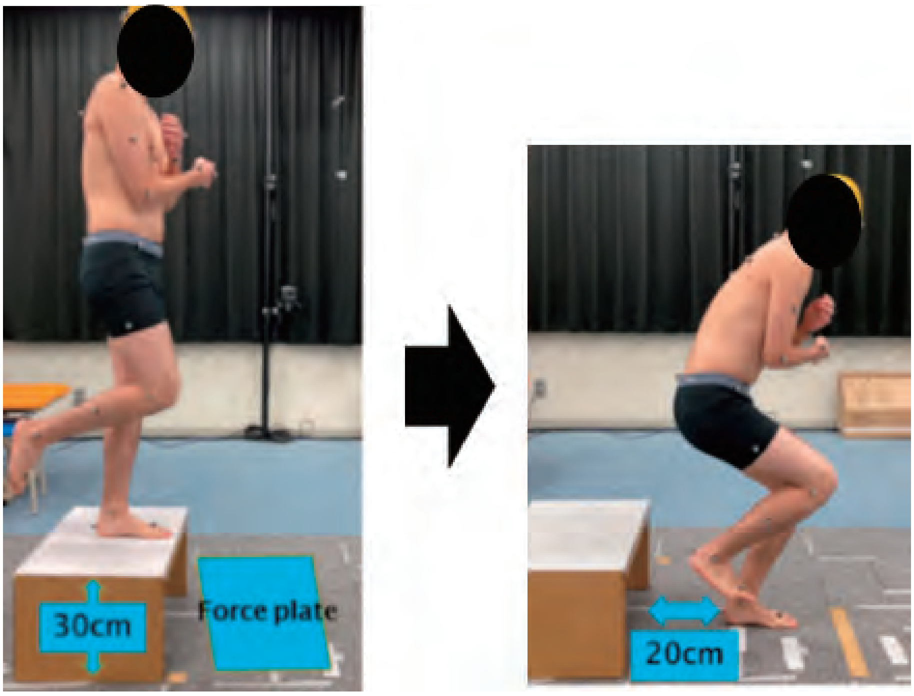

Fig. 1. One-legged landing motion measurement.

gravity is deflected backwards, and the PGRF and proximal tibia increase the forward withdrawal force.

The risks of ACL injury increase at the end of competition when fatigue accumulates[8]. ACL and other sports injuries may also be caused by fatigue at the end of long games such as basketball and soccer[8]. There is a difference between injuries during games and practice, with game injuries accounting for 66% of all injuries[8]. When performing stop jumps before and after fatigue, there is an increase in peak anterior shear force and a decrease in knee flexion angle of approximately 14%[9]. Oonishi et al. reported that fatigue from desk-based computational tasks can delay the switch between primary and antagonist muscles and reduce neuromuscular coordination during jumping, based on electromyography[10]. However, fatigue during physical activity can be divided into peripheral and central factors, and central fatigue, including brain fatigue during exercise, can be explained by a decrease in brain glycogen[11]. Such fatigue may affect dynamic muscle control, changes in movement patterns, and neuromuscular control. Most fatigue tasks were full-body exercise methods; landing movements after running or squatting movements[9]. However, no studies have compared peripheral and central factors separately, and it is unclear what kind of fatigue causes changes in dynamic alignment during physical activity. Without identifying the type of fatigue, it is unlikely that specific injury prevention and conditioning methods can be proposed.

The present study aimed to investigate how lower-limb muscle fatigue, cardiopulmonary fatigue, and brain fatigue tasks affect trunk and lower-limb alignment and GRF or time to peak vertical GRF (pVGRF) during a one-legged landing motion to inform primary and secondary ACL injury prevention.

Methods

The subjects were 12 men (mean age 23.3±2.9 years, height 173.6±5.8 cm, weight 65.9±8.3 kg). The number of subjects was calculated using Gpower version 3.1.9.4 with an effect size of 0.5 and power of 0.8. The exclusion criteria were as follows: (1) history of hip, knee, or ankle fracture or surgery; (2) hip, knee, and ankle joints below the reference range of motion specified by the Japanese Orthopedic Association[12].

The subjects performed a one-legged landing motion from a 30-cm platform before and after fatigue tasks. The one-legged landing motion was performed with the lower limb on the kicking side (Fig. 1). Fatigue tasks included lower-limb muscle fatigue, cardiopulmonary fatigue, and brain fatigue tasks (Fig. 2). To assess the degree of fatigue, a Borg scale was used during the motor and brain fatigue tasks, and salivary amylase levels were measured before and after the tasks using a salivary amylase sympathetic nerve monitor (Cocoro Meter, NIPRO Corporation, Osaka, Japan). Salivary amylase levels are elevated in response to mental and physical stress and are an excellent indicator when examining both types of stress[13]. Subjects were asked to refrain from drinking anything other than water for 2 h prior to saliva collection, following the method of Yamaguchi et al[14]. For measurement of joint angles and moments and GRF, a three-dimensional (3D) motion analysis device (Vicon Nexus, Vicon, Hauppauge, NY, USA) consisting of

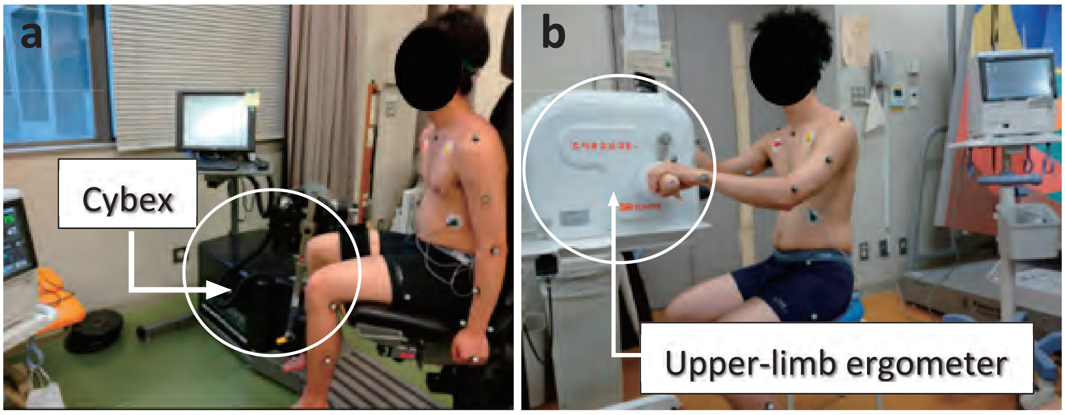

Fig. 2. Fatigue task implementation scene
a: Cybex implementation scene, b: Ergometer implementation scene

eight infrared cameras and a floor reaction-force meter (AMTI, Kanagawa, Japan) were used. The sampling frequency was set to 100 Hz for the infrared camera and 1,000 Hz for the floor reaction-force meter. The subjects wore sports spats and were measured barefoot. The Plug-in Gait Full Body AI model (Vicon) records 39 sites across the body with infrared reflective markers 14 mm in diameter. To ensure reproducibility of measurement, the joint angles in the static standing position before the measurement were checked, and the same examiner always wore the marker. The present study used this model to record the trunk and lower-limb joint angles and moments during the one-legged landing motion using a 3D motion analysis device.

Subjects were instructed to stand on one leg on the front side of a 30-cm platform, cross the upper limbs at the anterior chest, jump and land on one leg facing 20 cm in front of the platform, and remain still for 3 s after landing. They were instructed to look forward as much as possible (Fig. 1). If subjects could not avoid movement for 3 s after landing, moved the foot after landing, or moved the hands away from the chest, it was considered a failed trial. Three successful trials were recorded. There were no breaks between trials. The success data obtained for each of the three times before and after the task were analyzed with NEXUS version 2.8 (Vicon).

Initial grounding was defined as the point at which the vertical floor reaction force exceeded 10 N. The 3D motion analyzer measured the hip and knee/ankle joint angles and knee valgus angles at the pVGRF, the trunk flexion angle at the peak posterior GRF (pPGRF), and the maximum joint moments of hip and knee extension and ankle plantarflexion. The trunk flexion angle was calculated as the angle of the thorax in spatial coordinates. For the joint moment, in addition to measuring the maximum value, the integral value was calculated using the interval from the initial ground contact to the peak value as the integration interval. The GRF parameters selected were pVGRF, pPGRF, the time taken from initial ground contact to pVGRF (time to pVGRF), and loading rate (pVGRF/time to pVGRF), which indicates the impact absorption. The GRF was standardized by weight.

Fatigue tasks

The following fatigue tasks were conducted on different days. Each task was conducted more than one week after the previous experiment. In addition, each task was measured in random order. During each fatigue task, subjects were instructed to keep the trunk in the middle position. A total of 12 subjects performed all the following tasks.

Lower-limb muscle fatigue task (motor task)

We used a muscle function analysis exercise device (Cybex NORM, Lumex, Carol Stream, IL, USA) (Fig. 2) to move the leg muscles by performing isokinetic contractions with an angular velocity of 180°/s over a range of motion of 90° to 0° at the knee joint for 10 min. This movement was performed on the leg on the side of landing movement. To check the subjective level of fatigue, the Borg scale was constantly displayed, and a score of 13-14 was set as the target intensity. The heart rate and respiratory rate were monitored to ensure that they did not exceed 100 bpm (tachycardia) or 25 breaths/min (tachypnea), respectively.

Cardiopulmonary fatigue task (motor task)

We performed a 10-min movement using an upper-extremity ergometer (Terasu-ergoIII, Showa Denki, Osaka, Japan) (Fig. 2) to perform cardiopulmonary movements. To allow the movement load to be set at an aerobic level, the target heart rate during movement was set at approximately 70% of the predicted maximum heart rate (220-age) based on data from the American College of Sports Medicine[15]. Heart rate was monitored during movement using electrocardiogram pads worn on the chest. An upper-limb ergometer is a device for improving muscle strength and endurance by driving the upper limb, and the exercise was performed

Table 1. Degree of fatigue before and after each condition

		Lower-limb muscle fatigue group	Cardiopulmonary fatigue group	Brain fatigue group	Control group
Salivary amylase levels (KU/L)	Pre	22.4±9.8	22.8±7.0	20.4±6.6	22.1±6.0
	Post	49.0±16.2	47.7±15.7	46.1±16.6	20.8±6.3
	Diff	26.6±14.3**	24.8±13.1**	25.7±13.7*	-1.3±3.5
Borg scale scores	Pre	7.0±0.0	7.0±0.0	7.0±0.0	7.0±0.0
	Post	13.0±1.3	13.0±0.6	13.0±0.5	7.0±0.0
	Diff	6.0±1.2*	6.2±0.6*	5.5±0.5*	0.0±0.0

*: $p < 0.05$ vs. control group, **: $p < 0.01$ vs. control group, Diff: difference

by grasping a handle and rotating it in the sitting position.

Brain fatigue task (desk task)

The Uchida-Kraepelin test (Japan Psychiatric Technology Institute Inc.) was performed for 10 min. The Uchida-Kraepelin test a psychological test that repeatedly adds single digits and captures personality and behavioral characteristics from the total amount of work and incorrect answers. It was also used as a brain fatigue task in a previous study[10].

Control task

Subjects during the control task remained in a sitting position for 10 min.

Data analysis

The results were checked for normality by the Kolmogorov-Smirnov test, taking the difference between the pre- and post-task values for each task. Non-normally distributed values were subjected to the Friedman test to compare differences between the four tasks. When significant differences were identified, Bonferroni's adjustment was performed with the Wilcoxon signed-rank sum test as a multiple comparison test and the differences between the pre- and post-task values for each task were compared. The differences between the four conditions before fatigue were tested in the same way. Statistical analysis was conducted using EZR version 1.52[16], with all levels of significance set at 5%. This study was conducted with the approval of the Research Ethics Committee of Arakawa Campus, Tokyo Metropolitan University (approval number: 19073). In accordance with the Declaration of Helsinki, subjects were given a written explanation of the study and consent was obtained.

Results

Pre- and post-task differences in salivary amylase levels and Borg scale scores (Table 1)

A maximum of 5 trials of the landing movement were performed, and the 3 successful trials were analyzed. Results of the analysis of the landing movements before fatigue for each item showed no significant differences between the conditions.

There were significant differences in salivary amylase levels and Borg scale scores. There were also significant differences in salivary amylase levels within the lower-limb muscle fatigue, cardiopulmonary fatigue, and brain fatigue tasks, with higher values after each task compared to the control task, but there was no significant difference between the tasks. The Borg scale scores showed significant differences among the lower-limb muscle fatigue, cardiopulmonary fatigue, and brain fatigue tasks, with higher values after each task compared to the control task. No significant differences were found between the other tasks.

Pre- and post-task differences in joint angles (Table 2)

There was a significant difference in trunk flexion angle at pPGRF, but no significant differences in the other items. There were also significantly lower values for the trunk flexion angle at pPGRF in the brain fatigue task than in the control task. There was no significant difference in the trunk flexion angle between the other tasks.

Pre- and post-task differences in lower-limb joint moments (Table 3)

No significant differences were noted between tasks in the maximum joint moment or integral values after landing on one leg for the hip, knee, and ankle joints.

Pre- and post-task differences in GRF (Table 3)

There was a significant difference in time to pVGRF, but no significant difference was found in pVGRF, loading rate, and pPGRF. Time to pVGRF was significantly shorter in the lower-limb muscle fatigue task than in the control task. No significant differences were found between the other tasks.

Discussion

Regarding the relationship between fatigue and landing motion, drop jumps after fatigue increased the knee ab-

Table 2. Lower-extremity joint angles and trunk angle before and after each condition

		Lower-limb muscle fatigue group	Cardiopulmonary fatigue group	Brain fatigue group	Control group
Hip flexion at pVGRF timepoints (°)	Pre	25.7±6.7	26.8±8.6	26.0±6.7	27.7±6.0
	Post	26.8±8.4	27.3±8.7	24.1±6.3	26.2±6.8
	Diff	1.1±6.0	0.5±2.5	-2.0±2.4	-1.5±1.8
Knee flexion at pVGRF timepoints (°)	Pre	37.6±6.2	35.3±6.6	35.3±6.3	39.5±6.0
	Post	38.0±6.1	36.2±6.3	35.2±6.2	39.2±7.2
	Diff	0.4±5.3	0.9±1.9	0.0±2.3	-0.3±2.5
Knee valgus at pVGRF timepoints (°)	Pre	7.1±9.6	6.5±5.3	7.3±4.6	6.0±6.6
	Post	6.6±9.1	5.3±5.9	7.0±4.6	5.0±7.3
	Diff	-0.5±2.7	-1.2±3.3	-0.4±1.8	-1.0±2.0
Ankle dorsiflexion at pVGRF timepoints (°)	Pre	15.2±3.8	16.0±4.5	15.3±5.4	17.7±5.0
	Post	15.1±4.5	15.7±4.7	15.5±5.4	17.9±5.4
	Diff	-0.1±3.1	-0.2±1.4	0.2±2.0	0.1±1.9
Trunk flexion at pPGRF timepoints (°)	Pre	13.7±5.9	14.6±7.1	14.7±9.1	13.5±7.8
	Post	13.8±5.6	14.2±7.1	9.2±7.8	14.4±8.3
	Diff	0.1±4.0	-0.4±2.3	-5.5±6.9*	0.9±2.8

*: $p < 0.05$ vs. control group, Diff: difference, pVGRF: peak vertical ground reaction force, pPGRF: peak posterior ground reaction force

duction moment[17]. After performing unexpected running-stop movements during a fatigue task including squats and step-up movements, a decrease in knee flexion angle after fatigue was observed[18]. However, the effect of fatigue factors on landing movements is still unclear, and this study examined the differences in fatigue tasks.

No significant differences in salivary amylase levels and Borg scale scores were observed among the tasks, suggesting that the stress load levels were equivalent; salivary amylase levels after each task were significantly higher than those in the control task. Previous studies have suggested an association between salivary amylase levels and general fatigue and stress[19]. Our results suggest that the participants were able to load a certain amount of physical and mental stress for each 10-min task. Each task had a higher Borg scale score than the control task, and subjective fatigue was also recorded.

The brain fatigue task led to a significantly lower trunk flexion angle at pPGRF than the control task. However, there was no significant difference between the fatigue task groups, suggesting that the brain fatigue task may affect the landing strategy compared to the resting state. Ohji et al. found a negative correlation between pPGRF and the angle of trunk flexion during one-legged landing[20]. In this study, the trunk flexion angle of the landing motion was decreased in the brain fatigue task. Thus, the center of gravity of the body and the point of load on the foot is shifted backward. Although the present study found no changes in pPGRF, the reduction in trunk flexion angle observed due to brain fatigue caused by the brain fatigue task may be more pronounced during overlapping brain exhaustion during competition. Inoue showed that fatigue due to central exhaustion can cause a decrease in spontaneous behaviors, which may have caused the subjects to insufficient posture formation to adapt to the environment, such as landing movements[21]. Compared to the neutral trunk position in static standing, a trunk flexion posture that promotes shock absorption during landing seems to require active postural changes. Therefore, a possible reason for the decrease in trunk flexion angle in this study could be that posture formation was insufficient due to brain fatigue. In monkeys, brain fatigue from a simple visual response task resulted in a delay in reaction time[22]. Fatigue during the computational task may delay switching between the main actuators and antagonists and reduce neuromuscular coordination during a jumping task, based on electromyographic examination of the quadriceps and biceps femoris muscles after a 15-min Uchida-Kraepelin test[10]. Therefore, in the present study, the brain fatigue task with the 10-min Uchida-Kraepelin test may have an altered muscle response. Central fatigue, including cerebral fatigue during exercise, may also be explained by a decrease in glycogen in the brain[11]. The delayed reaction time, distraction, and changes in neuromuscular coordination caused by brain fatigue may have led to changes in postural strategies before and after landing, decreasing the trunk flexion angle. Neuromuscular coordination changes due to brain fatigue can delay the switching time of antagonist muscles[10], and if the same occurred in the antagonist muscles of the trunk and hip periarticular muscles, it may have affected postural control. However, since no brain function or exercise physiology tests were conducted in this study, it is unclear

Table 3. Maximum lower-limb joint moments and GRF parameters before and after each condition

		Lower-limb muscle fatigue group	Cardiopulmonary fatigue group	Brain fatigue group	Control group
Hip M. (Nm/kg)	Pre	0.356±0.286	0.338±0.297	0.394±0.245	0.345±0.129
	Post	0.299±0.174	0.369±0.261	0.337±0.190	0.341±0.151
	Diff	-0.057±0.290	0.031±0.109	-0.058±0.143	-0.003±0.115
Knee M. (Nm/kg)	Pre	0.088±0.052	0.124±0.067	0.101±0.055	0.101±0.049
	Post	0.083±0.055	0.102±0.040	0.098±0.051	0.104±0.053
	Diff	-0.006±0.058	-0.022±0.060	-0.003±0.028	0.003±0.045
Ankle M. (Nm/kg)	Pre	0.006±0.006	0.008±0.007	0.007±0.007	0.008±0.006
	Post	0.006±0.010	0.005±0.004	0.006±0.005	0.009±0.011
	Diff	0.000±0.010	-0.003±0.006	-0.001±0.004	0.001±0.005
Hip M. integral (Nm/kg)	Pre	-3.805±1.644	-3.837±1.405	-3.870±1.463	-3.575±1.564
	Post	-3.922±1.386	-3.605±1.609	-4.045±1.371	-3.624±1.279
	Diff	-0.118±0.770	0.233±0.767	-0.175±0.432	-0.049±1.097
Knee M. integral (Nm/kg)	Pre	0.038±0.242	0.100±0.254	0.091±0.284	-0.023±0.313
	Post	0.071±0.254	0.107±0.187	0.089±0.212	-0.050±0.313
	Diff	0.033±0.162	0.007±0.143	-0.002±0.112	-0.027±0.133
Ankle M. integral (Nm/kg)	Pre	-0.195±0.034	-0.188±0.042	-0.184±0.039	-0.178±0.044
	Post	-0.179±0.057	-0.184±0.036	-0.170±0.040	-0.185±0.045
	Diff	0.016±0.051	0.004±0.025	0.014±0.024	-0.007±0.030
pVGRF (%BW)	Pre	46.5±9.1	50.2±9.8	47.9±9.9	45.2±11.7
	Post	45.8±10.7	49.0±11.6	50.8±10.8	45.1±12.0
	Diff	-0.6±7.2	-1.1±4.7	2.9±5.4	-0.1±3.5
Time to pVGRF (ms)	Pre	58.3±10.7	53.7±9.5	55.5±13.1	56.9±13.0
	Post	54.0±10.8	53.8±11.0	53.4±10.2	56.6±13.7
	Diff	-4.3±2.9*	0.1±3.5	-2.1±5.1	-0.3±2.3
Loading rate (%BW/ms)	Pre	0.9±0.3	1.0±0.3	0.9±0.4	0.9±0.4
	Post	0.9±0.4	1.0±0.4	1.0±0.4	0.9±0.4
	Diff	0.1±0.2	0.0±0.2	0.1±0.2	0.0±0.1
pPGRF (%BW)	Pre	-5.8±1.2	-6.1±0.9	-6.1±1.2	-6.1±1.4
	Post	-5.9±1.2	-6.2±1.3	-6.2±1.1	-6.2±1.3
	Diff	0.0±0.6	-0.1±0.6	-0.1±0.6	-0.1±0.3

*: $p < 0.05$ vs. control group

Diff: difference; Hip M.: hip moment; Knee M.: knee moment; Ankle M.: ankle moment; pVGRF: peak vertical ground reaction force; Loading rate: pVGRF/time to pVGRF; pPGRF: peak posterior ground reaction force, BW: body weight

whether the brain fatigue task reduced neuromuscular coordination or brain glycogen. Although previous studies described the change in muscle reaction time in brain fatigue and the increase of anterior withdrawal force and ACL stress of the tibia with a decrease in trunk flexion angle, no study has focused on the trunk flexion angle in the landing motion before and after fatigue. The decrease of trunk flexion angle in the landing motion may be a factor of increased ACL stress due to the backward shift of the center of gravity. Therefore, it is important to consider that landing strategies can change during brain fatigue when compared to resting conditions.

The time to pVGRF was significantly shorter in the lower-limb muscle fatigue task than in the control task. Fatigue is an exogenous factor affecting the skeletal musculature and nervous system and is associated with decreased joint awareness and increased joint laxity[23]. Fatigued muscle fibers exhibit a reduced capacity to absorb energy and an increased anterior deviation of the tibia from altered neuromuscular function[24,25]. We are unable to describe the factors that contributed to the shortened time to pVGRF: there were no significant differences in joint range of motion or joint moment, and articulation, neuromuscular function, and tibial mobility were not measured. The shortened time to pVGRF indicated that the time to reach the maximum vertical floor reaction force after landing on one leg was shortened. Therefore, it is possible that in the lower-limb muscle fatigue group, the landing was such that the floor was slammed against their feet into the floor upon landing. It has been suggested that during such landing movements, the quadriceps muscle contracts more strongly, leading to increased anterior tibial translation[6]. There was no significant change in pVGRF. This may be due to the fact that changes in the fatigue task load and time to pVGRF were minor. The results of this study showed that the time to pVGRF was shorter in the leg-muscle fatigue group, suggesting that the risk of ACL injury may be increased during leg-muscle fatigue, at least when compared to rest.

The range of motion, joint moment, and floor reaction force did not change because the loading was from a light motor task (Borg scale score = 13). Analysis of the lower-extremity joint angle and moment during landing during the stop-jumping motion after the fatigue protocol found that the knee flexion angle decreased by 3.5° and the hip flexion angle decreased by 7.7°, but there was no significant difference in the knee joint moment[26]. The kinematics of the landing motion were analyzed by assuming the fatigue task before the one-legged landing motion as the maximum number of repetitions (Borg scale score = 18), or 85% of the predicted maximum heart rate[26]. Considering the minor changes in the lower-limb joint angle and floor reaction force values during the landing motion at near-maximal fatigue, it is reasonable to assume that the fatigue task in this study did not result in a significant change. However, one limitation of this study is the possibility of inducing ACL damage during landing movements when the task load is set to the maximum load, which makes it difficult to use in research.

Sporting games and practices last longer than the tasks in this study, and fatigue is expected to accumulate in the last stage. Time to pVGRF during lower-extremity muscle fatigue and trunk flexion angle during brain fatigue, which were altered during the 10-min task and prior to reaching maximal fatigue, may be more pronounced during such actual sports activities. Simply rinsing out the mouth with a sugar solution as a preventive measure against central fatigue has been shown to improve performance[27]. The results of this study indicate that the landing motion may be altered during fatigue compared to resting, which may provide important basic information for studying preventive measures. Research into strategies to eliminate brain fatigue and lower-limb muscle fatigue is necessary.

Conclusion

In this study, the kinematics and floor reaction forces of the trunk and lower limbs during a one-legged landing motion were measured using a 3D motion analysis system and GRF meter before and after lower-limb muscle fatigue, cardiopulmonary fatigue, brain fatigue, and the control task, and their differences were analyzed. The maximum trunk flexion angle on landing on one leg was significantly lower in the brain fatigue task than in the control task. The time to pVGRF was significantly shorter in the lower-limb muscle fatigue task than in the control task. No significant differences were obtained among the fatigue task groups. Even if the fatigue task is relatively minor, the effects of muscle and brain fatigue in the lower extremities may change the strategy during the landing movement when compared to the resting state.

Conflict of Interest: The authors declare no conflicts of interest related to this study.

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PHYSICAL
THERAPY
RESEARCH

SCIENTIFIC RESEARCH ARTICLE

The Effect of Toe-grasping Exercises on Balance Ability in Home-based Rehabilitation: A Randomized Controlled Trial by Block Randomization

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ABSTRACT. Objective: The purpose of the study was to clarify the causal effect of toe-grasping exercises on the improvement of static or dynamic balance ability in home-based rehabilitation users. Method: Our study included 34 subjects who met the criteria and were evaluable out of 98 rehabilitation service users at home nursing stations. This study was a randomized controlled trial. The intervention group performed towel gathering exercises in addition to the regular home-based rehabilitation program. The primary outcome was one-leg standing time, and the secondary outcomes were two-step test and toe grip strength. Results: Seventeen subjects were assigned to the intervention group and seventeen to the control group by block randomization. Data from 15 and 12 subjects in the intervention group and control group, respectively, who were able to complete the initial evaluation and the evaluation after 3 months, were analyzed. We compared the amount of change after 3 months of evaluation in the intervention group with the change in the control group. The results showed that the left/right mean value of oneleg standing time in the intervention group was significantly greater than that in the control group. In terms of the amount of change in the intervention period (T2-T1) within each assessment, there were significant improvements in both the toe-grip strength and the two-step values in the intervention group. Conclusion: We found that toe-grasping exercises could improve the balance ability of home-based rehabilitation users. This suggests the clinical significance of toe function in rehabilitation programs.

Key words: Toe-grip strength, Home-based rehabilitation, One-leg standing time, Two-step test, Randomized controlled trial

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As the birthrate declines and the population ages in Japan, it is becoming increasingly important to create a social system to support the elderly. Therefore the importance of home-care services, such as home-based rehabilitation, is constantly growing[1-3)]. However, there is currently little research to accumulate evidence-based data though the society recognizes the significance of home-based rehabilitation in fall prevention and postponing the need for nursing care[4)]. Hence, the specific benefits of home-based rehabilitation programs have not yet been completely determined.

The importance of fall prevention in daily life at home is recognized because falls in the elderly often have serious consequences such as bone fractures[5)]. Improvement in balance ability plays an important role among fall prevention strategies[5-7)].

There are two types of balance ability: static and dynamic. Static balance is the ability to maintain upright posture within the limits of the base of support; dynamic balance is the ability necessary to move out of and change the base of support. Both of them are essential for fall preven-

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tion[8].

Various systems are involved in the static and dynamic balance abilities of the musculoskeletal, neuromuscular, sensory/perceptual, and cognitive systems[9]. It has been suggested that toe functions, such as toe grip strength, play an important role in the musculoskeletal system[10]. However, there are few studies on how toe-grip strength affects the musculoskeletal function in the elderly with chronic diseases and those who require long-term care[11,12]. Benvenuti et al. reported as the activity level of the elderly declined, the toes' motor function, such as the toe-grip strength, declined too[13]. Murata et al. found a significant correlation between the toe-grip strength and the occurrence of falls in a prospective study of the elderly who could walk independently[14]. Nagai et al. investigated the effects of toe grip training on lower limb muscle strength and balance ability in elderly nursing home residents using a crossover test and found that toe grip strength and functional reach distance were improved in a pre- and post-training comparison[15]. Thus, we are gradually becoming aware of the growing importance of toe functions, such as toe-grip strength, on balance ability. However, there is little evidence to support the necessity of incorporating training to improve toe function in rehabilitation protocols in medical institutions and home care facilities. In particular, there are no randomized controlled trials that have examined the effects of toe training on balance performance in individuals with conditions requiring nursing care during rehabilitation.

We focused on the toe-grip strength in home-based rehabilitation. There is a relationship between the toe-grip strength and one-leg standing time, an index of static balance ability, in home-based rehabilitation users who require assistance or watchful waiting for movement, and presents significant correlation[16]. However, although such a correlation was determined in a cross-sectional study, the causal relationship remains unclear.

The purpose of our study was to clarify the hypothesis that there is a causal effect of the toe-grasping exercises on the improvement of static or dynamic balance ability in home-based rehabilitation users. A randomized controlled trial was conducted to investigate whether the implementation of toe-grasping exercises improves the static and dynamic balance ability.

Subjects and Methods

1. Subjects

Our study included 34 subjects who met the following criteria and were evaluable out of 98 rehabilitation service users attended by physical or occupational therapists at home nursing stations from April 2018 to March 2020. The inclusion criteria were: able to ambulate at or above watchful waiting level and absence of malignant or degenerative diseases. The exclusion criteria were: a significant change of medical condition (hospitalization, etc.) and inability to perform the towel gathering exercise.

All subjects gave their consent for participation after receiving written and oral explanation on the methods and procedures involved in the study. They were informed that they could discontinue participation at any time if they felt burdened, without any consequences, and that their personal information and privacy were guaranteed. This study was designed following the Declaration of Helsinki principles and was approved by the Ethics Committee of the Japanese Physical Therapy Association (approval number: H29-001). This study was registered as a clinical trial with UMIN (acceptance number: UMIN000043984).

2. Methods

Sample size setting

The sample size design was conducted using G*power 3 (Heinrich-Heine-University, free software) with an alpha error of 0.05, a power of 0.8, and a large effect size (0.8) based on Cohen's theory of differences in populations[17]. The required sample size was 26 subjects in each group.

Randomization method

This study was a randomized controlled trial based on the CONSORT 2010 guidelines[18] in which subjects were divided into an intervention group and a control group by computerized block randomization[19]. For the method of allocation, six subjects were allocated as a block, and 20 different combinations [e.g., (a)(a)(b)(a)(b)(b)] were created in which the number of the two types of groups, intervention group (a) and control group (b), were equal. The combinations were then determined by the numbers obtained by random number generation using Excel (Microsoft Corporation). The assignments were applied sequentially according to these combinations. The assignment order was set by a physical therapist working at the visiting nursing station, who was the researcher. It was based on the subject's schedule and the order of the new implementation of the home-based rehabilitation during the period. Another physical therapist working at the same home nursing station, who did not know the study's contents, was responsible for generating random numbers and managing the assignment table. In this way, each group was assigned a random number. Thus, the researcher was kept uninformed until the allocation of each group was completed and the subjects distributed in groups.

Evaluation Method

The evaluation period was determined by the first evaluation (T1) and the 3-month evaluation (T2), with a duration of 3-4 months. All evaluations were conducted indoors, at the subject's home, before the rehabilitation, and at a rehabilitation home visit. The evaluation items were toe-grip strength, one-leg standing time, and a two-step test for balance ability evaluation.

Table 1. Program content in the intervention and control groups

Intervention Group	Control Group
usual home-based rehabilitation program	usual home-based rehabilitation program
general coordination	general coordination
range of motion exercises	range of motion exercises
muscle strengthening exercises	muscle strengthening exercises
basic movement exercises	basic movement exercises
towel gathering exercises	

1) Toe-grip strength

The toe-grip strength was evaluated using a toe grip dynamometer (T.K.K. 3361; *Takei Scientific Instruments*, Niigata, Japan)[20]. The subjects sat on a bed, or a chair with the knee flexed at 90°, and after fixing the foot, the gripping force was measured at maximum effort[16]. The measurements were registered three times on each side, and the maximum value was used.

2) One-leg standing time

The subject was instructed to stand on one leg with their eyes open and with arms at their sides for a maximum of 30 sec. The maximum value of the three measurements on each leg was used for evaluation[21,22]. The criterion to stop the measurement was when the non-tested leg contacted the floor or when the tested leg was displaced. During the examination, subjects were closely observed for fall prevention from the side of the non-tested leg. If one-leg standing on either side was considered to be impossible or dangerous (due to skeletal conditions or pain) to perform, the test would be discontinued.

3) Two-step test

The Japanese Orthopaedic Association proposed a two-step test as one of the evaluation methods that can be easily performed for assessing the locomotive syndrome[23,24]. Its evaluation has been shown to have a relationship with the 10-m walking speed, 6-minute walking distance, and the degree of daily life independence[25]. Also, the two-step test is strongly correlated with dynamic balance assessments such as the Timed Up and Go test (TUG), indicating its usefulness as an indicator of dynamic balance ability[26]. The two-step test measures the length of two steps, and the two-step value for standardization is the ratio of the maximum length of two steps to the subject's height. Measurements were performed for the maximum length at which the subject's balance is maintained three times, and the maximum value was used for evaluation. The test should be conducted under the supervision and within the range of not losing balance and not jumping.

The above evaluations were performed by the researcher, a physical therapist working at a home-nursing station.

Intervention method

The control group's usual home-based rehabilitation program was conducted for 40 minutes per visit, focusing on general coordination, range of motion, muscle strengthening, and basic movement. Based on the usual home-based rehabilitation program provided in Table 1, each therapist implemented an individual program according to the needs and conditions of the subject. They were conducted twice a week on average.

The intervention group performed towel gathering exercises twice a week for about three months in addition to the regular home-based rehabilitation program described above (Table 1). Towel gathering is the most often used exercises for improving the toe-grip strength[27]. According to a schedule, seven physical therapists working at a home-nursing station, including the researcher, randomly provided the control and the intervention home-based rehabilitation services to the control and intervention group.

The towel gathering exercise consisted of sitting on a bed, or a chair with the knee bent at approximately 90° with the heel on the floor, flex back the foot with a maximum effort by flexing the toes. The subject repeated the exercise to feel his lower limbs felt tired; he/she stopped for a 30-sec break and then repeated the movement. This series of exercises was performed three times in a row for approximately three minutes per set. The towel gathering exercise was performed as one set in addition to the regular rehabilitation program during the therapist's visit. The subjects were also encouraged to voluntarily perform the towel gathering exercise the rest of the days and mark them on a calendar provided to them in advance. The number of therapists' visits was determined by the number of days provided by the nursing care insurance during the evaluation period. The number of days of towel gathering exercises was counted based on the number of marks on the calendar handed to the subject in advance.

Statistical analysis

The statistical analysis was performed by a different researcher from the one who organized the data. JMP 12.0.1 software (SAS Institute, Cary, NC, USA) was used for the statistical analysis. The primary outcome was one-leg standing time, and the secondary outcomes were two-step test and toe grip strength. Statistical methods were determined based on the results of the Shapiro-Wilk test for normal distribution. Parametric methods were used for normally distributed data, and non-parametric methods were used for non-normal distribution. Wilcoxon signed-rank

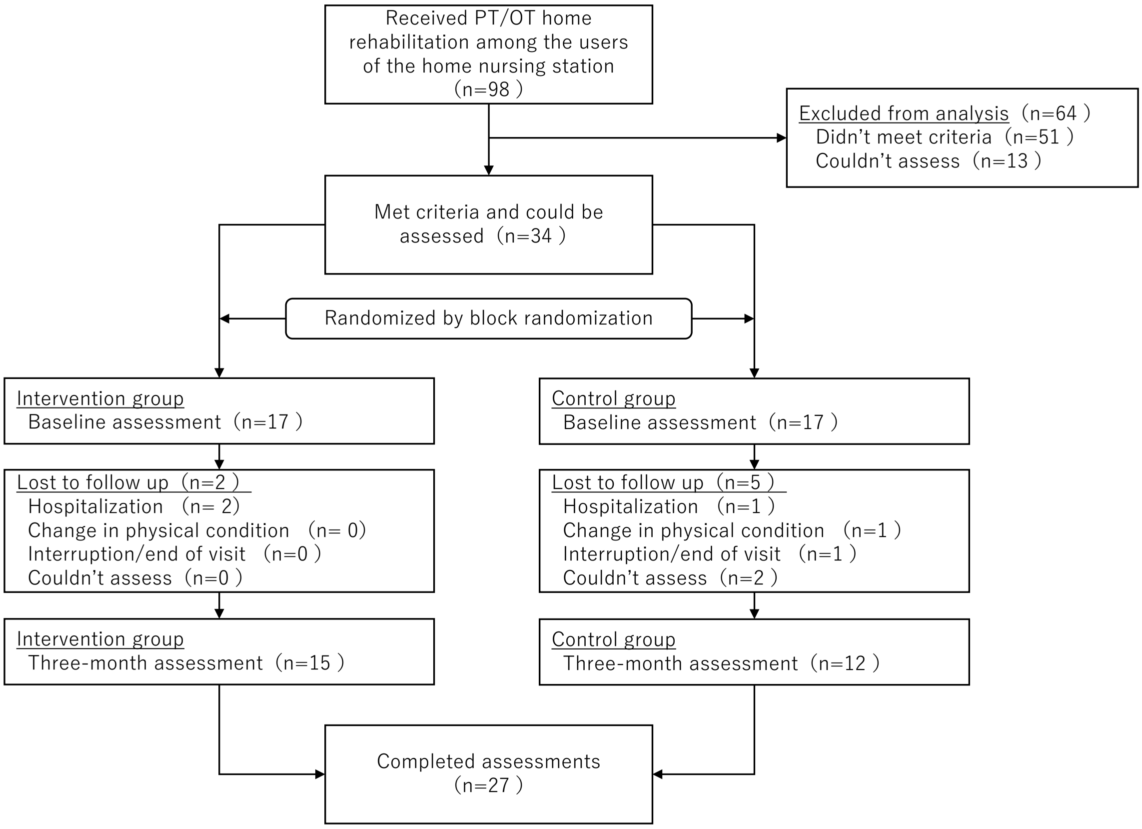

Fig. 1. Flow diagram of participants

test determined changes in data assessed before and after the intervention, and comparisons with the control group were calculated using Wilcoxon rank-sum test. The level of statistical significance was set at 5%.

Results

1. Subjects

The flow diagram of the subjects is shown in Figure 1. Seventeen subjects were assigned to the intervention group and seventeen to the control group by block randomization[19]. Data from 15 and 12 subjects in the intervention group and control group, respectively, who were able to complete the initial evaluation and the evaluation after 3 months, were analyzed.

2. Baseline Characteristics

The baseline values were compared for the basic attributes and background factors in both groups (Table 2). There were no significant differences in age, sex, nursing care level, home-based rehabilitation period, evaluation period, number of days visited by home-based rehabilitation during the evaluation period, or frequency of visits between the groups.

3. Comparison between the intervention and the control group (Table 3)

First, each assessment was compared between the intervention and control groups at the initial assessment time (T1) as a baseline. There was no significant difference in one-leg standing time, two-step values, and the toe-grip strength. Next, we compared the amount of change after 3 months of evaluation (T2-T1) in the intervention group with the change in the control group. The results showed that although there was no significant difference in the one-leg standing time in the results of both the right and left leg, the left/right mean value in the intervention group was significantly greater than that in the control group. No significant difference was observed in toe-grip strength and two-step values between the groups.

In terms of the amount of change in the intervention period (T2-T1) within each assessment, there was no significant change in the control group in any of the assessments. In contrast, there were significant improvements in both the toe-grip strength and the two-step values in the intervention group. There were no significant intragroup changes in the one-leg standing time in either the intervention or control group.

Discussion

1. Changes in toe-grip strength

In the present study, we compared the change in the intervention group (T2-T1) with the change in the control

Table 2. Baseline comparison of intervention and control groups

Data Item	Intervention Group (*n*=15)	Control Group (*n*=12)	*P value*
Age (years, mean±SD)	76.2±12.2	80.5±7.7	0.51#1
Sex (male/female)	5/10	5/7	0.71#2
Level of nursing care#3			0.20#2
Support level 1	2	0	
Support level 2	3	4	
Care level 1	1	4	
Care level 2	6	3	
Care level 3	2	1	
Care level 4	1	0	
Care level 5	0	0	
Disease (including duplication)			0.33#2
Cerebral vascular disorder	7	3	
Orthopedic disorders	4	8	
Internal disorder	5	5	
Hypertension	5	2	
Diabetes	3	2	
Self-immune disorders	1	0	
Mental disorder	0	1	
Home-based rehabilitation period#4 (days, mean±SD)	928.7±993.1	907.1±991.9	0.79#1
Evaluation period (days, mean±SD)	105.5±8.1	107.8±7.4	0.51#1
Number of days visited (days, mean±SD)	26.0±11.7	28.0±6.4	0.21#1
Frequency of visits (days/week, mean±SD)	1.7±0.8	1.8±0.5	0.61#1

#1: Wilcoxon rank sum test

#2: Chi-squared test

#3: Level of nursing care determined by the long-term care insurance system. Patients apply for the care need assessment at the city office.

#4: Utilization period determined by the number of days from the start of use of the home nursing station to the date of the first evaluation.

group after 3 months of evaluation. There was no significant difference in toe-grip strength. This result suggests that toe-grasping exercises had no effect on toe-grip strength. However, the results of the pre/post comparison within the groups showed that there was no significant change in both the left/right values and the mean values in the control group, while there was a significant improvement in the intervention group. This result supports the usefulness of toe-grasping exercises to some extent. In previous studies, results in young people[28)] and in other older adults who require care[29)] have shown that training improves toe-grip strength regardless of age or disease status. In any case, the effect of the current toe-grasping exercises may have been small. The method and frequency of training are issues to be studied in future researches.

2. Effect of toe-grasping exercises on balance ability

We compared the amount of change after 3 months of evaluation (T2-T1) in the intervention group with the change in the control group. As a result, although there was no significant difference in one-leg standing time in the right and left leg results, the left/right mean value in the intervention group was significantly greater than that in the control group.

Since we found a significant correlation between the toe grip strength and one-leg standing time results in home-based rehabilitation users who require assistance or supervision for mobility[16)], the hypothesis of the present study, that improvement of toe-grip strength by toe-grasping exercises would affect the improvement of balance ability such as one-leg standing time, was confirmed by the results of this study. However, it is necessary to consider the reasons for the rather weak results to confirm the hypothesis, such as the fact that no significant difference was obtained in the results of the one-legged standing time measurement for the left and right sides. One of the reasons for this, as mentioned above, was that the toe-grasping exercises had little effect on toe-grip strength. Another consideration is that toe-grip strength has a small influence on one-leg standing time. Yamauchi et al.[30)] examined whether postural stability during one-legged standing, using the center of pressure, was related to the toe-grip strength in healthy young adults

Table 3. Comparison of the amount of change in measurements between the intervention group and the control group

		Intervention Group (n=15)				Control Group (n=12)				T1	T2-T1	T2-T1
		T1	T2	T2-T1	P value#1	T1	T2	T2-T1	P value#2	P value#3	P value#4	r value#4
		mean±SD	mean±SD	mean±SD		mean±SD	mean±SD	mean±SD				
Toe-grip strength (kgf)	Right	7.3±6.7	8.3±6.2	1.0±1.6	0.04*	4.5±3.1	4.7±3.5	0.2±1.6	0.31	0.31	0.42	0.52
	Left	5.3±2.8	6.7±3.3	1.4±1.6	0.001**	5.0±2.9	5.1±3.6	0.04±2.4	1.00	0.79	0.08	0.78
	Maximum	7.7±6.6	8.8±6.1	1.1±1.6	0.02*	5.3±3.1	5.7±3.9	0.3±1.8	0.38	0.35	0.45	0.61
	Average	6.3±4.5	7.5±4.5	1.2±1.4	0.001**	4.8±2.9	4.9±3.3	0.1±1.8	0.69	0.41	0.14	0.80
Two-step value		0.6±0.3	0.8±0.3	0.1±0.2	0.048*	0.6±0.2	0.6±0.2	-0.02	0.47	0.71	0.08	0.51
One-leg standing time (sec)	Right	5.7±7.6	6.2±8.1	0.5±2.8	0.57	1.8±2.6	2.0±3.6	0.2±1.6	1.00	0.06	0.80	0.05
	Left	7.0±10.0	8.2±10.6	1.2±3.3	0.36	5.0±6.5	2.7±3.5	-2.3±4.7	0.16	0.75	0.14	0.28
	Maximum	8.1±9.8	9.5±10.4	1.4±3.4	0.16	5.1±6.5	3.2±4.0	-1.9±4.2	0.23	0.48	0.17	0.26
	Average	6.3±8.0	7.2±8.6	0.8±1.8	0.19	3.4±4.5	2.3±3.2	-1.1±2.3	0.19	0.34	0.03*	0.40

**P<0.01, *P<0.05

T1 indicates the pre-measurement, and T2 indicates the post-measurement.

Abbreviations: P=Significance probability, r=Effect size, SD=Standard deviation

#1: Before and after comparison of intervention groups

#2: Before and after comparison of control group

#3: Comparison of the measurements at T1 between the intervention group and the control group

#4: Comparison of the amount of change in measurements between the intervention group and the control group and found no significant correlation. This result suggests that the toe-grip strength does not have a substantial role in postural stability during static standing. Therefore, it is possible that toe-grasping exercises are not effective in influencing one-leg standing time.

On the other hand, the two-step value[26] did not show a significant difference between the intervention and control groups at the 5% level. However, it could be argued that a result of P=0.083 and an effect size of r=0.51 do not mean that there is no significant difference, but that there is a tendency for some improvement. In fact, within-group comparisons before and after the intervention showed a significant improvement in the intervention group. Fukuda et al.[28] found that toe-grip strength training significantly improved walking speed and stride length during a 10 m walk in young, healthy subjects. They attributed the increase in toe-grip strength to an increase in stride length due to increased propulsive force and stability at the time of stepping off the toes. The present results may have affected the two-step value for the same reason. These results indicate that increasing toe-grip strength can leads to an increase in dynamic balance ability.

These results suggest the clinical significance of providing more training to improve toe function in rehabilitation programs at medical institutions and nursing facilities.

3. Limitations of this study

This study has several limitations. First, the sample size was smaller than previously estimated because of the inability to secure a sufficient number of cases within the study period and the difficulty in extending the study period due to the researchers' change in affiliations. As a result, the power of the study was reduced, the rate of β-error increased, and significant differences may have been overlooked. Therefore, we did not discuss only the significant difference, but also the effect size. Second, there is a possibility that the control group may have been mixed with the intervention group. Since the home-based rehabilitation program is individualized to meet the needs and conditions of the subjects, we cannot deny the possibility that some toe-grasping exercises were conducted for the subjects in the control group. However, in the current home-based rehabilitation program, it is realized that each therapist does not provide toe-grasping exercises to all subjects by default. The fact that there was a significant difference between the two groups, even with the possibility that the control group was included in the intervention, may strengthen this significance. Third, all assessments in this study were conducted by a single physical therapist. There may be some influence of bias because other therapists participating in the intervention could grasp the study's contents to some extent. Further study is warranted to verify our findings in larger-scale trials.

Conclusion

In this study, we found that toe-grasping exercises could improve the balance ability of home-based rehabilitation users who require assistance or supervision for mobility. This suggests the clinical significance of providing more training to improve toe function in rehabilitation programs at medical institutions and nursing facilities.

Conflict of Interest: None.

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PHYSICAL THERAPY RESEARCH

Brief Reports

Sex Differences in Physical Activity in People After Stroke: A Cross-sectional Study

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ABSTRACT. OBJECTIVE: Adequate physical activity after stroke is critical for cardiovascular health. Although sex is a potential factor associated with post-stroke physical activity, its mechanism remains unclear. This study aimed to examine sex differences in human physical activity following stroke. METHOD: A cross-sectional study with 62 participants (men: 42, women: 20) was conducted. Physical activity was measured for three consecutive days using a step activity monitor. The walking durations per day in light physical activity, moderate-to-vigorous physical activity, and total physical activity were calculated. Sex differences in walking duration were compared using Welch's t-tests or Mann-Whitney U tests. RESULTS: Women had a significantly greater walking duration in light physical activity and in total than did the men. In contrast, no significant differences were found in moderate-to-vigorous physical activity. CONCLUSION: This study reported sex differences in the walking duration after stroke. Moreover, it found that women spent more time in low intensity physical activity than men. Our results will be useful for planning interventions to increase physical activity and decrease sedentary behavior after stroke.

Key words: Physical activity, Stroke, Intensity, Guideline

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Increasing physical activity (PA) after stroke is important to control risk factors associated with further cardiovascular disease[1)]. The American Stroke and Heart Association's PA recommendations[2)] state that people with stroke should engage in aerobic activity, defined as 40-70% of the maximal oxygen consumption reserve or heart rate reserve (equivalent to moderate-vigorous physical activity; MVPA) for 20-60 minutes, 3-5 days per week. Nevertheless, many community-dwelling people with stroke are physically inactive[3)].

Although sex is a potential factor associated with post-stroke PA, the results obtained to date are controversial[4-6)]. Two systematic reviews[4,5)] concluded that there were no significant correlations between PA levels and sex. Another meta-analysis[6)] reported a small relationship between PA and sex. However, the meta-analysis findings[6)] were based on the results of only two studies (n = 58).

Sex may have an impact on different PA categories[7,8)]. In healthy older populations, men tend to spend more time in some domains, including vigorous and leisure-time PA, compared with women, whereas women tend to spend more time in light physical activity (LPA), such as in household and non-leisure/non-sport activities compared with that in men[7,8)]. In terms of MVPA patterns, one study[9)] reported that women accumulated more short bouts (1-9 minutes) of MVPA than men did; in contrast, men accumulated more long bouts (>10 minutes) of MVPA than women did. Thus, it is necessary to consider the PA intensity and MVPA bout length when analyzing sex differences in PA after stroke.

The present study aimed to examine the sex differ-

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ences in physical activity after stroke. We hypothesized that women would spend more time than men in LPA and short-bout MVPA, and that men would spend more time than women in long-bout MVPA.

Methods

Study design and participants

This study used a cross-sectional design and is part of a prospective study aiming to determine the longitudinal PA changes in stroke people after discharge. Individuals with ischemic or hemorrhagic stroke were recruited from a rehabilitation hospital. All participants were enrolled at discharge from the rehabilitation ward. Inclusion criteria were 1) first-ever stroke, 2) discharge to home, 3) independently mobile over 10 meters with or without walking aids or orthosis, and 4) able to understand simple instructions. Exclusion criteria were 1) Mini-Mental State Examination score <24, 2) mobility problems before stroke, and 3) severe medical conditions, such as recent myocardial infarction or unstable angina. All individuals provided written informed consent to participate. This study was approved by the Ethics Committee at Ibaraki Prefectural University of Health Sciences (approval number: e171).

Procedure

Measurements of participant characteristics were collected at discharge and home visit. A systematic review[6] reported that age, sex, physical function, depression, fatigue, and self-efficacy were factors associated with post-stroke physical activity. The 2-minute walk test[10] (one trial), 10-meter walk test[11] (three trials at fastest speed), timed-up and go test[12] (three trials) were performed at discharge to measure physical function. The Mini-Mental State Examination[13] (cognitive status) was also examined. Then, research staff conducted a home visit within one month after discharge and evaluated patients via the Patient Health Questionnaire-9[14] (depression), Fatigue Severity Scale[15] (fatigue), Modified Falls Efficacy Scale[16] (self-efficacy) and activity monitor (PA).

A StepWatch Activity Monitor (Modus Health, Edmonds, Washington) was strapped above the lateral malleolus of the less-affected lower extremity. The StepWatch Activity Monitor is a valid and reliable tool for measuring walking activity in people with stroke[17]. Participants were asked to wear the monitor for three consecutive days during all waking hours, except during bathing and swimming activities. At discharge, participants received standard advice to perform PA, but no instruction was given to encourage PA at home visit. Step data were collected every 5 seconds.

Data Analysis

Data for wearing times greater than 8 hours per day were used for data analysis. Non-wearing was defined when no stride was detected for at least 90 consecutive minutes. The start of a walking bout was defined as three strides within a 15-second interval, and the end of a walking bout was defined as a 10-second interval in which no strides occurred[18,19]. Because the StepWatch Activity Monitor detects a stride on the mounting side, the output was doubled and expressed as steps. The number of steps, walking duration, and walking cadence for each walking bout were calculated.

To define the intensity of activity, we calculated the peak cadence ratio as the ratio of walking cadence in each walking bout to the maximum walking cadence during the measurement period. For example, when the walking cadence in a walking bout was 50 steps/min and the maximum walking cadence during the measurement period was 100 steps/min, the peak cadence ratio was 0.5. Energy expenditure in walking at a comfortable pace among stroke survivors was approximately 3 metabolic equivalents[20], corresponding to MVPA. Cadence during low-sequential-step bouts cannot be considered a comfortable walking pace, because these activities are performed at a slower speed[21]. In contrast, cadence during high-sequential-step bouts can be used to define MVPA because it represents walking toward a destination or exercise[22]. We operationally defined a high-sequential-step bout as ≥300 steps[19] and classified each walking bout into either LPA or MVPA based on the peak cadence ratio during high-sequential-step bouts.

We used SPSS version 25 (IBM Corp, Armonk, NY) for the statistical analyses. Sex differences in participant characteristics were compared using Fisher's exact test, Welch's t-tests, or Mann-Whitney U tests according to the normality of the data. We used the cut-off point of a high-sequential-step bout (≥300 steps) in relation to the peak cadence ratio to define activity intensity (LPA or MVPA). The cut-off point was determined by receiver operating characteristic curves and Youden's index. Then, walking durations per day in LPA, MVPA, and total (LPA plus MVPA) were calculated. MVPA was further divided into two types according to length of each walking bout: short-bout MVPA (1-9 min) and long-bout MVPA (≥10 min)[9]. The walking durations per day are expressed as the product of duration per bout and the number of bouts per day. Therefore, we calculated the median duration per bout and the number of bouts per day in LPA, MVPA, and Total. The step activity was calculated for each day, and the average values across days were used in the analysis of group differences. Sex differences in each walking variable were compared using Welch's t-tests or Mann-Whitney U tests according to the normality of the data. A p-value <0.05 was used to determine statistical significance.

Table 1. Participant demographics

	Men (n=42)	Women (n=20)	*p*-value
Age (y)	63 ± 13	64 ± 7	0.89
Stroke type, n (infarction/hemorrhage)	29/13	10/10	0.12
Lesion side, n (right/left)	27/15	3/17	<0.001
Post-stroke duration (days)	143 ± 51	155 ± 49	0.41
Post-discharge duration (days)	17 ± 9	16 ± 8	0.66
Mini-Mental State Examination (0–30)	30 (26–30)	29 (25–30)	0.11
Patient Health Questionnaire-9 (0–27)	2 (0–5)	1 (0–5)	0.79
Fatigue Severity Scale (9–63)	24 (16–40)	18 (14–30)	0.29
Modified Falls Efficacy Scale (0–140)	129 (105–139)	131 (119–139)	0.44
Walking with orthosis, n (%)	16 (38%)	5 (25%)	0.23
Walking with cane, n (%)	18 (43%)	8 (40%)	0.53
2MWD (m)	150 ± 45†	153 ± 47	0.79
Gait speed: fastest (m/s)	1.5 ± 0.7†	1.5 ± 0.5	0.82
Timed up and go test (s)	12 (9–14) ‡	10 (8–14)	0.26

Abbreviations: 2MWD, 2-minute walk distance

† n = 1 missing, ‡ n = 2 missing

Mini-Mental State Examination score ranges from 0 to 30. High scores indicate good cognitive function. Patient Health Questionnaire-9 score ranges from 0 to 27. High scores indicate higher levels of depressive symptoms. The Fatigue Severity Scale score ranges from 9 to 63. High scores indicate greater fatigue severity. The Modified Falls Efficacy Scale score ranges from 0 to 140. High scores indicate higher fall efficacy.

Results

In total, 239 people with stroke were screened, 162 fulfilled the inclusion criteria and 62 participants (42 men, 20 women) agreed to participate in the study. Table 1 presents the participant characteristics and the comparisons between men and women. No sex differences were found among factors associated with post-stroke PA[6)]. Although PA data for 10 participants (men: seven; women: three) were available for only two days, all 62 participants were included in the analyses. Mean wearing time was 712 ± 144 min/day in men and 803 ± 122 min/day in women.

The receiver operating characteristic curves analysis revealed that the area under the curve for high-sequential-step bout (≥300 steps) in relation to the peak cadence ratio was 0.961 (95% confidence interval: 0.957-0.966), and the optimal cut-off value was 0.655, correlating to 65.5% of the maximum walking cadence during the measurement period. Therefore, walking bouts in which the peak cadence ratio was less than 0.655 were defined as LPA, and those with a peak cadence ratio greater than or equal to 0.655 were defined as MVPA. The mean maximum walking cadence during the measurement period for all participants was 106 ± 14 steps/min. The cut-off value corresponded to a walking cadence of 69 ± 9 steps/min.

Table 2 presents the comparison of sex differences in walking duration. Women had a significantly greater walking duration in total and LPA. No sex differences were found in any parameter in MVPA. In all participants, the average MVPA duration was 44 minutes. Of these, 75% were short-bout MVPA. Figure 1 shows a comparison of sex differences in the median duration per bout and the number of bouts per day. Women had a significantly greater number of Total and LPA bouts per day. No sex differences were found in the median duration per bout.

Discussion

The present study aimed to examine sex differences in human physical activity after stroke. The results showed that women had significantly greater Total and LPA walking durations. In contrast, there were no significant sex differences in any parameter in MVPA.

This study showed that women had a significantly greater walking duration per day than men did. Previous studies[4-6)] have reported mixed results in terms of sex differences in PA after stroke. Our results demonstrated sex differences in participant's walking durations after stroke.

This study showed that the greater walking duration observed in women was attributable to an increased walking duration in LPA compared with that of men. This is consistent with previous studies[7,8)] that reported healthy older woman spent more time in LPA, such as in household activities, than older men. These findings suggest that, compared with men, women spend more time in housework before stroke and continue to be involved in household activities after stroke. Gender roles could explain the sex differences in LPA in people after stroke.

Table 2. Comparison of walking duration between men and women

	Men (n=42)		Women (n=20)		*p*-value
	mean ± SD	Median (25%–75%)	mean ± SD	Median (25%–75%)	
Total (min)	115 ± 59	108 (70–152)	140 ± 41	143 (110–164)	0.042
LPA (min)	68 ± 45	56 (40–86)	103 ± 36	106 (78–128)	0.001
MVPA (min)	47 ± 31	45 (18–68)	37 ± 19	34 (22–54)	0.45
Short-bout	30 ± 22	24 (14–43)	26 ± 14	24 (17–31)	1.00
Long-bout	17 ± 20	6 (0–31)	11 ± 16	3 (0–17)	0.21

Short-bout: lasting 1–9 min, Long-bout: lasting ≥ 10 min

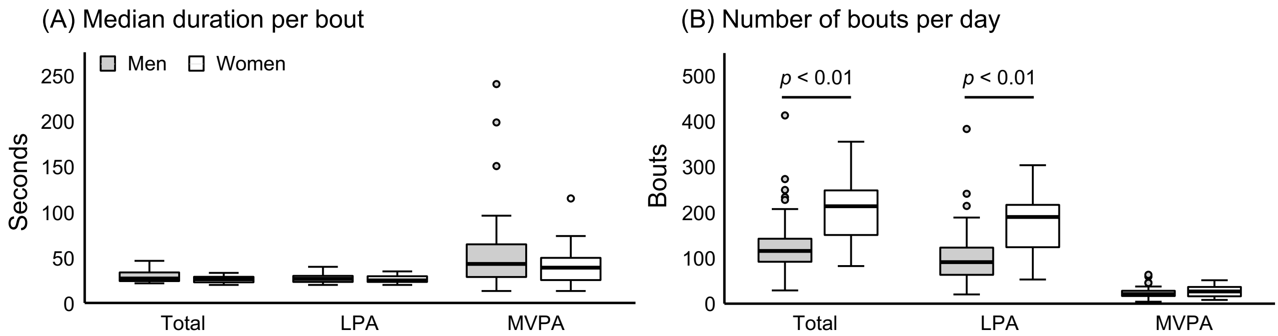

Fig. 1. Comparison of median duration per bout and the number of bouts per day between men and women

The median duration in LPA was 56 min/day in men and 106 min/day in women. A previous study[23] reported that replacing one hour of sedentary time with LPA was associated with 18% lower mortality. Thus, differences in LPA duration of approximately 40 minutes between men and women in our sample may affect health outcomes. This study also showed that the greater duration of LPA in women than men was due, not to an increase of duration per bout, but to an increase in walking bouts (Fig. 1). These findings suggest that after stroke, men could benefit from interventions, such as counseling aimed to encourage replacing sedentary time with frequent LPA.

Little is currently known about sex differences in MVPA after stroke. Our results revealed no significant sex differences in MVPA duration, regardless of the length of the walking bout. In this study, 75% of the total MVPA were short-bout MVPA. This result suggests that short-bout MVPA is easily acceptable for people after stroke compared to long-bout MVPA. Total MVPA duration was strongly associated with lower mortality, regardless of how the MVPA was accumulated[24].

We defined the intensity of activity based on the relative indicator of cadence. The advantages of this method are that it is adaptable to a range of stroke participants with various walking abilities. The threshold between LPA and MVPA was 0.655 in the peak cadence ratio, corresponding to a cadence of 69 ± 9 steps/min. This cut-off definition was higher than that reported in previous studies[25,26], which defined MVPA as ≥30 steps/min. In addition, our cut-off definition was close to the established threshold value of 100 steps/min for MVPA in healthy adults[27]. Although there is no established definition of MVPA after stroke, we believe that our definition of activity intensity was reasonable and useful for people after stroke with various walking disabilities.

The present study involved several limitations. Firstly, we asked participants to wear a step activity monitor for three consecutive days. However, data for 10 participants were only available for two days. A previous study reported that monitoring for more than a 3-day period is recommended for high reliability[28]. Secondly, we collected step data every 5 seconds to ensure accurate representation of continuous stepping. Although the optimal epoch length to measure PA for people after stroke remains unclear, our results might have differed if we had collected step data using a longer epoch[29]. Thirdly, although one female participant walked in a pool during the measurement period, swimming activities were not considered due to restrictions of the step activity monitor. Finally, the results have limited generalizability because our patients had mild walking disability (2-minute walk test of 151 m and a fastest gait speed of 1.5 m/s).

Conclusion

In conclusion, sex differences were found in the walking duration in people after stroke. Women more frequently engaged in and spent more time in LPA than men. In contrast, no sex differences were found in MVPA. Our results will be useful for planning interventions to increase PA and decrease sedentary behavior after stroke.

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Conflict of Interest: The authors declare that there is no conflict of interest.

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PHYSICAL
THERAPY
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CASE REPORTS

Impairment in Physical Function and Mental Status in a Survivor of Severe COVID-19 at Discharge from an Acute Care a Hospital: A Case Report

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ABSTRACT. Background: Early mobilization and rehabilitation interventions should be provided to patients who survived severe COVID-19 to improve their physical function and activities of daily living (ADL). However, their physical and mental status at discharge has not been well described in Japan. We report the intervention provided for a survivor of severe COVID-19 and his physical and mental status at discharge from an acute care hospital. Case Report: A 62-year-old man was admitted to our emergency department with a diagnosis of COVID-19 with severe acute respiratory dysfunction. He had complicated intensive care unit-acquired weakness (ICU-AW) and delirium during mechanical ventilation therapy. Rehabilitation intervention was initiated on the seventh day post-admission and was gradually performed according to his respiratory and hemodynamic status. As a result of the rehabilitation intervention, ICU-AW and cognitive function gradually improved. On hospital day 37, he independently performed basic ADL and was discharged. However, he lost approximately 9% of his body weight at discharge. In addition, his hand grip strength and six-minute walking distance were lower and shorter than the reference values, respectively. His mental component summary of the Short Form-8™ was lower than the national standard deviation for the Japanese population. Conclusion: Although survivors of severe COVID-19 who undergo early rehabilitation can be discharged from an acute care hospital, they may have several impairments in their physical and mental status, including muscle function, diffusion capacity, exercise tolerance, and health-related quality of life.

Key words: SARS-CoV-2, COVID-19, Early mobilization, Rehabilitation, Post-ICU syndrome

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Severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), a new coronavirus that emerged in 2019, causes coronavirus disease 2019 (COVID-19)[1)]. Although approximately 5% of COVID-19 patients who are admitted to the intensive care unit (ICU) require advanced critical care such as mechanical ventilation support or extracorporeal membrane oxygenation[2)], the mortality among patients admitted to the ICU ranges from 39% to 72%[3)].

However, even if these patients survive, survivors of severe COVID-19 are thought to experience complications such as severe respiratory dysfunction, ICU-acquired weakness, and delirium[4,5)]. Therefore, World Health Organization (WHO)[6)] recommends that early mobilization and rehabilitation interventions should be provided when it is safe to do so.

The clinical course of oxygenation, physical function, cognitive function, and activities of daily living (ADL) in survivors of severe COVID-19 who underwent early rehabilitation have not been well described. Even if they have a good clinical course, recovery of their physical and mental status at discharge from the acute care hospital may be in-

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adequate. However, it has not been clarified enough to understand the impairments after COVID-19 recovery.

We encountered a case of severe COVID-19 in which the patient underwent early rehabilitation in the ICU. We report on the course of his physical function and mental status and present the problems that a survivor of severe COVID-19 may have at discharge from an acute care hospital.

Case Presentation

A 62-year-old man (body mass index: 27.4 kg/m^2) was admitted to our emergency department in early April 2020 with severe acute respiratory infection. He had some risk factors for developing severe COVID-19, such as being male and having at least one co-existing comorbidity (hypertension/diabetes)[3]. Patient tested positive for SARS-CoV-2 by reverse-transcriptase polymerase chain reaction. Then, he was intubated and placed on a mechanical ventilator. After admission to the negative-pressure room in the ICU, the patient was provided with deep sedation using of vecuronium, a neuromuscular blocking agent, for the first 48 hours to prevent ventilator-induced lung injury, which could occur if a patient exerts strong spontaneous respiratory efforts and has continuous refractory hypoxemia. He was managed with high positive end-expiratory pressure ventilation (PEEP) and lung-protective ventilation according to the treatment guidelines[7] of acute respiratory distress syndrome (with plateau pressure less than or equal to 30 cm H_2O and tidal volumes based on the patient's height). In addition, favipiravir and azithromycin were administered for compassionate use for 14 days.

The treatment and rehabilitation courses during the ICU stay are shown in Fig. 1. On day 4 of ICU admission, PEEP decreased as the P/F ratio improved to 304, and sedation was reduced to initiate a daily awake. On day 7, rehabilitation was started to improve physical function and prevent post-intensive care syndrome (PICS). However, as the sedative was reduced, the patient became agitated, and the P/F ratio decreased to <100; hence, midazolam was used in addition to propofol. On day 9, propofol was discontinued due to elevated creatinine kinase and suspected propofol-infusion syndrome, which is a potential risk factor for hypercoagulation. Therefore, rehabilitation from day 7 to day 10 consisted of a range of motion exercises and positioning by a physiotherapist. The physiotherapist who provided rehabilitation to patients with COVID-19 had specialized knowledge and skills with previous ICU experience and was trained in appropriate donning and doffing of personal protective equipment (PPE). Whenever the patient undergoes exercise and rehabilitation, the attending physiotherapist and other staff entering the negative-pressure room used full PPE (isolation gown, gloves, N95 mask, hair cap, and face shield to protect the eyes).

We stopped sedation and resumed daily awake on day 10. The next day, the patient was able to follow orders from the medical staff, and his status (clinical presentation, respiratory, and hemodynamic function) was stable, so the mobilization program was started actively. Mobilization was performed in serial stages of sitting, standing, and stepping with doctors, nurses, and the physiotherapist wearing full PPE (Fig. 2) from day 11 to day 16 (approximately 30 min/day). We performed the first physical function (Medical Research Council Sum Score: MRC-SS) and mental health (Confusion assessment method for the intensive care unit [CAM-ICU]) assessment on day 11 of ICU admission. In the initial stage, the patient had significant muscle weakness and was cognitively impaired. In addition, the functional status score for the ICU (FSS-ICU), which is a 5-item and 35-point assessment of movement on a bed, transfers, and ambulation designed for ICU patients, was very low (5 points). The patient required assistance in all his movements during the ICU stay. The spontaneous breathing trial began on day 14, and the patient was successfully extubated the next day. He was discharged from the ICU on day 16. His hemodynamic status remained stable (mean arterial pressure >65 mmHg) during the ICU stay, and he had no other signs of organ failure, such as acute kidney injury or acute liver injury.

After ICU discharge, the patient was managed in a dedicated COVID-19 ward, and his activity was still restricted due to the risk of infecting other patients. Rehabilitation was continued with full PPE and direct intervention once a day after ICU discharge. Then, we gave him an exercise pamphlet prepared by physiotherapists to encourage self-training. After discharge from the ICU, his muscle strength and cognitive function gradually improved. The MRC-SS increased to more than 48 points on day 22, and his disorientation improved on day 24. It took the patient 21 days from ICU admission for bed mobility and transfer to become independent of medical staff, and 31 days to regain ambulation in his room. On day 37 after admission, the patient was discharged home after confirmation with two negative PCR results. Prior to discharge, the patient's physical function and mental health status were evaluated.

Physical Function and Mental Health Status at Discharge

The patient's physical function and mental health status at the time of discharge are shown in Table 1. Disability in performing basic ADL was assessed by the functional independence measure (FIM) score at discharge; FIM score was 126 points, indicating functional independence in the motor and cognitive domains. However, body composition decreased slightly: his body weight decreased by 7.2 kg from admission, and body mass index decreased from 27.4 kg/m^2 to 25.1 kg/m^2. Muscle strength was assessed us-

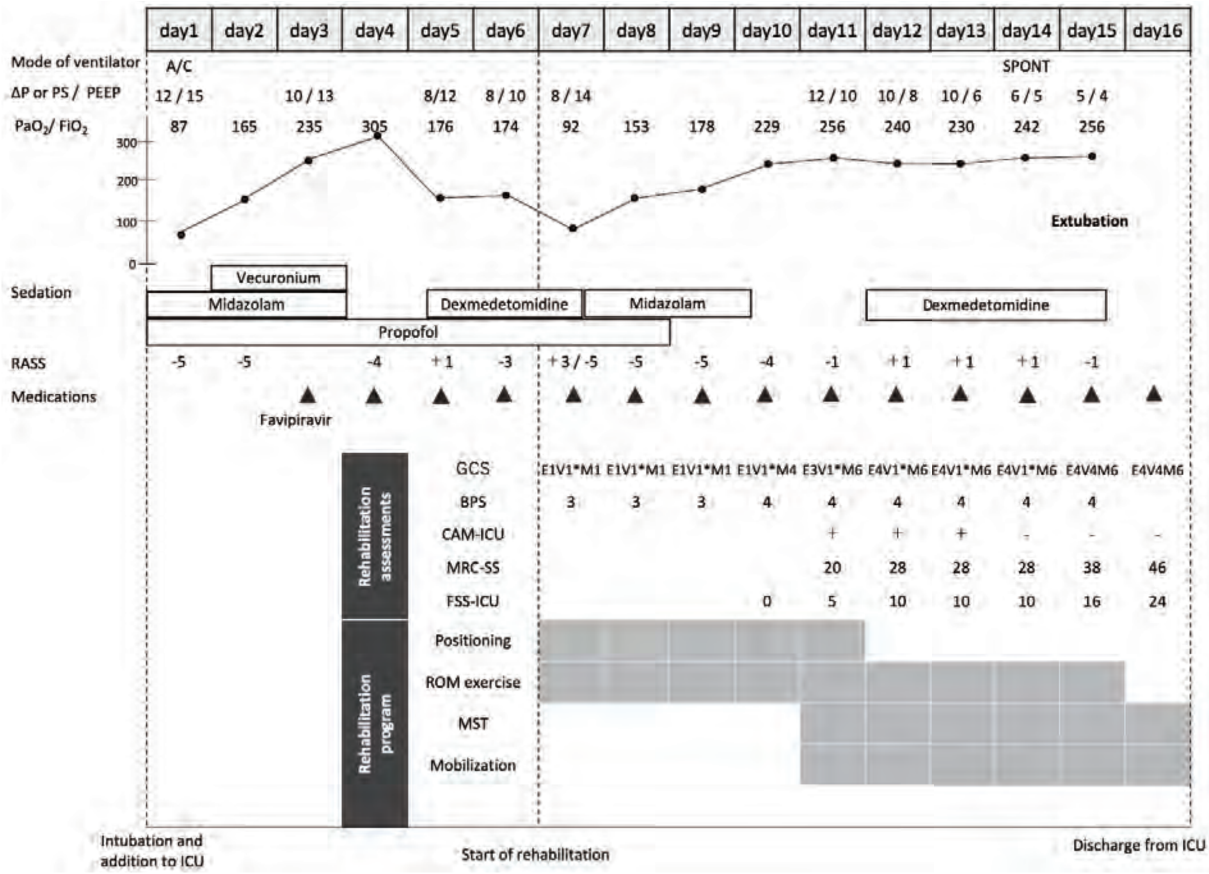

Fig. 1. Treatment and rehabilitation course during intensive care unit stay

*: intubated

A/C, Assist/Control; SPONT, Spontaneous; ΔP, inspiratory positive airway pressure above PEEP; PS, pressure support; PEEP, positive end-expiratory pressure; PaO_2, partial pressure of arterial oxygen; FiO_2, fraction of inspiratory oxygen; RASS, Richmond Agitation-Sedation Scale; GCS, Glasgow Coma Scale; BPS, Behavioral Pain Scale; CAM-ICU, Confusion assessment method for the intensive care unit; MRC-SS, Medical Research Council Sum Score; FSS-ICU, Functional status score for the intensive care unit; ROM, range of motion; MST, muscle strengthening training.

Fig. 2. Active mobilization with medical staff wearing full personal protective equipment in a negative-pressure room

ing the Jamar handgrip dynamometer (Sammons Preston Rolyan, Bolingbrook, IL, USA) and isometric knee extension strength using a handheld dynamometer (μ-Tas MT-1; Anima, Tokyo, Japan). The average grip strength on the left and right was 30.4 kgf, and the average isometric knee extension strength on the left and right was 37.2 kgf. We conducted a six-minute walk test to assess exercise tolerance. The six-minute walk distance (6MWD) was 425 m, and percutaneous arterial oxygen saturation (SpO_2) decreased from 96% to 92% at the end of walking.

Finally, mental health was assessed at discharge using the Short Form-8 ™ (SF-8™) questionnaire (Japanese version) and the five-item version of the Geriatric Depression Scale (GDS-5). The SF-8™ is a short version of the Short Form-36 ™ (SF-36™), which measures health-related quality of life using eight subscales, and can be classified into a physical component summary (PCS) and a mental component summary (MCS). His PCS was about the same as the national standard deviation for the Japanese population, while his MCS was markedly lower than the national standard deviation for the Japanese population. On the GDS-5,

Table 1. Result of rehabilitation assessment at time of home discharge

Outcome measure	Assessment tool	Value (on admission to hospital)
Body composition	Body weight	76.8 kg (84 kg)
	Body mass index	25.1 kg/m^2 (27.4 kg/m^2)
	Calf circumference	34.0 cm (35.0 cm)
	Arm circumference	32.5 cm (34.0 cm)
	Triceps skinfolds	1.3 cm
Muscle strength	Hand grip strength (Rt.)/(Lt.)	29.9/30.8 kgf
	Quadriceps isometric strength (Rt.)/(Lt.)	34.1/40.2 kgf
Balance function	Berg balance scale	56 points
Physical performance	SPPB total score	11 points
	-Balance score	4 points
	-Gait speed score	4 points: 4.42 sec
	-Standing chair score	3 points: 13.64 sec
Activities of daily living	FIM total score	126 points
	-Motor subtotal score	91 points
	-Cognitive subtotal score	35 points
Exercise tolerance	6-minute walk test (room air)	
	Distance	425 m
	SpO_2 (pre) → (post)	96 → 92 %
	Pulse rate (pre) → (post)	96 → 134 bpm
	Respiratory rate (pre) → (post)	20 → 28/min
	Rate of perceived exertion	chest: 3/leg: 0.5
Health-related quality of life	SF-8 physical component summary	48.4
	SF-8 mental component summary	39.4
Depression symptom	Geriatric depression scale-5	3 points

SPPB, short physical performance battery; FIM, functional independence measure; SpO_2, oxygen saturation of peripheral artery; SF-8, Short Form -8.

which is a screening tool for depression, the patient scored 3 points. In addition, he was anxious about his life and returned to work after discharge from the hospital.

Discussion

The patient was a survivor of severe COVID-19 and underwent early mobilization and rehabilitation in the ICU. Although he developed ICU-AW and delirium due to muscle relaxation, prolonged immobility, and other factors associated with the ICU situation, his muscle weakness and cognitive function gradually improved. Finally, the patient attained independence in performing basic ADL and was discharged. However, he had several impairments in physical function and mental health at discharge.

First, the patient had skeletal muscle dysfunction due to reduced skeletal muscle mass and muscle strength. He lost approximately 9% of his body weight during his 37-day hospital stay. In addition, both calf and arm circumferences decreased compared to those at the initial assessment. Weight loss is strongly associated with total-body bone-free lean mass in older adults[8]. These results suggest a decrease in muscle mass during the hospital stay. Handgrip strength in this patient was lower than the reference value for the Japanese community-dwelling elderly population[9]. The quadriceps isometric strength (% body weight) was 48.4% and was considered to be low compared with the best predictive cutoff for an estimated five metabolically-equivalent exercise capacity levels in patients with coronary artery disease[10]. These changes may have occurred due to severe inflammation secondary to COVID-19, which causes protein catabolism. Having limited activity in the hospital might have contributed too. Survivors of acute respiratory distress syndrome who presents with severe inflammation have been reported to have significant impairment in skeletal muscle function for six months to two years after discharge from the ICU[11]. Similarly, survivors of severe COVID-19 may require longer time to recover skeletal muscle function.

Second, his 6MWD was lower than the estimated reference value obtained from the healthy subset[12], and he had remained a significant decrease in SpO_2 on effort. Mo et al.[13] revealed abnormalities in pulmonary function in COVID-19 patients when they performed spirometry and pulmonary diffusion capacity tests at discharge. Impairment of diffusion capacity was the most common abnormality in pulmonary function; an anomaly was noted in diffusion capacity of the lungs for carbon monoxide (DLCO) in 47.2%

of all cases. Although in this case we could not assess spirometry and pulmonary diffusion capacity before discharge, it is possible that there was a decline in DLCO, as seen in these reports. SARS is an acute, severe, lower respiratory tract illness caused by infection with SARS coronavirus that spread worldwide during 2002-2003[14)]. A cohort study of a selected SARS survivor showed significant impairment of DLCO and lowered exercise tolerance compared to that in the healthy controls of the same age groups at 24 months post-illness[15)]. In particular, the severe cases that required intubation after admission to the ICU had a significantly lower DLCO than non-intubated patients at 24 months post-illness. These findings suggest that the diffusion capacity and exercise tolerance may decline and persist for a long time in patients with severe COVID-19.

Third, with regard to mental health, there was a marked decrease in MCS on the SF-8™. The GDS-5 score was also above 2 points, which is the cutoff score for screening for depression[16)]. These results suggest depression in health-related quality of life (QOL). This depression at discharge may pertain to his anxiety regarding his life after discharge and returning to work. In addition, the decline in physical function may also be associated with an impaired health-related QOL. A prospective cohort study of SARS showed that the patient's SF-36™ was lower than that of the healthy population throughout the study. Moreover, 29.6% of the healthcare workers (HCW) and 7.1% of non-HCWs who survived SARS did not return to work for two years after illness onset[15)]. Mental health appears to be a common problem in COVID-19 patients, and long-term follow-up is necessary.

These findings indicate that survivors of severe COVID-19 show improvement in ADL and acute respiratory symptoms; however, they still have impairments in physical function and mental health at discharge. Although the majority of COVID-19 patients do not require ICU admission, we should note that patients who received intensive care and required ventilators may be discharged with several impairments. Recently, the lasting symptom burden after COVID-19 recovery, such as chronic cough, shortness of breath, chest tightness, cognitive dysfunction, and extreme fatigue, have been reported[17,18)]. These symptoms have persisted for six months after acute infection[19)] and have come to be known as "long COVID" or "post-COVID-19 syndrome"[20)]. Although there have been no follow-up studies of patients with severe COVID-19 exclusively, these patients may have more impairments, as in this case.

A previous study involving a 6-week respiratory rehabilitation training program for elderly patients with COVID-19 after discharge showed that it improved respiratory function, exercise tolerance, and QOL[21)]. At present, our hospital and many hospitals in Japan have not yet established a system to provide outpatient rehabilitation for survivors of COVID-19. Physical therapists should carefully assess COVID-19 inpatients, especially those with severe COVID-19, not only for the return of ADLs to healthy levels but also for lasting impairment in disease-specific physical function and mental status. In addition, a system that can provide continuous rehabilitation and assessment for survivors of severe COVID-19 affected with muscle atrophy, exercise intolerance, and lower QOL should be considered necessary in the future.

Conclusion

We reported physical function and mental health status at the time of discharge in a patient with severe COVID-19 in Japan, in addition to the course of rehabilitation. After discharge, several impairments were evident in the patient's physical and mental status, such as muscle function, diffusion capacity, exercise tolerance, and health-related QOL.

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Informed consent and patient details: Written informed consent was obtained from the patient for publication of the anonymized case details and images.

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PHYSICAL
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CASE REPORTS

Effect of Rehabilitation Nutrition Care Process on Physical Function in Lung Cancer Cachexia: A Case Report

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ABSTRACT. Objectives: Patients with cancer cachexia have poor adherence to treatment, which affects their prognosis. Currently, there are many studies on the effects of rehabilitation on cancer cachexia, but there is a lack of evidence on the effects of nutrition therapy alone or in combination with rehabilitation and nutrition therapy. This article describes a case in which rehabilitation nutrition care process was effective in a patient with lung cancer who developed cancer cachexia. Methods: A 68-year-old woman was hospitalized for treatment of lung adenocarcinoma. The patient had moderate malnutrition, sarcopenia, and cachexia at the time of admission, so the authors intervened according to rehabilitation nutrition care process. The physiotherapist mainly prescribed resistance training and aerobic exercise, 40-60 minutes a day, 5-6 days a week. And the dietitian provided oral nutritional supplements (100 kcal, branched-chain amino acid: 3.0 g) in addition to hospital food and adjusted the patient's energy intake to 26.96-33.05 kcal/kg/day and protein intake to 1.07-1.14 g/kg/day. Outcomes: Comparing the initial evaluation with the discharge, nutritional status, such as body mass index and skeletal muscle mass, and physical functions, such as maximum grip strength, gait speed, and functional independence measure (motor items), were improved. Conclusions: Rehabilitation nutrition care process-based interventions may improve nutritional status and physical functions more than exercise therapy alone in patients with lung cancer cachexia.

Key words: Case report, Exercise, Lung neoplasms, Malnutrition, Nutrition therapy

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Cancer cachexia pathophysiology is characterized by progressive skeletal muscle loss that is difficult to recover adequately with conventional nutritional support[1], and 83% of hospitalized lung cancer patients have cachexia[2]. Patients with cancer cachexia have decreased physical function and quality of life (QOL), and shorter survival[3,4].

A systematic review that examined the effects of intervention with nutrition therapy alone in patients with advanced cancer found that it may lead to improved quality of life and reduced postoperative complication rates, but no consistent efficacy has been demonstrated[5]. Two systematic reviews of the effects of exercise therapy have reported that aerobic exercise and resistance training alone or combined contribute to improvements in physical function and skeletal muscle mass in cancer patients undergoing medical treatment[6,7]. There is a concept of rehabilitation nutrition to provide high-quality care for cancer patients, who frequently develop nutritional disorders and physical dysfunction. The rehabilitation nutrition care process is a systematic problem-solving method, which consists of five steps: 1) rehabilitation nutrition assessment and diagnostic reasoning, 2) rehabilitation nutrition diagnosis, 3) rehabilitation nutrition goal setting, 4) rehabilitation nutrition intervention, and 5) rehabilitation nutrition monitoring[8]. For patients with cancer cachexia, multidisciplinary intervention with rehabilitation and nutrition therapy is expected to improve physical function and nutritional status[9]. However, there is insufficient evidence[10], and to the author's knowledge, no cases of cancer cachexia treated by rehabilitation nutrition care process have been reported. In this article, the authors report a case of lung cancer cachexia that showed improved nutritional status and physical functions using re-

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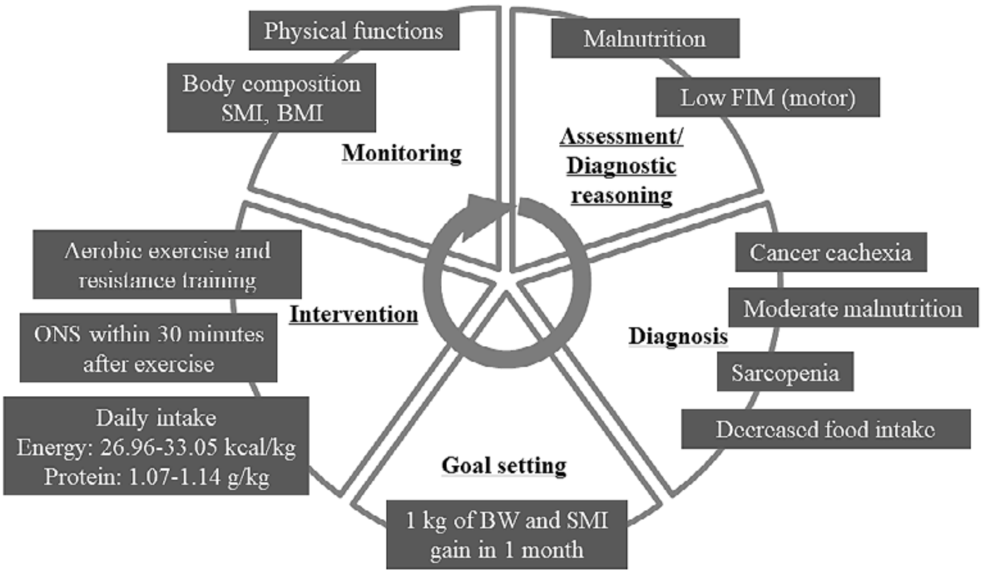

Fig. 1. Rehabilitation nutrition care process in this patient
BW, body weight; SMI, skeletal muscle mass index; ONS, oral nutritional supplement.

Table 1. Timeline of patient's physical and nutritional status

Hospitalization days	Day 2	Day 10	Day 25	Day 32	Change from day 10 to day 32
Body weight (kg)	42.7	39.5	40.4	41	3.5%
BMI (kg/m^2)	21.8	20.2	20.6	20.9	3.5%
SMI (kg/m^2)		4.3	4.8	4.9	14.0%
ECW/TBW		0.39	0.395	0.400	2.6%
Grip strength, Rt (kg)		8.3		11.3	36.1%
Grip strength, Lt (kg)		11.4		13.9	21.9%
Gait speed (m/s)		0.87		1	14.9%
FIM, motor items (points)		61		83	36.1%
FIM, cognitive items (points)		23		25	8.7%
Hemoglobin (g/dl)	12.1	13.2		12	
CRP (mg/dl)	3.2	0.12		0.04	
Albumin (g/dl)	-	3.5		3.4	

BMI, body mass index; SMI, skeletal muscle mass index; ECW/TBW, extracellular water/total body water; FIM, functional independence measure; CRP, C-reactive protein.

habilitation nutrition care process.

Case

A 68-year-old woman was admitted to the hospital for a thorough examination because of decreased food intake and increased fatigue. The patient was diagnosed with adenocarcinoma of the left upper lobe of the lung and started treatment. The following was found at the time of cancer diagnosis: performance status 0; distant metastasis malignant pericardial effusion.

Rehabilitation Nutrition Assessment, Diagnostic Reasoning, and Diagnosis (Fig. 1, Table 1)

The patient was of normal weight (Body Mass Index: 21.8 kg/m^2) at admission, but had a weight loss of -6% on day 10 of admission, and had moderate malnutrition according to the Global Leadership Initiative on Malnutrition (GLIM) criteria[11]. In addition, the motor items of the Functional Independence Measure (FIM) were 61 points 8 days after admission[12]. A physical function assessment was performed on day 10 of admission. Bioelectrical impedance analysis (Inbody 770, Inbody Co., Seoul, Korea) was used to evaluate the patient's skeletal muscle mass index, which was 4.3 kg/m^2. In addition, the patient's grip strength was

Table 2. Timeline of patient's clinical course

Hospitalization days	Day 1	Day 10	Day 28
Chemotherapy			Osimertinib 80mg (day 15-)
Exercise therapy			
Aerobic exercise		10 to 15 minutes	
Resistance training, lower limbs		25-70kg, 2 sets of 10 times	
Resistance training, upper limbs		10-17kg, 2 sets of 10 times	
Nutritional therapy			
BEE (kcal/day)	981	953	966
TEE (kcal/day)	1280	1185	1230
Energy intake (kcal/day)	600	1065	1355
Body weight ratio of energy intake (kcal/kg/day)	14.07	26.96	33.05
Body weight ratio of protein intake (g/kg/day)	0.58	1.07	1.14

BEE, basal energy expenditure; TEE, total energy expenditure.

11.4 kg, and walking speed was 0.83 m/s. Applying the Asian Working Group for Sarcopenia 2019 criteria[13], the patient was diagnosed with severe sarcopenia due to low muscle mass, low muscle strength, and low physical function (normal walking speed less than 1.0 m/s). The patient was also diagnosed with cancer cachexia[1] because they had sarcopenia and weight loss of more than 2%.

Rehabilitation Nutrition Goal Setting, Intervention, and Monitoring (Table 2)

Physical therapy was started on the 8th day of admission, and its primary goal was to improve sarcopenia and cachexia. Exercise therapy consisted of aerobic exercise and resistance training, 40-60 minutes a day, 5-6 days a week. Aerobic exercise was performed on an ergometric bicycle for 10 to 15 minutes with a target heart rate (60% load) calculated using a formula developed by Karvonen[14]. Resistance training was performed targeting the upper and lower limbs, and the load was gradually increased to a target of 10 repetitions maximum. The subjective strength during exercise was assessed using the modified Borg Scale. To ensure that effective exercise could be continued, the exercise therapy program was adjusted as necessary to ensure that general fatigue and muscle fatigue during and after exercise were less than modified Borg Scale 4 (low intensity load)[15,16]. At the time of admission, the patient's goal was to maintain the weight, but anorexia persisted, and daily energy and protein intake were low. Therefore, after the tenth day of hospitalization, when rehabilitation started, the goal was gaining about 1 kg of body weight and improving SMI during 1 month. Dietitians increased the daily energy intake to 26.96-33.05 kcal/kg/day and protein intake to 1.07-1.14 g/kg/day during hospitalization. In addition, an oral nutritional supplement (100 kcal, Branched Chain Amino Acid: 3.0 g) was provided within 30 minutes after exercise therapy and on patient request to promote muscle protein synthesis.

Outcomes

During hospitalization, there were no side effects of osimertinib. Comparing the initial evaluation (on day 10) with the discharge (on day 32), BMI had improved from 20.2 kg/m^2 to 20.9 kg/m^2, SMI had increased from 4.3 kg/m^2 to 4.9 kg/m^2, maximum grip strength had improved from 11.4 kg to 13.9 kg, gait speed had improved from 0.87 m/s to 1.00 m/s, and FIM (motor items) from 61 to 83 points (Table 1).

Discussion

In this study, it was suggested that interventions following rehabilitation nutrition care process improved the nutritional status and physical functions more than exercise therapy alone in patients with lung cancer cachexia.

This case was a lung cancer patient with complications of cancer cachexia. It has been reported that 83% of hospitalized lung cancer patients have cachexia[2], and many inflammatory and metabolic changes are primary factors in cancer cachexia, including systemic inflammation, acute phase response, protein and lipolysis, lipid mobilization, increased resting energy, decreased protein and fat synthesis, and decreased appetite[17]. This case showed anorexia before admission and significant weight loss 10 days after admission, suggesting that primary factors from cancer cells caused cancer cachexia. It has been reported that patients with lung cancer have a poor prognosis if they present with sarcopenia, in which cachexia is one of the factors[18]. Therefore, it is important for patients with lung cancer cachexia to improve nutritional status and physical functions.

Interventions following rehabilitation nutrition care process improved the nutritional status and physical functions more than exercise therapy alone in patients with lung cancer cachexia. A review of the effects of exercise therapy alone in cancer patients found that the combination of aerobic exercise and resistance training[6,7] affected physical function and skeletal muscle mass. Still, the improvement in grip strength was slight (improvement rate 4%)[19], and the improvement in skeletal muscle mass was less consistent, ranging from 0.4 to 3.1%[20,21]. Also, consistent efficacy of nutrition therapy as a single intervention in cancer patients[5] has not been demonstrated. The effects of combined exercise and nutritional therapy for advanced cancer has been discussed, but the evidence is currently lacking[10]. In this case, the authors thought it necessary to improve nutritional status and physical functions to continue anticancer therapy and improve prognosis. They intervened according to the rehabilitation nutrition care process. The effect was to improve the nutritional status of the patient, such as BMI and SMI, and their physical functions during hospitalization. In particular, the improvement rate of SMI and grip strength exceeded the results of previous studies[19-21], which was considered the effect of multidisciplinary treatment by the rehabilitation nutrition care process.

Conclusion

The case showed that the rehabilitation nutrition care process might improve the nutritional status and physical functions more than exercise therapy alone in patients with lung cancer cachexia. It is important to use the rehabilitation nutrition care process to develop multidisciplinary treatment according to the stage of cachexia to maintain and improve the physical function of patients with lung cancer cachexia.

This case report was performed following the 1964 Declaration of Helsinki's ethical standards and later amendments. The patient provided informed consent for the publication of this case report.

Conflict of Interest: The authors have no financial relationships to disclose.

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PHYSICAL THERAPY RESEARCH

CASE REPORTS

Biobehavioural Physiotherapy through Telerehabilitation during the SARS-CoV-2 Pandemic in a Patient with Post-polio Syndrome and Low Back Pain: A Case Report

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ABSTRACT. Post-polio syndrome refers to the physical and psychological sequelae caused by poliovirus infection. For this reason, according to which the emotional and sensorimotor sphere is affected, we consider a biobehavioural approach based on education and therapeutic exercise to be necessary. The aim of this case report is to evaluate the effect of a biobehavioural approach in a patient with post-polio syndrome and low back pain. We describe a 57-year-old man with post-polio syndrome and low back pain following a fall at the end of February 2020. The pain, disability and lack of functionality caused by both processes led him to contact a physiotherapy service. A therapeutic planning was carried out for 3 months, where a biobehavioural approach based on therapeutic exercise and education, with an assessment and three face-to-face sessions which were complemented by online follow-up and finalised due to the Sars-Cov-2 pandemic in a telerehabilitation approach. It was organised in two phases; the initial phase lasted 2 weeks with the aim of reducing the symptoms of the lumbar region, and the advanced phase in which the aim was to improve his physical condition. During the three-month intervention, four assessments were conducted (Pre, at 4 weeks, at 8 weeks and at 12 weeks). At follow-up, improvements in functional and psychological variables were obtained. This case suggests that a biobehavioural approach through telerehabilitation was a useful option in this reported case and could be an option of treatment to improve psychological, physical and functional variables in this patient.

Key words: Post-polio syndrome, Biobehavioural physiotherapy, Therapeutic alliance, Therapeutic exercise, Biobehavioural strategies

(Phys Ther Res 24: 295-303, 2021)

Poliomyelitis is a disease derived from the poliovirus, which caused an epidemic that began with a high infection rate in the 1940s and lasted until the 1970s, mainly affecting children younger than 5 years and spreading through the oral and faecal routes. A high percentage of those infected are typically asymptomatic; however, some patients start with central nervous system symptoms that cause acute flaccid paralysis[1)]. Survivors of this epidemic can experience a late onset of new symptoms and a worsening of sequelae after a mean of approximately 15 years, which leads to a series of symptoms that determine the so-called post-polio syndrome (PPS), which include muscular weakness and reduced muscular resistance, accompanied by fatigue, atrophy and musculoskeletal pain[1,2)]. The pathogenesis is not well defined, but the most currently supported hypothesis describes these sequelae as a metabolic depletion of motor units, caused by an increase in motor neuron size in response to distal axon reinnervation, coupled with an inflammatory process with high concentrations of proinflammatory cytokines in the cerebrospinal fluid[2,3)].

The physiotherapeutic approach to PPS patients is essential, with the aim of delaying functional deterioration. Functionality may have been affected in the population due

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to the Sars-Cov-2 pandemic, lack of physical activity due to confinement in the months of March to May and the increase in home work which further encourages this sedentary lifestyle, increasing musculoskeletal deterioration and decreasing aerobic capacity, and leading to increased insulin resistance and inflammatory states[4]. So telerehabilitation has become important. A recent systematic review concludes that active approaches using telerehabilitation have shown comparable clinical outcomes to conventional face-to-face rehabilitation approaches[5]. However, for patients with PPS, the literature is contradictory regarding the choice of exercise modality, as strength or aerobic exercises have shown little or no improvement in functional tests[6].

Currently, a biobehavioural approach aims to change the experience of pain based on biological, behavioural and cognitive systems[7]. This is defined as an approach in which the patient must be an active processor and agent in order to generate adaptive learning. It takes into account how cognitive, individual and environmental factors influence physiological processes and the experience of pain[8,9]. Focusing treatment on education and therapeutic exercise (TE) through telerehabilitation could be more useful in patients with PPS. It allows both the medical interview and the development of objectives and treatment to be carried out telematically, being a cheap and effective resource. Teleassistance allows remote contact and the possibility of communicating in a specific time and being able to resolve questions directly, addressing all the factors that may intervene in the treatment of PPS. That influence this pathology, but it has been observed that there is a lack of evidence regarding the application of this approach in patients with PPS. The main objective of the biobehavioural approach is to provide the patient with active coping strategies and thus to empower him/her and to develop an increased internal locus of control[10]. Research studies on patients with chronic musculoskeletal pain have shown that techniques such as education or TE can be included in the biobehavioural approach as they increase self-efficacy and improve somatosensory, motor and psychological variables[11-13].

This is the first case study that evaluates a biobehavioural physiotherapy treatment by means of telerehabilitation in the described clinical picture. Therefore, the purpose of this study was to evaluate and treat a patient with back pain and PPS through a biobehavioural approach based on the patient centred biopsychosocial model.

Case Presentation

The study was conducted in accordance with the Declaration of Helsinki and the informed consent form was signed by the patient prior to the start of the procedure.

We report the case of a 57-year-old male patient (weight, 70 kg; height, 170 cm) who presented a PPS and low-back pain after a fall a week previously. His pathological history included hypertension and post-polio sequelae. He had contracted polio when he was 5 months of age and had an operation on each foot at the age of 8 years, due to an excessive deformity of the plantar arch of the foot, normalising the cavus foot position and lengthening the plantar tendons with a subsequent cast for 3 months.

The patient is currently taking a medication based on 2.5-12.5 mg of ramipril-hydrochlorothiazide for arterial hypertension and 100 mg of aspirin due to an ocular microinfarct with a rise in blood pressure.

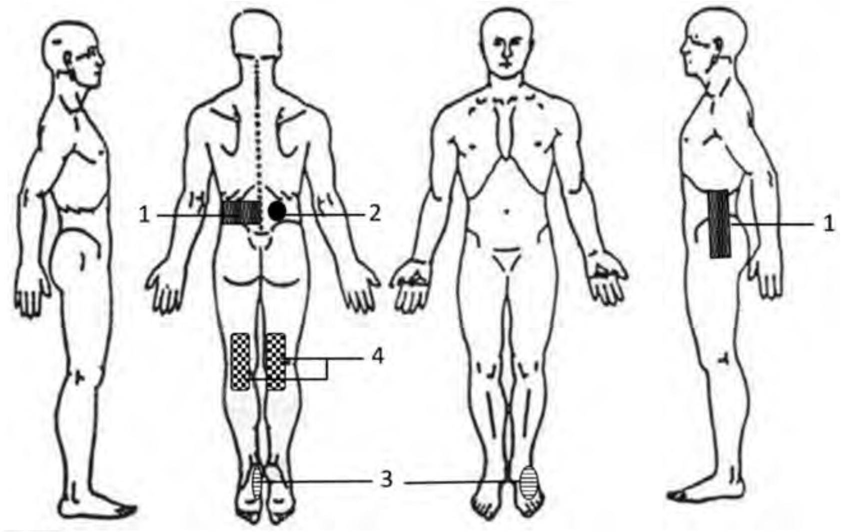
The patient reported an initial episode of pain that occurred 2 days prior to the initial evaluation, in which there was an increase in walking-related pain when supporting his weight on the right leg. Also reported a second pain in the transition from sitting to standing. The symptoms of the initial episode of low back pain were described as deep pain of a mechanical nature, with the sensation of puncture located in the right lumbar area, with an intensity of 50 mm on the visual analogue scale (VAS), which increased with physical effort to 70 mm on the VAS. The second pain was described as superficial, diffuse pain, located in the left lumbar region, referred to as a constant pressure that radiated towards the lateral face and went down the leg, with an intensity of 40 mm on the VAS. Figure 1.1 shows the body chart of the initial assessment with the representation of the symptoms, adding a third intermittent episode of pain in the left foot with articular characteristics and another intermittent episode of pain in both popliteal holes with myotendinous characteristics.

Physical examination

After the medical interview, a physical examination was performed. The patient was asked to perform active trunk flexion movements, which caused discomfort on the left side; during the extension, the first episode of pain described above was evoked at the end of the range. There was no pain during the passive physiological movements, but the accessory physiological movements on the right side, located on the lumbar facets L3 and L4, reproduced his pain described as deep and prick. During palpation, the left paravertebral musculature presented local hyperalgesia with the referred symptoms described in figure 1.1.

The patient subsequently performed functional tests aimed at static balance, given that he mentioned having a falling frequency of twice a month.

The patient first performed the Functional Reach Test, which has been proven to be valid and reliable for evaluating static stability[14]. The physiotherapist measured the postural stability in the forward direction, obtained through the movement achieved by the patient (in cm) by shifting the centre of gravity to the limits of the support base, while the feet remained stationary. The evaluation employed a measuring device consisting of a measuring tape that was placed at the height of the patient's acromion. The patient placed



Pain number 1: deep mechanical pain with a prick sensation, with an intensity of 50 mm on VAS with an occasional increase to 70 mm on VAS.

Pain number 2: superficial, diffuse, constant pressure that radiates towards the lateral face and descends the leg, with an intensity of 40 mm on VAS.

Pain number 3: pain with joint characteristics.

Pain number 4: pain with myotendinous characteristics, intermittent.

Fig. 1.1. Pre-intervention body chart with symptom distribution.

both arms at 90 degrees of flexion, with the elbows and hands at full extension. He then had to reach as far as possible while maintaining the posture for 2-3 seconds without lifting his feet off the ground[14,15].

The patient's capacity for effort was evaluated by means of the 6-minute walk test (6MWT), a general purpose functional test for cardiac and respiratory diseases, which has been proven to be valid and reliable. Provides information as a follow-up measure of the functional change in an activity such as walking, employed in combination with the modified scale of perceived effort[16]. In this case, the test was modified so that the number of steps taken during this time and the effort involved were counted on the Borg scale, employing a wrist pedometer[17].

Next, the evaluation of fear of movement was performed using the 11-item Spanish version of the Tampa Scale of Kinesiophobia (TSK-11), whose reliability and validity have been demonstrated[18]. The TSK-11 consists of 2 subscales: 1 related to fear of physical activity and the other related to fear of harm. The final score can range from 11 to 44 points, with higher scores indicating greater perceived kinesiophobia[18].

Finally, functionality was assessed using the Lower Limb Functional Index (LLFI) questionnaire, a self-registration tool used as an outcome measure that assesses bodily functions, activities, participation factors, and the environment both at the beginning of an intervention and the result of said treatment. The questionnaire has 25 items in Likert format, with an internal consistency of 0.91[19].

Four measurements were taken: the first was a preintervention test (T0), and the rest were undertaken every 4 weeks (T1, T2, T3). The last 3 measurements were performed telematically in the same manner as the initial assessment by the patient, given that the environmental conditions did not change; these measurements were supervised by a physiotherapist via videoconference. The measurements from the LLFI and TSK-11 self-recording questionnaires were only taken at T0 and T3.

Therapeutic intervention

The patient underwent 4 measurement days (MD), 3 physical therapy sessions on-site during the first two weeks (PT), 4 therapeutic patient education sessions (TPE) and 32 TE sessions lasting 60 minutes over 3 months were conducted, divided in two routines: strength training (ST) and cardiorespiratoryresistance training (CRT), carried out with a frequency of two days per week each. During the first two weeks, 6 sessions based on exercise for low back pain (ELBP) were carried out. Appendix 1 specifies the treatment followed during the process, while Table 1 shows the established planning. A treatment model based on the biobehavioural paradigm focusing on therapeutic education

Table 1. Programming of the physiotherapeutic approach.

	1st Month					2nd Month					3rd Month				
	M	T	W	Th	F	M	T	W	Th	F	M	T	W	Th	F
1st Week	MD*	ELBP**	ELBP**	PT*	ELBP**	MD**	TPE**		TE (ST) **		MD**		TE (ST) **		TE (CRT) **
2nd Week	ELBP**	PT*	ELBP**	ELBP**	PT*	TE (CRT) **	TPE**		TE (ST) **		TE (CRT) **		TE (ST) **		TE (CRT) **
3rd Week	TE (CRT) **	TPE**		TE (ST) **		TE (CRT) **		TE (ST) **		TE (CRT) **	TE (CRT) **	TE (ST) **		TE (CRT) **	TE (ST) **
4th Week	TE (CRT) **	TPE**		TE (ST) **		TE (CRT) **		TE (ST) **		TE (CRT) **	TE (CRT) **	TE (ST) **		TE (CRT) **	MD**

M, Monday; T, Tuesday; W, Wednesday; Th, Thursday; F, Friday; MD, Measurement days; TPE: Therapeutic Patient Education; ELBP, Exercise focused on low back pain; PT, Physical therapy on-site session; TE (ST), Strength training; TE (CRT): Cardiorespiratory resistance training.*on-site sessions; **telematically sessions.

and TE was used. This paradigm is defined as one in which the patient must be an active processor and agent in order to generate adaptive neuroplastic changes, thus providing the patient with active coping strategies[8,9].

On the first day of the intervention, the initial assessment and test treatment were carried out. During the second week, the planned approach was continued and two face-to-face sessions were required for pain management and organisation of the TE programmes. The 3 on-site sessions (PT) focused on managing low back pain with manual therapy, as well as prescribing TE based on physical reconditioning, combined with therapeutic education focusing on the benefits of exercise based on a Strengths, Weaknesses, Opportunities and Threats (SWOT) analysis (Fig. 2). The approach through this analysis is to present to the patient what Strengths (physical, motivation, desire to change, etc.) and Weaknesses (pain, functionality, hopelessness, control, strength deficit, etc.) he had and to elaborate a way to address them with tools, transforming them into an opportunity or therapeutic strategy. No longer seeing these weaknesses as a fragile pillar but as a motivation for change. And to expose threats from an objective point of view (how likely is an event to happen just because you believe it? educate in maladaptive beliefs, etc.).

The remaining sessions were conducted telematically via a video call system due to the SARS-Cov-2 pandemic, in which the methodology to be followed was presented by means of a table of contents in slides. The online follow-up time was divided into 60 minutes in which the topic of therapeutic education in pain and exercise neurophysiology was presented, as well as different coping and motivational strategies. A SWOT model was used within a biobehavioural paradigm in order to address all patient needs.

Therapeutic patient education

Therapeutic education is a tool that aims to change maladaptive beliefs and erroneous thoughts that interfere with the patient's pathology and pain perception, which lead to an increase in the presence of psychological variables such as fear of movement[20,21]. Research studies on patients with chronic musculoskeletal pain have shown that the application of the technique leads to significant improvements in variables such as disability, fear of movement, catastrophizing, anxiety and physical fitness[22-24]. Four sessions were conducted, one session per week between the third and sixth week of treatment. The intervention covered topics related to the benefits of physical activity, the influence of psychosocial factors and maladaptive beliefs.

Therapeutic exercise

TE were defined as a physical exercise plan designed and prescribed to facilitate recovery from illness or any impairment of movement and activities of daily living[25,26]. Research has shown that a low level of physical activity can

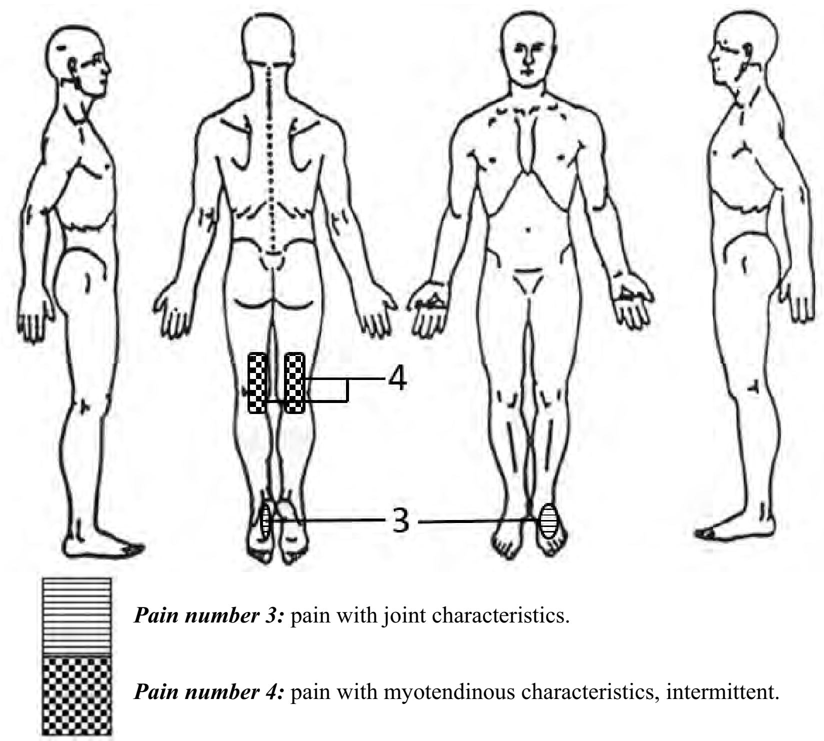


Fig. 1.2. Post-intervention body chart with symptom distribution.

Table 2. Baseline and follow-up measurements from T0 to T3

Measure	T0	T1	T2	T3
TSK-11 (points)	33	-	-	14
FRT (cm)	24	23	25	25
6MWT (steps)	645	651	663	668
6MWT (meters)	490	496	505	508
Modified Borg Scale from 0 to 10 points	6	6	7	6
LLFI (percentage of functionality)	56%	-	-	64%
Pain number 1 (VAS)	5	3	1	0
Pain number 2 (VAS)	4	1	0	0

T0, baseline measurement; T1, measurement at the 4th week; T2, measurement at the 8th week; T3, measurement at the 12th week; TSK-11, Tampa Scale of Kinesiophobia; FRT, Functional Reach Test; 6MWT, 6-minute walk test; LLFI, Low Limb Functional Index; VAS, Visual analog scale.

lead to reduced neuromuscular efficiency and decreased strength, resulting in a number of negative consequences on functionality and postural control[27-29]. On the basis of the above, we consider it necessary to implement a TE programme based on strength and cardiorespiratory endurance exercise for 12 weeks at a frequency of 2-3 times a week.

Results

The results are shown in Table 2. The patient showed a improvement between the T0 and T3 measurements in terms of kinesiophobia level (from 33 to 14 points), with a reported minimum detectable change of 5.46 points considered relevant[30], as well as improvement in the LLFI from 56% to 64% of functionality[31]. In terms of pain intensity, there was also a improvement, exceeding the minimum detectable change for the first reported episode of pain from 50 mm to 0 mm and in the second reported episode of pain from 40 mm to 0 mm[32]. Figure 1.2 demonstrates the improvement after three months of intervention in terms of pain expansion using the body chart.

Static stability showed a slight improvement. The available evidence indicates that, for the 50-59-year age range, the distance in the Functional Reach Test should be 27.6 ± 6.6 cm[33]. The patient showed an improvement in the variable of distance walked during the 6MWT, but he did not exceed the minimum detectable change in this population for the test. In relation to the 6MWT, the patient pre-

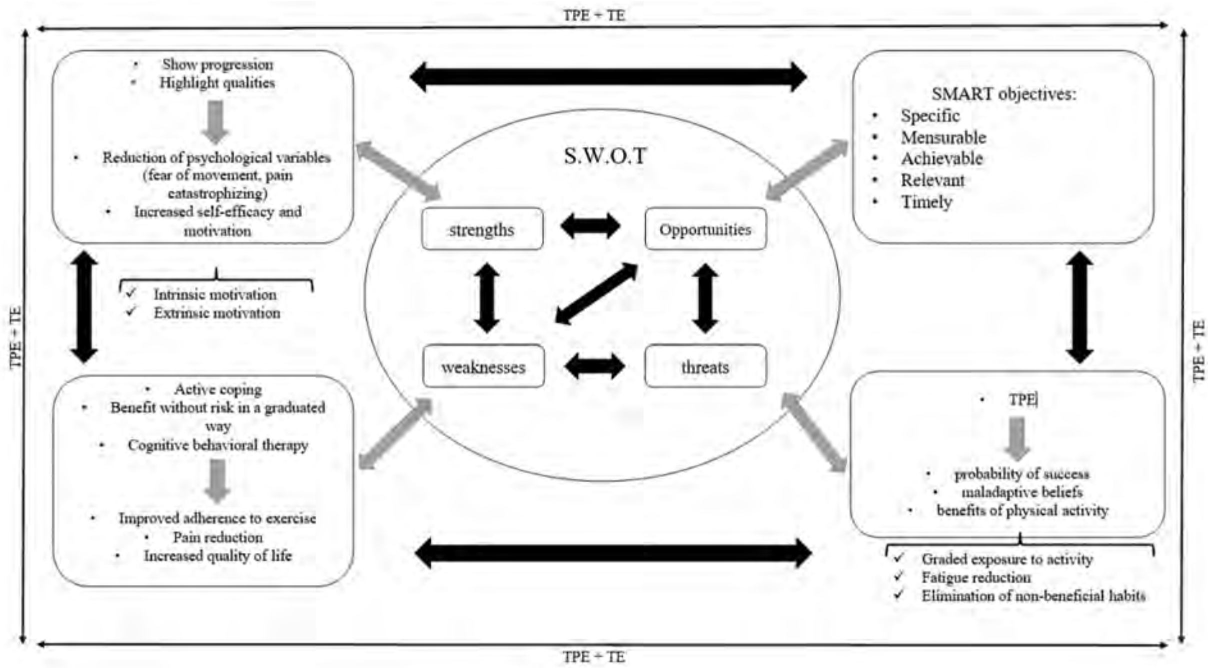


Fig. 2. S.W.O.T analysis for therapeutic approach
TE: Therapeutic exercise; TPE: Therapeutic Patient Education.

sented the same perceived fatigue for the T0 and T3 measurements.

Discussion

The reported case shows an evaluation and treatment option from a biobehavioural paradigm of a patient with PPS and low back pain, with the aim of improving functionality. Currently, there is a lack of scientific evidence on biobehavioural physiotherapy treatment in PPS, even more so on the approach of this type of patient with physiotherapy through telerehabilitation. There is a growing use of telematic intervention and online assessment, an excellent low-cost tool[34)], that is limited by the lack of interpersonal proximity. It is therefore crucial to employ strategies that increase the patient's self-efficacy and adherence to TE, given this is a primary pillar of treatment. We recommend using indicators during the session that provide a better therapeutic alliance, such as reinforcing positive actions, planning real objectives and the process towards achieving them and providing instruction that supports self-management[35)]. Moore et al. in their study stated important barriers that interfere with the success of exercise therapy, such as the existence of pain itself, low self-efficacy and lack of motivation, as well as various long-term facilitators for patient improvement that help patients to adhere to exercise. Describing "exercise awareness" as a pillar that benefits and prevents episodes of pain, modifying such exercises if necessary according to the patient's perception and thus improving their self-efficacy by having greater capabilities and allowing them to do so even when in pain[36)]. And finally the "therapeutic alliance" with its three characteristics of warmth, collaboration and support, coupled with skills, emotion management and communication, being the therapeutic alliance an activity to be practised[36,37)]. Showing empathy and authenticity during the session and monitoring the therapist-patient relationship by facilitating 2-way feedback will foster such a therapeutic alliance by creating a positive emotional bond that will lead to greater adherence to fulfilling the planned goals[38-40)].

One of the most powerful strategies in physical therapy with greater impact on increased self-efficacy is performing TE. Based on the current literature, however, the evidence from certain modalities, such as aerobics and strength training, is contradictory due to the heterogeneity and lack of studies published on this population[2,3)]. Regardless, the neurophysiological and functional benefits of TE are well known in general terms, even in other complex painful or pathological conditions, such as sarcopenia and chronic fatigue syndrome, in which there is also a lack of homogeneity in research studies[41-44)].

Based on these results, we set up a TE programme according to the effort perceived by the patient as an active strategy from a cognitive-behavioural perspective, accompanied by manual therapy techniques and therapeutic education, using an approach based on a SWOT analysis, which highlights the strengths of the programme.

In this way, the ability to resolve an activity is demonstrated by highlighting the quality of the action, addressing the weaknesses to be overcome and using an approach that shows the way forward by setting specific objectives.

This methodology has been employed as a clinical guideline when making decisions in other health areas[45].

Although cognitive-behavioural therapy has not been studied in this population with respect to pain, the effect of such therapy on variables such as fatigue has been studied, but no beneficial effect has been reported[46]. The biobehavioural approach has been shown to have beneficial effects in various populations with chronic pain by reducing pain intensity and improving quality of life[47], addressing aspects of the bio-psycho-social sphere by intervening in maladaptive beliefs, expectations, self-efficacy and motivation[48-51].

The results of this intervention were positive with respect to reducing the intensity of low back pain improvement in kinesiophobia, balance, number of steps and metres walked in 6 minutes, as well as data obtained from the LLFI. This intervention comprised a physical therapy approach based on a biobehavioural paradigm centred on the prescription of exercise and on obtaining tools that promote self-management and adherence to exercise.

There are several limitations in this study to consider, the first of which was the lack of monitoring during the exercise, given that monitoring helps provide greater motivation and easier correction of the proposed activities. Second, the recovery time required by the patient due to the major fatigue induced by performing the exercise sessions made it necessary to reduce the volume of training and increase the resting time. The third limitation was the lack of heart rate monitoring during the activities and the lack of anthropometric measurements. Another important limitation is the lack of assessment of adherence and the patient's subjective perception of improvement after treatment, which could provide more clinical information and, as the study by Moore et al., found, may have a direct effect on motivation[36]. The last limitations were the lack of knowledge of the long-term effectiveness and that of each intervention, given that different strategies were presented during the process, and the lack of reproducibility due to the variability of the measurements taken at T0 (face-to-face) and the rest of the measurements that were guided and collected remotely.

Conclusion

In conclusion, focusing treatment on a biobehavioural paradigm centred on TE and education throught telerehabilitation can be a treatment option, as observed in this patient with PPS and musculoskeletal pain, as it can lead to improvements in the medium term on functional and psychological variables.

Conflict of Interest: The authors declare that they have no competing interests.

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Supplementary material (Appendix):
1. Appendix 1. Therapeutic intervention

Appendix 1. Therapeutic intervention

Low back pain management

Therapeutic intervention	Description
Manual therapy	Accessory physiological mobilizations central and unilateral AP grade I-II Maitland with a velocity of 2 Hz around 2 minutes, 3 sets. Active neural tube sliders for 10 repetitions, 3 sets.
Therapeutic exercise	Lumbar motor control exercises in supine-prone-quadruped: In supine position, the patient makes an inspiration; then, they perform a pelvic retroversion by performing a lumbar stabilization to press the lumbar spine to the mat in the expiratory phase. Progress is made in prone and quadruped exercise. Repetitions: 10–12. Series: 3–4. Sit-to-Stand in chair: While sitting, the patient performs an inspiration; then they perform a lumbar stabilization and while exhaling, then he gets up from the chair. Repetitions: 10–12. Series: 3–4. Increase in daily activity: Walk 15-30 minutes.

AP, antero-posterior.

Centered approach for PPS

Therapeutic intervention	Description
Establishment of agreed objectives	
Biobehavioral strategies and therapeutic education	- Know what is PPS. - Education in Therapeutic Exercise. - Psychosocial factors. - Cognitive strategies against demotivation-pain.
Strength circuit: 4 sets of 6-8 repetitions at a perceived effort of 6-8 according to the modified Borg scale.	Squat with support: A squat is executed with support on the wall. Hip thrust: in supine with flexed knees, a hip thrust is performed by lifting the lumbar region from the ground with a ballast in the pelvic area. Push-ups with or without knee support. Overhead press: with a load a vertical thrust is made on the head (like a military press). Lounge with assistance (optional - more advanced): while leaning on a chair or the wall, a front long step is performed by alternating legs.

	Static Plank (optional): in supine, we support the elbows and feet on the floor keeping the trunk in static on the floor during 20-30 seconds, in the event of being very demanding or not being able to support the knees instead of the feet.
Cardiorespiratory Circuit: 3 sets of the circuit at 40 seconds per station with 25 seconds rest. Perceived effort between 6-8.	Mountain climbers at a height of 1 meter: being supported at a height of 1 meter we separate the trunk and the feet to realize a raising of knees with the maximum flexion of hip alternating legs. Knee raise: a walk is performed at the site by raising the knees with a 90-degree hip flexion angle. Walk semi-tandem. Farmer's Walk: A continuous march is carried out with a load caught in one of the arms, having to make a trunk eccentric avoiding the inclination. Squats. Conventional deadlift with superband: is a basic exercise, you put your feet just under the hips and exercise a vertical force overcoming the tension of the

	superband that we have supported on our shoulders and fixed with our feet.

PPS, post-polio syndrome.

Physical Therapy Japan Vol.47 (2020) ABSTRACTS

The Japanese Physical Therapy Association publishes the "Journal of the Japanese Physical Therapy Association", the most recent Japanese volume (Physical Therapy Japan) being number 47, which includes 66 articles. Each year 6 issues are published.
For the past 22 years, the English volume of "The Journal of the Japanese Physical Therapy Association" has been published once a year. The journal has changed its' name to "Physical Therapy Research" and the publishing organization changed to Japanese Society of Physical Therapy in 2016, and has published two times per year from 2017, and three times per year from 2021.
To further acquaint our English volume readers with the articles published in the Japanese volume, the English abstracts of the present Japanese volume will be included in the English volume published this year.

Vol. 47, No. 1 (pp 1-9)

Three-Dimensional Kinematics of the Radiocarpal and Midcarpal Joints of the Wrist during Reverse Dart Throw Motion Using Computed Tomography: To Evaluate the Range and Direction of Motion

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Purpose: This study aimed to analyze three-dimensional kinematics of the radiocarpal and midcarpal joints of the wrist during reverse dart throw motion.
Methods: We analyzed the kinematics of the radiocarpal and midcarpal joints of the wrists of 12 healthy volunteers using CT images. We measured the range and direction of motion for the radiocarpal and midcarpal joints. Paired t-tests were used to compare the results between the radiocarpal and midcarpal joints.
Results: The range of motion of the radiocarpal joint was significantly greater than that of the midcarpal joint. The motion of the radiocarpal joint in the flexion/extension plane was also significantly greater than that of the midcarpal joint. For the midcarpal joint, the motions of the lateral and central articulations were significantly greater in the radial/ulnar deviation plane compared to those of the radiocarpal joint.
Conclusion: The range of motion of the radiocarpal joint was greater than that of the midcarpal joint during reverse dart throw motion. The radiocarpal joint, especially, contributed to the motion in the flexion-extension plane. The midcarpal joint contributed to the motion in the radial/ulnar deviation plane.

Key Words: Reverse dart throw motion, Three-dimensional kinematics, Radiocarpal joint, Midcarpal joint

Vol. 47, No. 1 (pp 10-19)

Effect of Neuromuscular Electrical Stimulation in Postoperative Patients with Femoral Proximal Fractures: A Stratified, Randomized Controlled Trial using a Surgical Approach

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Purpose: This study aimed to examine the effect of neuromuscular electrical stimulation (NMES) on leg function and movement ability for muscle strength training of the quadriceps in postoperative patients with femoral proximal fractures.

Methods: Our study was a stratified, randomized controlled trial using a surgical approach in patients with proximal femoral fractures. Eighty-two patients were randomly divided into two groups: the NMES group or control (muscle strength training with no NMES) group. NMES was applied once a day from the next day following surgery. We measured knee extension muscle strength, the Japanese Orthopedic Association (JOA) scores, and the number of days taken for gait and activities of daily living (ADL) to become independent.

Results: Knee extension muscle strength and JOA scores were significantly better in the NMES group. The number of days taken for gait and ADL to become independent were significantly lower in the NMES group. In addition, patients in the NMES group were able to obtain a higher gait ability at discharge than those in the control group.

Conclusion: Training of the quadriceps using NMES from the next day following surgery in postoperative patients with femoral proximal fractures contributed to early improvement in knee extension muscle strength, early acquisition of gait and ADL independence, and improved gait ability at discharge.

Key Words: Femoral proximal fractures, Neuromuscular electrical stimulation: NMES, Gait, Early after surgery, Surgical approach

Vol. 47, No. 1 (pp 20-26)

Effects of Simulated Postural Kyphosis on Pulmonary Function and Voluntary Cough Strength

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Purpose: The purpose of this study was to investigate the influence of postural kyphosis on voluntary cough strength.
Methods: Sixteen healthy males participated in this study. Cough peak flow, respiratory function, respiratory muscle strength, chest expansion, maximum phonation time, and respiratory impedance indices (respiratory system resistance at 5 Hz, R5; resonant frequency, Fres) were evaluated under four conditions: non-kyphosis, mild kyphosis, moderate kyphosis, and severe kyphosis. One-way analysis of variance and multiple comparison tests (using the Bonferroni method) were performed to compare the four conditions. Correlations between the change rate of each measured variable by the degree of kyphosis were analyzed using Spearman's correlation coefficients.
Results: Cough peak flow, vital capacity, chest expansion, and maximum phonation time were significantly decreased in moderate kyphosis and severe kyphosis compared with those in non-kyphosis. Respiratory muscle strength and Fres were significantly decreased in severe kyphosis compared with those in non-kyphosis. Moreover, there were significant positive correlations between cough peak flow and vital capacity, expiratory muscle strength, and chest expansion at the xiphoid process ($r = 0.27, 0.33, 0.37$, respectively, $p < 0.05$).
Conclusions: Our data suggest that cough peak flow is reduced due to decreased lower chest expansion, respiratory muscle strength, and vital capacity at moderate or higher kyphosis.

Key Words: Postural kyphosis, Respiratory function, Voluntary cough strength

Vol. 47, No. 1 (pp 27-34)

Influence of Acute Arm-cranking Exercise with Electrical Muscle Stimulation on Vascular Endothelial Function

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Purpose: The purpose of this study was to assess the effect of submaximal arm-cranking exercise with EMS on vascular endothelial function.
Methods: Ten healthy young men performed submaximal arm-cranking exercise at 50%$\dot{V}O_{2\,max}$ for 20 min. All subjects performed submaximal arm-cranking exercise alone (A) and with EMS (A+E). In the A+E trial, the submaximal arm-cranking exercise was performed at 50%$\dot{V}O_{2\,max}$ for 20 min while EMS was applied to their thigh and calf muscles during the exercise. The flow-mediated dilation (FMD) at the brachial artery was measured before and after exercise to calculate the normalized FMD (nFMD).
Results: In the A+E trial, the nFMD was significantly increased 30 minutes after exercise compared to the rest value and was increased 30 minutes after exercise compared to the A trial.
Conclusion: These findings suggest that arm-cranking exercise with EMS increases vascular endothelial function.

Key Words: Arm-cranking exercise, Electrical muscle stimulation, Brachial artery, Flow-mediated dilation, Vascular endothelial function

Vol. 47, No. 1 (pp 35-41)

Study of Responsiveness and Minimal Clinically Important Difference (MCID) of Functional Assessment for Control of Trunk (FACT) in Acute Stroke Patients

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Purpose: This study aimed to examine responsiveness and Minimal Clinically Important Difference (MCID) of Functional Assessment for Control of Trunk (FACT) in patients with acute stroke.
Methods: This study included 30 patients who were hospitalized with stroke. Trunk function was assessed on the 7th day of hospitalization and the final intervention date of physical therapy. For each test, responsiveness and MCID were examined. Improvement in activity of daily living was used to detect a clinically meaningful change. The MCID for the trunk function assessment tool was estimated by meaningful change.
Results: FACT, a tool used to assess trunk function, showed a large degree of responsiveness. The MCID of FACT was 4 points, and its discrimination accuracy was very high.
Conclusions: This study indicated FACT had good responsiveness and high accuracy in discrimination of MCID. These results suggest that FACT is useful trunk function assessment tool in patients with acute stroke.

Key Words: Stroke, Trunk function assessment tool, FACT, Responsiveness, MCID

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Factors Associated with Re-Admission with Nursing and Healthcare-Associated Pneumonia

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Purpose: The purpose of this study is to determine factors affecting re-admission with nursing and healthcare-associated pneumonia (NHCAP). Design: Single-center, retrospective clinical study.
Method: A total of 123 patients who readmitted to the hospital due to NHCAP from January 2016 to November 2016 were reviewed. Clinical characteristics, laboratory test values, Functional Independence Measure score (FIM score), the status of nursing care insurance services, social information, and methods of providing information were extracted from medical records. Cox proportional hazards analysis was performed to determine the factors affecting readmission.
Results: Age, FIM score (exercise items) at discharge, serum albumin, the days between admission and first ambulation, face-to-face communication were detected as significant factors.
Conclusion: This study provides valuable information about factors leading to readmission with NHCAP.

Key Words: Nursing and healthcare-associated pneumonia, Re-admission, Hospitals for Community-based Care

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The Relationship between the Step Side Knee Joint Movement and Elbow Valgus Torque

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Purpose: The purpose of this study was to investigate that the characteristic of the step leg motion that increase elbow valgus torque.
Method: Twenty-seven youth baseball pitchers participated in this study. Elbow valgus torque measurement and video analysis were performed on outdoor mound. The participants divided by the qualitative assessment of stride knee motion, then compared elbow valgus torque and flexion angle of step knee joint between both groups.
Result: There was significant greater flexion knee joint angle at maximum external rotation and ball release and greater joint torque of elbow and less ball speed for the forward movement group.
Conclusion: This group showed inadequate bracing the knee of step leg. It caused increasing elbow torque. To evaluate the stride leg motion is important for assessment of risk on elbow injury.

Key Words: Pitching motion, Elbow values torque, The motion of the step leg

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(pp 113-121)

Examination of the Factor Related to the Acute Phase Motor Functional Prognosis of Branch Atheromatous Disease

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Purpose: The acute motor functional prognosis was evaluated in patients with branch atheromatous disease (BAD).

Method: Overall, 101 patients with BAD were enrolled from March 2016 to February 2019. Patients with paralysis in their upper limbs and lower limbs were classified into good and bad groups based on their paralysis status at discharge. The patients' age, gender, paralyzed side, National Institute of Health Stroke Scale (NIHSS) at admission, lesion area, infarct area, rehabilitation start date, Fugl-Meyer Assessments (FMA) of the upper and lower limbs, starting Mini-mental State Examination (MMSE) score, hospitalization days, OT session, and PT session were analyzed. Thereafter, univariate and logistic regression analyses were performed.

Results: The univariate analysis revealed significant differences in age, NIHSS at admission, infarct area, FMA, MMSE at initiation, and hospital days in both patients with paralysis in their upper and lower limbs. The logistic regression analysis revealed that FMA was an independent factor in both patients with paralysis in their upper and lower limbs. The cut-off values were 18 for the upper limb (area under the curve, 0.94; sensitivity, 0.80; and specificity, 0.93) and 19 for the lower limb (area under the curve, 0.88; sensitivity, 0.80; and specificity, 0.82).

Conclusion: The initial FMA in patients with BAD was most relevant to motor functional prognosis from the acute phase in the upper and lower limbs.

Key Words: Stroke, Acute phase, Prognosis prediction, Motor paralysis

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Characteristics of Sagittal Knee Joint Kinematics Dynamics and Quadriceps Muscle Activity during Stair Ascent and Descent in Patients after Total Knee Arthroplasty

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Purpose: The aim of this study was to evaluate the characteristics of sagittal knee joint kinematics and quadricep muscle activity during stair climbing in patients after total knee arthroplasty (TKA).
Methods: Eight and ten limbs were included in the TKA and control groups, respectively. The maximum knee extension moment (KEM) and maximum afferent and centrifugal knee power during stair climbing stance phases were measured by a three-dimensional motion analysis system. Maximum muscular activity of the quadriceps femoris was measured by surface electromyography.
Results: The knee joint load and afferent power in stair ascent of the TKA group was significantly lower than that of the control group. The centrifugal power in stair descent of the TKA group was significantly lower than that of the control group. Quadriceps activity during stair ascent was significantly higher in the TKA group than in the control group, and the descending muscle activity was low in both groups.
Conclusion: One year post-operation, TKA patients strongly contract the quadriceps during stair climbing, but the joint load and afferent power decreased during ascension and the centrifugal power decreased during descension.

Key Words: Total knee arthroplasty, Stair climbing, Sagittal knee joint kinematics dynamics, Quadriceps femoris muscle activity

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Effectiveness of Electrostimulation of the Quadriceps for 4 days in the Acute Phase after Total Hip Arthroplasty

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Purpose: This study aimed to investigate the effectiveness of electrostimulation of the quadriceps for 4 days in the acute phase after total hip arthroplasty (THA).
Methods: In total, 52 women with hip osteoarthritis participated in this study. They were randomized to the control and intervention groups. The intervention group (n = 26; age 64.4 ± 8.9 years) underwent electrostimulation of the quadriceps twice a day during knee extension exercises for 4 days. The control group (n = 26; age 66.0 ± 9.9 years) performed knee extension exercises twice a day without electric muscle stimulation for 4 days. Additionally, both groups received the standard protocol in our hospital. Quadriceps strength, gait speed, and pain during gait in both groups were assessed 1 month before surgery and on Day 4 after surgery. Changes in quadriceps strength and gait speed were quantified as relative (percent) changes from the preoperative values (Δquadriceps strength and Δgait speed). Changes in pain during gait were quantified as relative (difference) changes from the preoperative values (Δpain during gait). The Mann–Whitney U test and unpaired t-test were used to compare these values between the groups. Significance was set at $P < 0.05$.
Results: Compared with the control group, the intervention group showed greater Δquadriceps strength ($P = 0.014$), Δgait speed ($P = 0.009$), and Δpain during gait ($P = 0.027$).
Conclusions: Electrostimulation of the quadriceps for 4 days in the acute phase after THA improves knee extensor strength and gait speed, and reduces pain during gait.

Key Words: Total hip arthroplasty, Electrostimulation, Knee extensor strength

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Effect of Glenohumeral External Rotation Position on the Posterior Glenohumeral Distance in the Throwing Shoulders of College Baseball Players: An MRI Study of the Simulated Late Cocking Phase during Baseball Throwing

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Purpose: The purpose of this study was to assess the effects of external glenohumeral rotation position on the posterior glenohumeral distance (PGHD) in asymptomatic throwing shoulders.
Methods: Eleven asymptomatic male college baseball players (11 throwing shoulders) participated in this research. The PGHD was calculated using MRI scans. MRI measurement positions were 90° of shoulder abduction with external rotations of 90°, 100°, and 110°.
Results: Measures of PGHD were significantly less during 110° external rotation compared to 90° external rotation.
Conclusion: The PGHD was significantly less when shoulder abduction occurred in more externally rotated positions.

Key Words: Shoulder joint, Glenohumeral external rotation position, Posterior glenohumeral distance

Vol. 47, No. 2 (pp 146-152)

Association of Back and Knee Pain with Physical Function in Community-dwelling Older Adults: Effects of Acute/Chronic Pain on Gait Speed and Grip Strength

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Purpose: Approximately 80% of community-dwelling older adults present with musculoskeletal pain accompanied by low gait speed and grip strength. This study investigated the effects of acute or chronic back and knee pain on gait speed and grip strength in community-dwelling older adults.
Methods: This study included 735 community-dwelling older adults (aged ≥65 years, mean age 74.8 years, 62.9% women) (Tarumizu study 2018). Type of pain (acute vs. chronic) was determined using a questionnaire. We investigated the association between acute or chronic pain and low gait speed (<1.0 m/s) and low grip strength (men <26 kg, women <18 kg).
Results: Of the 735 participants, 347 (47.2%) reported no pain, 144 (19.6%) reported acute pain, and 244 (33.2%) reported chronic pain. Low back and knee pain were observed in 121 participants (16.5%), of which 46 (38.0%) reported acute pain and 75 (62.0%) reported chronic pain. Logistic regression analysis revealed that low gait speed was significantly associated with chronic pain (adjusted odds ratio 2.55, p = 0.001) but not with acute pain (adjusted odds ratio 1.19, p = 0.632) (adjusted for age, sex, the 15-item Geriatric Depression Scale, medication use, the Appendicular Skeletal Muscle Mass Index, and grip strength). Notably, no association was observed between pain and low grip strength.
Conclusion: Community-dwelling older adults with chronic low back and knee pain showed low gait speed.

Key Words: Community-dwelling older adults, Gait speed, Grip strength, Chronic pain, Acute pain

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Effects of Physical Therapy in the Patients with Degenerative Disorders of the Cervical Spine: Combined Effects of McKenzie Method, Deep Cervical Muscle Exercise, and Physical Agents

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Purpose: This study investigated the combined effects of the McKenzie method, deep cervical muscle exercise, and physical agents in patients with degenerative disorders of the cervical spine.
Methods: Study participants included 112 patients diagnosed with degenerative disorders of the cervical spine at our hospital. The patients were divided into three therapeutic groups, which were treated with: the McKenzie method and physical agents (MDT group, 51 cases); the McKenzie method, deep cervical muscle exercise, and physical agents (DCME group, 43 cases); and physical agents alone (physical agents group, 18 cases). The effects of these therapies were evaluated using the active ROM of cervical spines (hereafter, CROM), Neck Disability Index (NDI), JOACMEQ, Visual Analogue Scale (VAS) scores for neck pain, and SF-8 before therapy and 1, 2, 3, and 5 months after therapy. Statistical analysis was performed using the mixed-effects model for repeated measures.
Results: The following evaluation items showed interaction. Compared with before therapy, CROM, NDI, JOACMEQ, and SF-8 scores were significantly improved 1 month after therapy in the MDT and DCME groups. VAS scores significantly improved 1 month after therapy in the MDT and DCME groups, and 2 months after therapy in the physical agents group. These effects were highest in the MDT group, followed by the DCME group and the physical agents group.
Conclusion: Compared to physical agents alone, MDT and DCME resulted in greater symptomatic, functional, and psychological improvement.

Key Words: Degenerative disorders of the cervical spine, McKenzie method, Deep cervical muscle exercise, Physical agents

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The Effect of Nutritional Status on Walking Ability at Discharge in Patients with Acute Exacerbations of COPD

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Purpose: This retrospective study aimed to clarify the associations between nutritional status and walking ability at discharge in patients with acute exacerbation of chronic obstructive pulmonary disease (AECOPD).
Methods: We enrolled 101 patients hospitalized for AECOPD and who underwent physical therapy. Walking ability was assessed by Functional Independence Measure (FIM). The subjects were classified into the independent group (FIM ≥6) and non-independent group (FIM <6) by walking ability at discharge. The presence of malnutrition (% ideal body weight <80%) and adequacy of caloric intake (% estimated target calories: intake/estimated target calories × 100) were examined as indices of nutritional status. Multivariate logistic regression analysis was performed to assess whether nutritional status affected walking ability at discharge (FIM ≥6 or FIM <6) adjusted by age, A-DROP, and severity of airflow obstruction.
Results: Despite being independent before hospitalization, 21 patients could not walk independently at discharge, and 31 patients had malnutrition before admission. The average % estimated target calories was 78.7 ± 31.7%. Multiple logistic regression analysis showed presence of malnutrition (OR 3.9, 95% CI 1.3–11.7, p<0.05) and % estimated target calories (OR 0.7, 95% CI 0.5–0.9, p<0.05) to be significantly associated with walking ability at discharge.
Conclusion: Nutritional status affected walking ability of AECOPD patients at discharge. Therefore, nutritional status should be evaluated when providing effective exercise and adequate nutritional therapy during hospitalization. These findings may imply that oral nutritional supplements should be provided immediately after hospitalization for patients with inadequate caloric intake.

Key Words: Acute exacerbation of COPD, Walking ability, Nutritional status

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Feasibility of an Exercise Therapy in Lymphoma Patients with Cytopenia: Preliminary Study by Retrospective Observational Study

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Purpose: This study aims to assess the relationship between blood data and the safety and feasibility of physical therapy in lymphoma patients with cytopenia.
Methods: Total 79 patients with lymphoma who underwent chemotherapy were included in this study. All patients received exercise therapy (13 on the Borg scale) six days per week, 20 min per day. Physical therapy adherence (implementation/scheduled days) was calculated after stratification according to the white blood cell and platelet counts. In addition, the occurrence of adverse events was investigated.
Result: The median physical therapy adherence rate of the patients was high at 96.8% (range, 61.7%–100.0%), and no adverse events were observed during or after the physical therapy. However, the adherence rate significantly decreased when the white blood cell count was <1,000/μL and platelet count was <20,000/μL ($p < 0.001$).
Conclusion: The results of this study suggest the safety of exercise therapy in patients with lymphoma. In addition, the results suggest that decreased white blood cell and platelet counts are associated with poor physical therapy adherence.

Key Words: Cytopenia, Malignant lymphoma, Feasibility

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The Reliability and Validity of the Trunk Impairment Scale for Patients with Spastic Cerebral Palsy

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Purpose: This study aimed to assess the reliability and validity of the Japanese version of the Trunk Impairment Scale (TIS-J) for patients with spastic cerebral palsy.
Methods: A cross-sectional study was conducted, in which a total of 69 patients were enrolled. The reliability of the results were tested for 20 patients by intra-rater and inter-rater reliabilities and minimal detectable change at 95% confidence interval (MDC95), and construct validity by comparing them with the Gross Motor Function Classification System scores.
Results: The intra-class and interclass correlation coefficients for test–retest reliability were 0.90–0.99. The intra-rater MDC95 values for static sitting balance, dynamic sitting balance, coordination, and total score were 0.44, 1.35, 0.44, and 0.96, respectively, while the inter-rater MDC95 values for the same were 1.54, 1.97, 1.15, and 2.37. The Spearman correlation coefficient were −0.63, −0.76, −0.30, and −0.74. It revealed a good relationship for validity between the change in score for the dynamic sitting balance and total TIS-J scores.
Conclusions: The TIS-J was found to be reliable and valid for patients with spastic cerebral palsy.

Key Words: Cerebral palsy, Trunk Impairment Scale, Reliability, Validity, Function of the trunk

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Representative Value of Nutritional Status and Physical Function Stratified by Age and Sex in Maintenance Hemodialysis Patients

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Purpose: The aim of this study was to clarify the representative values and the proportion below the cut off value related to nutritional status and physical function in maintenance hemodialysis patients.
Methods: A total of 670 hemodialysis outpatients participated in this cross-sectional study. Patient's background, body mass index (BMI), geriatric nutritional risk index (GNRI), grip strength, knee extension force (KEF), gait velocity, and short physical performance battery (SPPB) were investigated. The validity of the sample size was confirmed, and representative values and the proportions below the cut off values were compared.
Results: A sufficient sample size was able to be set for patients aged 50-years and older. GNRI, grip strength, KEF, gait velocity, and SPPB decreased with increasing age, and many patients aged 80 years or older were below the cut-off value.
Conclusion: This study showed the representative values of nutritional status and physical function by age and demonstrated an actual decrease in elderly patients.

Key Words: Hemodialysis, Physical function, Representative value

Vol. 47, No. 3 (pp 215-223)

Prediction Accuracy of Walking Independence in Mini-Balance Evaluation Systems Test with Spinocerebellar Degeneration

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Purpose: We aimed to investigate whether the Mini-Balance Evaluation Test (Mini-BESTest) can be applied to assess walking impairment severity in individuals with spinocerebellar degeneration (SCD) and to compare the difference in walking impairment severity assessed using Mini-BESTest and Berg Balance Scale (BBS).
Methods: Thirty individuals with SCD participated in the study and were divided into three groups according to the SCD severity classification. They were assessed using Mini-BESTest, BBS, and Functional Independence Measure (FIM). The total scores and distribution of scores from Mini-BESTest and BBS were compared among the three groups. In addition, a receiver-operating characteristic (ROC) plot was used to compare the overall accuracy in assessing walking severity using Mini-BESTest and BBS and to determine appropriate cutoff scores for identifying whether an individual can walk independently.
Results: The total Mini-BESTest and BBS scores showed significant differences among the three groups. Both scores decreased with an increase in walking impairment severity. Mini-BESTest and BBS had high area under the curve and sensitivity and specificity. A ceiling effect and deviation in bias in the distribution were identified only on BBS.
Conclusion: Mini-BESTest had a higher accuracy and sensitivity than the BBS was thus considered useful for assessing properties that identify individuals with SCD who can walk independently.

Key Words: Spinocerebellar Degeneration, Balance ability, Mini-BESTest, Walking independence

Vol. 47, No. 3 (pp 224-230)

Relevance of Scapula Function and Preoperative Factor after Reverse Total Shoulder Arthroplasty

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Purpose: To confirm the relevance of preoperative factors based on post-reverse total shoulder arthroplasty (RTSA) scapula function using scapula-45 radiography.
Method: Twenty-eight patients were observed for more than 6 months after RTSA. We evaluated how the preoperative physical findings had an influence on their postoperative scapular index, which indicates postoperative scapula function.
Results: The only significant independent variable that could be extracted for the postoperative scapular index was the preoperative scapular index.
Conclusion: The only factor affecting the postoperative scapular index is the preoperative scapular index.

Key Words: Reverse total shoulder arthroplasty, RSA, RTSA, Scapula index, Scapular notching

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Electromyographic Analysis of Shoulder Muscle Activity after Reverse Shoulder Arthroplasty: A Comparison with Healthy Shoulders

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Purpose: To analyze shoulder muscle activity after reverse shoulder arthroplasty (RSA) using electromyography to identify any differences from the muscle activity of healthy shoulders.
Methods: The subjects included 12 RSA-treated shoulders and 17 healthy (control) shoulders. Shoulder muscle activity was evaluated using surface electromyography at 45° and 90° of shoulder elevation. The subjects held their arms aloft in three directions during recording at flexion, scaption, and abduction. Ratios of integrated electromyographic activity for different muscles at 45° and 90° were calculated and compared between the two groups.
Results: Muscle activity ratios in the posterior deltoid during flexion, the upper trapezius and posterior deltoid during scaption, and the clavicular pectoralis major during abduction were significantly higher in the RSA group ($p<0.05$).
Conclusions: Our results suggest that RSA-treated shoulder muscles behave differently from healthy shoulders during sustained elevation between 45° and 90°.

Key Words: Reverse total shoulder arthroplasty, Electromyography, Massive rotator cuff tears, Muscle activity

Vol. 47, No. 3 (pp 239-246)

Usefulness of Six Minute Walking Distance as a Predictor of Complications after Gastric Cancer Laparotomy

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Purpose: We investigated the factors significantly associated with postoperative complications after laparotomy for gastric cancer.
Methods: The study included 24 patients who underwent perioperative rehabilitation before surgery. Patients were categorized into the postoperative complication and the non-postoperative complication groups, and intergroup comparison was performed for statistical analysis. Logistic regression analysis was used to identify factors significantly associated with postoperative complications. The cutoff value was calculated using the receiver operating characteristic (ROC) curve.
Result: The preoperative 6-min walk distance was significantly lower in the postoperative complication group (257.7 m vs. 353.1 m, $p<0.01$). Logistic regression analysis showed that the selected factor was only the preoperative 6-min walk distance, and the cutoff value based on the ROC curve was 300 m.
Conclusion: We observed that the preoperative 6-min walk distance was significantly associated with postoperative complications after laparotomy performed for gastric cancer. Therefore, the preoperative 6-min walk distance might effectively predict complications after laparotomy for gastric cancer. Active prehabilitation and improvement of preoperative exercise tolerance are important in patients showing a 6-min walk distance <300 m.

Key Words: Gastric cancer, Postoperative complication, Six minute walking distance, Cutoff value

Vol. 47, No. 3 (pp 247-254)

Relationship between N-type Test and Kinder Infant Development Scale

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Purpose: This study aimed to examine the relationship between N-type test and each developmental domain of the Kinder Infant Development Scale (KIDS).
Methods: This study included 42 children aged 3-6 years along with their parents. The N-type motor image test for toddlers (N-test) was used to evaluate motor imagery, and scores were calculated for selecting picture cards representing posture (card task) and for change in posture (postural task). Parents answered questions from the KIDS (Type C), and each subscale was scored (etc. physical-motor, receptive language, expressive language, social relationships with children, and social relationships with adults). These scores were then used to examine the relationship between the N-test scores and the development of each domain.
Results: 32 children completed the N-test. The scores of the N-test and age (in months) showed a significantly positive correlation. The scores for the card task were significantly related to the scores for physical-motor, receptive language, and expressive language from the KIDS. The scores for the postural task were significantly related to the age (in months) as well as scores for physical-motor, receptive language, social relationships with children, and social relationships with adults from the KIDS.
Conclusion: Our results suggest that the tasks of the N-test are associated with the development of different domains. Postural tasks are related to social development, and it is hypothesized that interpersonal communication experience may be involved in the function of motor imagery.

Key Words: Motor imagery, Development, Childhood, Sociality

Vol. 47, No. 4 (pp 299-305)

Examination of Factors Associated with Fear of Falling in Elderly People Hospitalized Due to Fractures and Discharged to Their Homes

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Objective: To comprehensively examine factors associated with fear of falling in elderly who were hospitalized due to fractures and discharged to their homes.
Methods: This study included 39 participants aged >65 years who sustained a bone fracture injury and were discharged from our hospital. Relationships between fear of falling and the number of falls, motor function, and residential environmental risk were investigated using Spearman or Pearson correlation analyses. A multiple regression analysis was performed with fear of falling as the dependent variable and independent variables determined using results of the correlation analysis.
Results: The factors significantly correlated with the fear of falling were the number of falls, Berg Balance Scale (BBS), Timed Up and Go test, 10-m walk test, Functional Independence Measure, Tokyo Metropolitan Institute of Gerontology index of competence, and residential environmental risk. In the multiple regression analysis, BBS, residential environmental risk, and the number of falls were identified as factors related with the fear of falling.
Conclusion: External factors such as residential environmental risk as well as common internal risks should be evaluated in elderly patients who sustained fracture to reduce fear of falling.

Key Words: Fear of falling, Fracture, Elderly people, Residential environment, Fall prevention

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Pelvic Floor Muscle, Trunk Muscles, and Lower Limb Muscles Co-contraction at the Positions of Increasing Abdominal Pressure in Young Nulliparous Subjects

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Purpose: This study aimed to investigate the co-contraction of the pelvic floor muscle (PFM), trunk muscle, and lower limb muscles at different positions when the abdominal pressure is increased.
Methods: The subjects were 15 young nulliparous women, mean age 25.5 ± 2.5 years. We measured vaginal pressure at rest and during PFM contraction. Simultaneously, we also measured the rectus abdominis muscle, external oblique muscle, internal oblique muscle (IO), multifidus muscle, gluteus maximus muscle, and hip adductor muscle activities using a surface electromyograph. We compared vaginal pressure for each measurement position (supine, standing, half sitting, and load-lifting) by two-way analysis of variance with the task performed (rest, PFM contraction), using position as a variable factor, and multiple comparison tests. Additionally, we compared the rate of increase in muscle activity during PFM contraction in each position.
Results: For task factors, vaginal pressure and all tested muscle activity were significantly higher during PFM contraction. For position factors, vaginal pressure and all tested muscle activity showed significantly higher values in the half sitting and load-lifting. The rate of increase in muscle activity of the IO was higher than that of the other muscles in the supine, standing, and the half sitting.
Conclusion: It was suggested that IO increased the activity as a co-contraction muscle with PFM in the half sitting, supine, and standing in comparison with other muscles.

Key Words: Half sitting position, Pelvic floor muscle, Internal oblique muscle, Co-contraction, Stress Urinary Incontinence

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Relationship between Health-related Quality of Life and Exercise Capacity or Physical Activity Status in Children and Adolescents with Congenital Heart Disease

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Purpose: The purpose of this study was to evaluate the relationship between health-related quality of life (HRQOL) and exercise capacity or physical activity status in children and adolescents with congenital heart disease (CHD) and healthy controls.
Methods: The study included 22 patients with CHD (mean age 13 ± 3 years) and 22 healthy controls (13 ± 3 years). We assessed HRQOL, exercise capacity (using cardiopulmonary exercise testing), physical activity level, and exercise habits, and evaluated the relationships between each index.
Results: Among the HRQOL subscores, physical well-being (PW) was significantly lower in children with CHD ($p < 0.05$). In children with CHD, there was a significant correlation between PW and anaerobic threshold ($rs = 0.472$, $p < 0.05$), but not between PW and peak oxygen uptake. Further, there was a correlation between physical activity level and PW in children with CHD ($rs = 0.504$, $p < 0.05$), and children with CHD who had regular exercise habits had higher PW ($p < 0.05$) than those without regular exercise habits.
Conclusion: HRQOL in children with CHD is associated with anaerobic threshold and daily physical activity status.

Key Words: Congenital heart disease, Health-related quality of life, Exercise capacity, Physical activity, Cardiac rehabilitation

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Impaired Postural Stability in Patients with Adult Spinal Deformity: Evaluation Based on Computerized Stabilometry

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Purpose: Recent insights suggest that spinal deformity impacts various functional disorders. However, there are few reports of examinations of postural balance in patients with adult spinal deformity (ASD), and the effect of kyphotic changes in ASD on postural balance remains unclear. The aim of this study was to evaluate standing balance and the influence of kyphotic changes on standing balance in patients with ASD.
Method: We investigated 46 female patients with ASD (age: 67.4 ± 10.0 years) and compared the results with those of 21 age-matched healthy female adults. Based on the sagittal vertical axis (SVA), patients were allocated to the SVA >100 mm and SVA <100 mm groups. Postural stability was examined using a stabilometer. Using the stabilometer, the sway of the gravity center was measured at the upright position with eyes open for 60 seconds. We used 2 parameters for evaluation: the enveloped area (ENV), which measures the degree of sway of the gravity center, and total track length (LNG), which measures the sway length in the standing posture.
Results: The mean ENV in the patient group was 5.3 ± 3.9 cm^2, whereas that in the control group was 3.3 ± 1.1 cm^2, revealing significantly larger postural instability in the patient group compared to that in the control group. The LNG in the patient group was significantly worse than that in the control group. It was also shown that postural instability was significantly larger in the patients with SVA >100 mm than that in patients with SVA <100 mm.
Conclusion: The results of the present study demonstrated impairments in postural stability in patients with ASD. In these patients, kyphotic changes were associated with greater postural instability. Therefore, exercises that delay the progression of kyphosis may be crucial for postural stability in patients with ASD.

Key Words: Adult spinal deformity, Postural stability, Stabilometry

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Longitudinal Examination of Factors Related to Shoulder Pain in High School Baseball Players

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Background: Baseball players who have shoulder pain due to throwing have reduced shoulder joint range of motion and shoulder external rotation muscle strength, which are also recognized as general features of baseball players. The purpose of this study was to examine whether these factors affect the development of shoulder pain through prospective studies.
Methods: In members of high school baseball teams, shoulder joint function was evaluated by field position. during the off-season and observations were collected over a 2-month period during the season. Subsequently, evaluation items that affected the occurrence of shoulder pain were analyzed.
Result: Twenty-four out of the 84 participants developed shoulder pain, and multiple logistic regression analysis extracted the shoulder rotator strength ratio and field position as significant variables. **Consideration**: A decrease in the shoulder rotator strength ratio significantly affected the occurrence of shoulder pain in all field positions. Although stretching has been reported to be important for preventing throwing disorders, attention must also be paid to muscle strengthening exercises that take into account the balance of rotator muscle strength.

Key Words: Baseball, Throwing obstacles, Shoulder pain, Shoulder joint function, Shoulder rotator muscle strength

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The Course of Patient Reported Outcome and Physical Function after Surgery with LSS

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Purpose: The purpose of this study was to prospectively clarify the course of postoperative patient-reported outcomes and physical function in patients with lumbar spinal stenosis.
Methods: We analyzed the data of 78 patients who completed pre-, 1-month, 3-month, 6-month, and postoperative evaluations (maximum follow-up was 12 months). Thirty-seven patients had undergone fusion surgery (68.4 ± 10.5 years), and 41 patients had undergone decompression surgery (68.9 ± 7.8 years). We evaluated the Japanese orthopaedic association back pain evaluation questionnaire (JOABPEQ), visual analog scale (VAS) scores (low back pain, lower extremity pain, and numbness), 6-minute walk test results, and trunk muscle strength. This study was approved by the institutional review board of the authors' affiliated institutions.
Results: In the fusion surgery and decompression surgery, the four scales of the JOABPEQ, VAS (low back pain, lower limb pain and numbness), and 6-minute walk distance improved from 1 month after surgery. On the other hand, lumbar dysfunction of the JOABPEQ improved from 6 months after surgery. Trunk muscle strength improved from 3 months after decompression surgery.
Conclusions: The course of postoperative JOABPEQ and physical function was clarified. These are considered to be useful as explanations for surgery and target values for the postoperative course.

Key Words: Lumbar spinal stenosis, Change of postoperative outcome, Patient-reported outcomes, Physical function

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Factors Predicting Functional Outcome in Acute Stroke Patients: A Multicenter Study

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Purpose: We investigated potential predictors of functional outcome in acute stroke patients.
Methods: This multicentric prospective cohort study evaluated NIH stroke scale (NIHSS), Brunnstrom recovery stage, Trunk control test, Revised version of the ability for basic movement scale, Scale for contraversive pushing (SCP), Scale for the assessment and rating of ataxia, Functional ambulation category (FAC), and stroke type (cerebral infarction or hemorrhage) in 447 acute stroke (294 cerebral infarction) patients at the outset of their rehabilitation and assessed whether these measures predicated functional outcome (home discharge or rehabilitation hospital discharge). Multivariable logistic regression analysis was used to evaluate outcome predictors.
Results: The identified significant factors associated with outcome were NIHSS (OR: 1.234, 95%CI 1.110–1.372, $p<0.01$), SCP (OR: 6.270, 95%CI 1.461–26.904, $p<0.05$), FAC (OR: 0.527, 95%CI 0.417–0.668, $p<0.01$), and stroke type (OR: 3.369, 95%CI 1.896–5.986, $p<0.05$), with the percentage of correct classifications was 81.6%.
Conclusion: It was suggested that evaluation data at the early mobilization is useful to predict the functional outcome.

Key Words: Acute stroke, Functional outcome, Functional evaluation at first time, Multicenter study

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Castration-Induced Pelvic Floor Muscle Specific Atrophy and the Effect of Voluntary Wheel-Running Exercise

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Purpose: Pelvic floor muscles play an important role in excretion control and thus maintaining their function is crucial to quality of life. The aim of this study was to examine muscle atrophy in a mouse model of androgen deprivation and the effect of voluntary wheel-running exercise on pelvic floor muscles.
Methods: Castration and sham-operation were performed on 3-month-old male mice (C57BL/6J). Castrated mice were randomly housed in cages equipped with a running wheel. After 8 weeks from the operation, muscle samples were collected from limb and perineal (Limb muscles: tibialis anterior, gastrocnemius, extensor digitorum longus, plantaris and soleus. Perineal muscles: bulbospongiosus and levator ani). Myofibers were isolated from extensor digitorum longus and peri-urethral sphincter and the diameters were measured.
Results: Castration significantly decreased perineal muscles' mass and myofiber diameter of peri-urethral sphincter, whereas limb muscles were not affected. Voluntary wheel-running exercise cannot ameliorate castration-induced muscle atrophy in pelvic floor muscles.
Conclusion: Whole-body exercise cannot prevent pelvic floor muscle loss caused by androgen deprivation and thus it is suggested that target-muscle-specific training needs to be considered for the intervention.

Key Words: Men's Health, Androgen, Skeletal Muscle

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Correlation between the Psychological Aspects of Exercise about Post-discharge and Exercise Time after Discharge in Hospitalized Patients in the Recovery Ward

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Purpose: This study investigated the correlation between questionnaire survey responses and exercise time after discharge from the recovery period in hospitalized patients.
Methods: This study recruited 100 patients in the recovery ward. In addition to the questionnaire survey, we requested records on exercise time. The questionnaire was based on existing models and psychology theories on exercise adherence. Exercise time was measured for one month from the discharge day by placing a sticker on a calendar as a diary of self-activity.
Results: Data from 100 questionnaires and 35 exercise times were obtained. Factor analysis of the questionnaire, converged to 25 items and four factors. To verify the reliability, the α coefficient was calculated for 25 items, resulting in an α of 0.895. Correlation analysis with the average exercise time after discharge was confirmed as a significant weak correlation as verification of validity.
Conclusion: The results suggested a relationship between the psychological aspects of exercise after discharge from the convalescent ward and exercise time after discharge.

Key Words: Psychological aspects, Exercise adherence, Questionnaire, Recovery ward

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Interlimb Coordination in Patients Undergoing Total Knee Arthroplasty

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Purpose: In this study, we compared interlimb coordination in patients before and after total knee arthroplasty (TKA) using the phase coordination index (PCI). Additionally, we investigated its association with other variables at each time.
Methods: This study included 55 patients who underwent TKA (mean age 76.1 ± 7.4 years). We assessed and compared the preoperative PCI with the PCI measured on the day before discharge (approximately 17 days after TKA). Pearson's correlation and multiple regression analyses were used to determine factors affecting the PCI.
Results: We observed no significant difference between the pre- (6.73% ± 3.09%) and post-TKA (6.94% ± 2.97%) PCI. The pre-TKA PCI was significantly correlated with knee extension strength on the nonoperative side and knee pain on the operative side, and knee extension strength on the nonoperative side was selected as an independent variable in this study. Postoperatively, a significant correlation was observed only between the PCI and patient age.
Conclusions: This study showed that pre- and post-TKA interlimb coordination was comparable; however, different factors were associated with the pre- or post-TKA PCI.

Key Words: Total knee arthroplasty, Interlimb coordination, Phase coordination index

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Factors Related to Lung Compliance in Patients with Permanent Ventilation Dependence

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Objective: We aimed to clarify factors related to lung compliance in patients with permanent ventilation dependence.
Methods: This was a cross-sectional study. We measured the static lung compliance (Cstat) and dynamic lung compliance (Cdyn) of 29 patients, and compared the values between those with and without atelectasis, pleural effusion, and spontaneous breathing. Correlation analyses were performed to examine the relationships between lung compliances and ventilation status, demographic parameters, and biochemical blood data.
Results: Cstat was significantly lower in patients with atelectasis than in those without. Cstat and Cdyn were significantly correlated with the body mass index (BMI), rapid shallow breathing index (RSBI), alveolar arterial oxygen partial pressure difference, and days of ventilator management. Cstat was also significantly correlated with age, C-reactive protein, and the number of pneumonia episodes.
Conclusion: The negative influence of BMI on Cstat and Cdyn was high, suggesting the need for nutritional management against obesity. This study also suggested that Cstat is affected by atelectasis, the number of pneumonia episodes, and inflammatory blood response. The decreases in Cstat and Cdyn may affect the ventilation efficiency reflected by RSBI. It is necessary to examine whether the improvements in atelectasis and pneumonia frequency affect Cstat and the ventilation efficiency index in the future.

Key Words: Permanent ventilation dependence, Lung compliance, Related factors

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Cost-effective Analysis of Exercise Programs Designed for Fall Prevention among Healthy Younger Old Community-dwelling Adults

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Purpose: The aim of this study is to reveal the cost-effectiveness of exercise programs designed for fall prevention among healthy younger old community-dwelling adults in Japan.
Methods: The analysis was conducted on behalf of public insurers for health and long term care services. Quality-adjusted life years (QALY) and expenses for health services and long-term care services were described in terms of "effectiveness" and "cost," respectively. The assumed subjects were healthy community-dwelling females (n=1,000) and males (n=1,000) aged 65 years old. The incremental cost-effective ratio (ICER) of the program was analyzed and simulated using a 10-year cycle Markov model (base case). The threshold for assessing cost-effectiveness was set at less than 5 million Japanese yen/QALY.
Results: The ICER for the female group was 1,550,900 Japanese yen/QALY, and 2,277,086 Japanese yen/QALY for the male group.
Conclusion: An exercise program for fall prevention among healthy younger old community-dwelling adults could be cost-effective in Japan.

Key Words: Younger Old Community-Dwelling Adults, Fall Prevention, Cost-Effective Analysis, Markov Model, Exercise Program

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The Effect of Exercise Therapy and the Impact of Joint Injection in Shoulder Joint Disease Patients with Night Pain Undergoing Physical Therapy

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Objective: This study aims to demonstrate the usefulness of exercise therapy for night pain improvement in patients with shoulder joint disease undergoing physical treatment. We examined the treatment course by the presence, and effect of joint injection or absence of night pain at the initial evaluation.
Methods: The subjects were 72 patients with unilateral shoulder joint disease undergoing physical treatment. Patients were classified into two groups based on the presence and absence of night pain at the initial evaluation. Then, the subjects in the group with night pain were further classified into two groups according to whether or not joint injection was performed at the initial examination. We analyzed the difference in the treatment course, including range of motion (ROM), visual analogue scale (VAS), and Athens Insomnia Scale (AIS) at 1 and 3 months after the start of treatment.
Results: In both groups, courses showed interaction. ROM, VAS on movement, AIS high degree of improvement were obtained in the night pain group. VAS on movement, high degree of improvement were obtained for one month later at the initial evaluation in the joint injection group.
Conclusion: Exercise therapy for patients with shoulder joint disease undergoing physical treatment can improve ROM, VAS, and AIS, regardless of the presence of night pain. In addition, pain can be improved early by joint injection at the initial visit.

Key Words: Shoulder joint disease patients, Night pain, Joint injection

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Kinematic Analysis of Lifting by Individuals with Lower Back Pain and Fear of Movement

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Purpose: The purpose of this study was to investigate the characteristics of impaired trunk movements during lifting in people with lower back pain (WLBP) with fear of movement.
Methods: Twenty-six WLBP and eighteen pain-free healthy workers (HW) were recruited. We calculated the peak angular velocity of trunk and motion time during lifting an object. WLBP were evenly divided into low-fear and high fear groups. We compared the angular velocity of trunk with three groups and examined the relationship between these factors and pain-related factors.
Results: Our kinematic analyses revealed significant differences in the extension phase and the peak angular velocity of trunk extension in the first trial among the three groups. The peak angular velocity of trunk extension in first trial was significant correlated with TSK.
Conclusion: It was shown that lifting in people with lower back pain with fear of movement was characterized by the movement of the trunk extension.

Key Words: Lower back pain, Lifting, Fear of movement, Medical care worker

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Gait Analysis in Healthy Elderly People with and without Walking Aids

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Objective: The purpose of this study was to examine the joint kinematics and kinetics during walking with three types of walking aids in healthy elderly people.
Methods: Nineteen healthy elderly people participated in this study. A three-dimensional motion capture system and force plates were used to obtain kinetic and kinematic data while walking on a level surface. All subjects walked without any aid and with walkers, rollators, and rollators with forearm support. We measured the peak values of lower extremity joint angles, moments, and ground reaction forces in healthy elderly people.
Results: The peak values of knee adduction moment (KAM) while using the aids were smaller than without any aid. Furthermore, KAM was significantly lower when walking with rollators and rollators with forearm support compared to with walkers.
Conclusion: The use of rollators and rollators with forearm support can help to reduce KAM during level walking in healthy elderly people.

Key Words: Gait analysis, Joint moment, Walking aids, Elderly

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Periodic Outpatient Self-training Guidance Improved Physical Function and the Instrumental Activity of Daily Living in a Breast Cancer Patient with Multiple Brain Metastases: A Case Report

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Introduction: We observed the effectiveness of periodic outpatient rehabilitation on physical function and the Instrumental Activity of Daily Living (IADL) in a patient with advanced breast cancer.
Case report: A 52-year-old woman with multiple brain metastases due to breast cancer visited our hospital for chemotherapy for 5 years. Before rehabilitation, the Frenchay Activities Index (FAI) for the evaluation of IADL was 18 points and the Short Physical Performance Battery (SPPB) for the evaluation of physical function was 6 points (balance: 1 point, gait: 4 points, and sit to stand: 1 point). Rehabilitation involved muscle strengthening exercise, balance exercise, and self-exercise guidance for 13 weeks; once for 20 minutes, 9 times in total, in the outpatient chemotherapy unit. After rehabilitation, the patient improved, with an FAI of 23 points and an SPPB is 9 points (balance: 3 points, gait: 4 points, and sit to stand: 2 points).
Conclusion: This report may suggest that periodic outpatient rehabilitation improved physical function, resulting in improvement of IADL in a breast cancer patient with multiple brain metastases.

Key Words: Palliative chemotherapy, Outpatient, Rehabilitation, Breast cancer, Brain metastasis

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Availability of Plantar Sensory Threshold for Fall Risk Determination

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Purpose: Decline of somatosensory function is associated with falls in the elderly. This study investigated the relationship between loss of plantar sensory threshold and fall risk in the elderly.
Methods: The sensory thresholds of plantar foot were measured in 110 people using day service facilities for the elderly with long-term care needs (33 men and 77 women; mean age, 80.7 years), using a new sensory testing device with high reproducibility. In addition, physical and cognitive functions including lower extremity strength and gait speed were measured. Fall history during the past 12 months was determined retrospectively, and each measurement variable was compared between the faller and non-faller groups. The relationship between plantar sensory threshold and fall history was examined by calculating the odds ratios of important variables determined by logistic regression analysis with the presence of a fall event as the objective variable.
Results: There were significant differences in the plantar sensory threshold, ankle dorsiflexion angle, and ratio of men to women between the fallers and non-fallers. The odds ratio adjusted by sex was significant in the plantar sensory threshold and the ankle dorsiflexion angle.
Conclusions: The plantar sensory threshold will be valuable information to explain falls in the elderly requiring long-term care. The results of this study suggested that assessment including the plantar sensory threshold in addition to conventional indices would be more effective for determining the risk of falls in elderly people who require long-term care.

Key Words: Plantar sensation, Falls, Elderly, Requiring long-term care, Risk factors

Vol. 47, No. 6 (pp 507-514)

Psychometric Properties of Mini-Balance Evaluation Systems Test in Patients with Acute Stroke

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Objective: We examined the validity, reliability, responsiveness, and interpretability of the Mini-Balance Evaluation Systems Test (Mini-BESTest) in patients during the acute phase of a stroke.
Method: This study included 42 patients in the acute phase of a stroke. We examined the correlations between Mini-BESTest scores and those of other similar scales, the internal consistency of the Mini-BESTest, the correlation between score changes when using the Mini-BESTest and when using the existing balance evaluation scale, and the discriminative ability of the Mini-BESTest in assessing walking independence.
Results: Mini-BESTest scores showed significant correlations ($r = 0.36–0.83$) with balance scores and other similar measures, and good internal consistency ($\alpha = 0.88$). Score improvements when using the Mini-BESTest and when using the existing balance evaluation scale showed a significant correlation ($r = 0.84$), but the discriminative ability of the Mini-BESTest in assessing walking independence was low.
Conclusion: We have suggested that the Mini-BESTest is a valid tool for assessing the balance ability of patients during the acute phase of a stroke. We have demonstrated the validity, reliability, responsiveness, and interpretability of the Mini-BESTest.

Key Words: Mini-BESTest, Stroke, Balance, Psychometric properties

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The Characteristics of the Site-specific Body of Muscle Mass and the Physical Functions in Community-dwelling Elderly Men Under Long-term Care

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Objective: The aim of this study was to investigate the characteristics of the physical functions and the site-specific muscle mass in elderly men under long-term care.
Methods: Fifty-three community-dwelling elderly (≥65 years of age) men participated in this study. The participants were classified into a robust elderly group (group R) and an elderly under long-term care group (group C). Their physical functions were evaluated by questions 6–10 of the Kihon checklist sub-items. Muscle thickness was evaluated in eight regions of the body using B-mode ultrasound, and body height, body weight, and body mass index (BMI) were measured.
Results: The total and individual physical function scores of group C were higher than those of group R. The anterior and posterior lower legs were the only sites where the muscle thickness of group C was significantly lower than that in group R.
Conclusion: The findings suggested that elderly men under long-term care often have the loss of muscle mass, particularly in the anterior and posterior lower legs.

Key Words: Community-dwelling elderly men under long-term care, Sarcopenia, Site-specific body of muscle mass, Physical functions

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Relationship between Blood Pressure Changes in the First Sitting Position and Neurological Deterioration in Patients with Acute Ischemic Stroke

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Objective: To elucidate the relationship between blood pressure changes in early sitting position and neurological deterioration (ND) in patients with acute ischemic stroke.
Methods: A total of 165 patients hospitalized within 24 h after the onset of ischemic stroke were seated for >10 min on bed at the earliest possible time. Blood pressure changes at 3 or 10 min after the sitting position were compared to those obtained in supine position. We divided the patients into two groups, with and without ND, indicating ≥ 2 points based on National Institutes of Health Stroke Scale, which worsened within 7 days after admission. The association between variables included in the multivariate model and occurrence of ND was examined.
Results: A total of 25 patients (15.2%) exhibited ND. On univariate analysis, perforator stroke, hemoglobin A1c level, high-density lipoprotein cholesterol (HDL-C) level, systolic blood pressure at 10 min while sitting, and elevated and reduced blood pressure while sitting exhibited a statistical significance ($p < 0.05$). On multivariate analysis, perforator stroke (odds ratio [OR], 5.35; 95%confidence interval [CI], 1.67–17.20), HDL-C level (OR, 0.96; 95%CI, 0.92–0.99), and reduced blood pressure while sitting (OR, 14.1; 95%CI, 3.93–55.70) demonstrated to be independent predictive factors.
Conclusion: Reduced blood pressure during an early sitting position shows to be related to ND within 7 days after admission in patients with acute ischemic stroke.

Key Words: Ischemic stroke, Neurological deterioration, Blood pressure change

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Descending Stairs in Patients after Total Knee Arthroplasty Fails to Reproduce Efferent Knee Joint Extension Moment in Healthy Volunteers

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Purpose: To clarify whether a patient can reproduce the elongation moment of the efferent knee joint in patient of the same age while descending stairs after total knee arthroplasty (TKA).
Methods: The subjects were 8 patients in the TKA group who were able to perform step-down movements in one step and 1 step 1 year after undergoing TKA, and 10 healthy volunteers of the same age. In the descending motion analysis, lower limb muscle activity was measured using a three-dimensional motion analyzer and ground reaction force meter by measuring the joint angle, joint moment, joint power, and surface electromyogram of the sagittal plane. All measured data were compared for the main measurement item, first peak of knee extension moment (20%), and second peak of knee extension moment (80%).
Results: In the TKA group, the elongating moment of the efferent knee joint during the lowering movement was significantly lower in both the early stance phase and late stance phase than that in the healthy group.
Conclusion: One year after the TKA, the efferent knee joint extension moment of healthy individuals of the same age cannot be reproduced while descending stairs.

Key Words: Total knee arthroplasty, Descending stairs, Efferent knee joint extension moment

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Effects and Safety of Early Resistance Training in Hospitalized Older Patients with Heart Failure: A Randomized Controlled Trial

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Purpose: The present study aimed to determine the safety and feasibility of early RT and its effects on physical function among hospitalized elderly patients with heart failure.
Methods: The remaining patients were randomly assigned to either a resistance training (RT) or a control group. The primary outcome was knee extension muscle strength, and the secondary outcome was comfortable walking speed and the SPPB.
Results: The pathological status of only one patient worsened. Knee extension muscle strength and comfortable walking speed significantly interacted, and the effect size of resistance training on knee extension muscle strength and comfortable walking speed was moderate, and small on the SPPB in the RT group.
Conclusions: These results suggest that early resistance training can be safe and effective for hospitalized elderly patients with heart failure when indications, contraindications, and exclusions are appropriately applied and training is gradually increased in stages.

Key Words: Hospitalization period, Older patients with heart failure, Resistance training, Safety, Effects

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Effect of Inspiratory Muscle Training on Physical Activity in Patients with Chronic Obstructive Pulmonary Disease: A Multicenter, Randomized, Placebo-controlled Trial

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Objective: This study aimed to investigate the efficacy of inspiratory muscle training (IMT) on physical activity in patients with chronic obstructive pulmonary disease (COPD).
Methods: Fifty-nine outpatients with stable COPD were enrolled in this study. The participants were randomly assigned to either an IMT group (set intensity at >30% of their maximal inspiratory pressure [PI_{max}]) or a sham training group (<10% PI_{max}). Patients of both groups underwent 30 breath IMT sessions twice daily for 3 months. The PI_{max}, 6-minute walk distance (6MWD), daily step counts, and moderate-to-vigorous intensity physical activity time (MVPA) were recorded before and after the 3 months intervention.
Results: Fifty participants (23 from the IMT group and 27 from the sham training group) completed the entire assessment. Significant interactions in the PI_{max}, daily step counts, and MVPA were observed. Only patients in the IMT group showed significant improvement in these attributes after the intervention. The 6MWD significantly improved in patients of both groups, and no significant interaction was observed.
Conclusion: This study suggests that the IMT improved the PI_{max} and could improve physical activity in patients with stable COPD.

Key Words: Chronic obstructive pulmonary disease, Inspiratory muscle training, Physical activity, Exercise capacity

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Characteristics of the Five Functional Domains about Gait Performance: Comparison between 3–10 Years Old Children and Healthy Adults

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Purpose: This study aimed to characterize the five functional domains (pace, variability, rhythm, asymmetry, and postural control) of gait performance in 3–10-year-old children.
Methods: A total of 76 healthy children aged 3–10 years and 14 young adults were included in this study. The child population was divided into four age groups: 3–4, 5–6, 7–8, and 9–10 years. Participants were instructed to walk at self-selected speed barefoot on a 6-m walkway. Spatiotemporal gait parameters (step length (SL), step velocity (SV), step time (ST), stance time (STT), and swing time (SWGT)) were calculated using a 10-camera VICON 3D motion analysis system. In addition, mean values, standard deviation, coefficient variation (CV), and symmetry index (SI) were calculated. These gait parameters were divided into five domains: pace (SL, SV, and SWGT_CV), variability (SL_CV, SV_CV, ST_CV, and STT_CV), rhythm (ST, STT, and SWGT), asymmetry (ST_SI, STT_SI, and SWGT_SI), and postural control (SW, SW_CV, and SL_SI).
Results: Differences in spatiotemporal parameters as regards a gait pattern were not significant in children aged 7–10 years and in adults (pace, rhythm, and asymmetry domains), whereas group differences in variability and postural control domains were significant in all children and adult groups.
Conclusion: Development of each of the five functional domains with respect to gait performance varies, and gait variability and stability mature longer than the gait pattern.

Key Words: Pediatric, Motor development, Gait

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Characteristics of Lower Muscle Flexibility and Generalized Joint Laxity at Around Age of Peak Height Velocity in Adolescent Male Soccer Players

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Objective: Decreased lower muscle flexibility and increased joint laxity, which are affected by bone growth, are considered intrinsic risk factors of sports injuries in adolescent players. However, little is known about changes in lower muscle flexibility and joint laxity at around age of peak height velocity (APHV).

Purpose: To examine the characteristics of lower muscle flexibility and joint laxity at around APHV in male soccer players.

Methods: Thirty-three adolescent soccer players participated in this cross–sectional study. Eligibility criteria included a) availability of height data from 4th grade of elementary school to 1st grade of junior high school and b) no pain throughout the body. Muscle flexibility of the hamstrings, quadriceps, and gastrocnemius was measured. Joint laxity was measured using the general joint laxity test. APHV was calculated based on the date height was measured. Maturity status was defined as the difference between actual age and APHV. Based on maturity status, participants were divided into three groups (G1: actual age ≤6 months before APHV, G2: actual age ≤6 months after APHV, G3: actual age 6-12 months after APHV)

Results: Flexibility of the gastrocnemius in the G1 group (−1.7 ± 4.3°) was significantly lower than in the G2 group (3.8 ± 5.3°), and the G1 group had significantly lower joint laxity (1.8 ± 1.0 points) than the G3 group (3.3 ± 1.3 points).

Conclusion: Our results suggest that muscle flexibility of the gastrocnemius and joint laxity before APHV were lower than those after APHV.

Key Words: Adolescent male soccer players, Age of peak height velocity, Maturational index, Lower muscle flexibility, Generalized joint laxity

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Sports Exercise can Induce Cortical Expansion of Upper Limb in Individuals with Complete Spinal Cord Injury

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Objective: Functional magnetic resonance imaging (fMRI) was used to clarify upper limb representation in the primary motor cortex (M1) in individuals with complete spinal cord injuries who had a history of playing sports.
Methods: Finger muscle and upper arm muscle contraction tasks during fMRI were conducted for seven individuals with complete spinal cord injury (SCI) and six healthy subjects, and the amount of brain activation was quantified. In addition, the brain regions that correlated with the number of years spent playing sports were calculated using population analysis.
Results: M1 activation size during finger muscle contraction was greater in the SCI group than in the healthy group. Further, brain activation during upper arm muscle contraction was correlated with the number of years spent playing sports in the population analysis.
Conclusion: After spinal cord injury, representation of the finger in the primary motor cortex was expanded by injury-induced plasticity, whereas representation of the upper arm was expanded by using dependent plasticity. This result suggests that intense physical activity such as sports is neurologically recommended in rehabilitation after SCI.

Key Words: Spinal cord injury, Primary motor cortex, Brain reorganization, Sports, fMRI

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Use of Patient-based Outcomes Obtained from the Simple Shoulder Test Evaluation to Predict Treatment Strategies for Japanese Patients with a Rotator Cuff Tear

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Purpose: We used a patient-based outcomes evaluation (Simple Shoulder Test) to predict treatment strategies for Japanese patients with a rotator cuff tear.
Methods: Subjects were 229 patients with a rotator cuff tear who provided answers to 12 questions in the Japanese version of the Simple Shoulder Test. Decision tree and propensity score analyses were used to calculate odds ratios.
Results: Patient were grouped according to their responses. Surgical group included patients who had night pain, pain at rest, limited physical mobility, and were unable to work; Conservative therapy group, those who had no night pain, no pain at rest, and were mobile; and Intermediate group those who provided mixed responses to these questions. The odds of patients selecting surgical treatment was 11.50 greater in Surgical group compared to Conservative therapy group and 3.47 greater in Group Surgical group compared to Intermediate group.
Conclusion: Four questions about night pain, pain at rest, mobility, and ability to work were predictive in the patient's selection of treatment and possibly the need for targeted physical therapy from an early stage.

Key Words: Shoulder Joint, Rotator Cuff Tear, Decision tree analysis, Patient-Based Outcomes

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Examination of Factors Related to Death Outcome of Patients Admitted to Psychiatric Ward with Pneumonia

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Objective: This study aimed to elucidate the factors associated with the outcome of death in patients who received physical therapy (PT) due to pneumonia in our hospital ward.
Method: This study included subjects who were admitted to our psychiatric ward, had nursing and healthcare-associated pneumonia (NHCAP), and underwent physical therapy between January 2015 and November 2018. The subjects were divided into two groups (survival group and death group) based on the outcome at 120 days from PT initiation. Cox proportional hazards analysis was used to examine the factors related to the outcome of death.
Result: The analysis included 81 people, of which 31 (38.3%) died within 120 days of PT initiation. Cox proportional hazards analysis revealed that age and onset body mass index (BMI) were significantly associated with the outcome of death.
Conclusion: The results suggested that the outcome of death in patients admitted to the psychiatric ward with NHCAP was influenced by age and onset BMI.

Key Words: Psychiatric ward, Death outcome, Nursing and Healthcare associated Pneumonia

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