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Abstract

Traditional knee-ankle-foot Orthosis causes irregularities and energy waste because it restricts knee bending when walking. High costs, size, and complexity limit accessibility.To fabricate a low-cost Stance Control Orthotic Knee Joint that allows free knee motion during a swing and resists knee flexion during stance.This was an experimental case study. A 24-year-old male with a paralyzed right leg due to polio was included. Tinetti scale and customized questionnaire were used to assess the risk of falls, dynamic balance, and patient satisfaction.The patient's dynamic balance improved and the risk of falling was also reduced, and the patient was delighted with the use of (SCKAFO).The newly developed stance-control orthotic knee joint offers a more affordable and effective solution, enhancing mobility and quality of life rather than an existing one.

Keywords: Stance Control Knee-Ankle-Foot Orthosis (SCKAFO), Orthotic Knee Joint, Gait Improvement, Mobility Enhancement

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Development of Stance Control Orthotic Knee Joint for Improvement of KAFO User

Abstract

Traditional knee-ankle-foot Orthosis causes irregularities and energy waste because it restricts knee bending when walking. High costs, size, and complexity limit accessibility. To fabricate a low-cost Stance Control Orthotic Knee Joint that allows free knee motion during a swing and resists knee flexion during stance. This was an experimental case study. A 24-year-old male with a paralyzed right leg due to polio was included. Tinetti scale and customized questionnaire were used to assess the risk of falls, dynamic balance, and patient satisfaction. The patient's dynamic balance improved and the risk of falling was also reduced, and the patient was delighted with the use of (SCKAFO). The newly developed stance-control orthotic knee joint offers a more affordable and effective solution, enhancing mobility and quality of life rather than an existing one.

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Contents

Introduction

Pathological disorders such as incomplete spinal cord injury (SCI), poliomyelitis, and other neuromuscular ailments may cause the quadriceps to weaken and become unstable while bearing weight. A drop lock is a common characteristic of knee-ankle-foot orthoses (KAFO), which place the knee on one axis. In order to prevent buckling their knees, a person with quadriceps weakness might lock their knee joint when walking and standing and only release it while seated. Accordingly, most wearers of KAFO are required to walk with their knees fully extended throughout the gait cycle. Swing-phase gait compensations resulting from walking with a locked knee joint include hip hiking and circumduction. Impact stresses on the knee and ankle are also brought on by a lack of stance flexion at initial foot contact. Stance control knee flexion (SCKAFO) is designed to prevent instability during stance and provide the proper knee flexion to facilitate clearance of the ground during the swing phase. Al-Kanany, 2020 The knee's movement is not controlled by traditional passive KAFOs. While in stance, SCKAFOs lock the knee joint; yet, they allow for unhindered rotations. Some SCKAFOs just move their body weight to transition from stance to swing, while others use some kind of control mechanism. Finally, throughout the swing and stance phases, the knee joint is regulated with dynamic KAFOs. 2. The simple stance-control system (SSCS) is a brand-new gadget created by Annkishi et al. "Carbon KAFO" is the term for the knee, ankle, and foot carbon fiber orthosis that is fastened to the upper lateral frame. A power source, an electrical circuit, a motor for the Swiss-lock knee joint, two pressure sensors connected to the metatarsal phalangeal and heel joints, and communication lines were all part of the SSCS. The knee joint with Swiss-lock automatically locks in the extended position when not in use. The only method to release the Swiss-lock knee joint is to raise the lever if the pressure sensors identify an obstacle during the swing phase and trigger the SSCS. The Swiss-lock knee joint was not released by the SSCS linked to the carbon KAFO in five real-world scenarios, which prevented the patient from bending their lower leg during the swing phase and kept it under control throughout the stance phase. (Andrysek, 2017).

A novel form of orthosis known as stance control knee ankle foot orthosis allows for free knee motion during the swing, resists knee flexion during stance, and supports the limb when bearing weight. Conventional KAFOs only lock in full extension, which stabilizes the lower limbs but causes patients to walk with abnormal gaits that, over time, may develop other issues. Traditional KAFOs also need more energy because they prevent the patient's knee from bending when they are walking. In contrast, stance control orthoses allow the patient's knee to flex during the swing phase of walking and prevent flexion for stability during the stance phase. Because a SCO may flex the knee during the swing period, patients can walk more symmetrically and with less effort. Patients with quadriceps muscular weakness who wear knee-ankle-foot orthoses have decreased knee joint drop, which limits their ability to walk. Designing stance-control orthoses might potentially increase their use. With this kind of orthosis, patients with spinal cord injuries and quadriceps muscle weakness may walk more comfortably than with a locked knee-ankle-foot orthosis. (Arazpour, 2014) Arazpour, 2013

Stance control KAFOs (SCKAFOs) are a new form of KAFO developed by researchers to prevent knee flexion during the stance phase of gait and permit unfettered knee mobility during the swing phase. Arazpour, 2016 Usually, ankle ROM mechanisms or limb inclination are what trigger mechanical SCKAFOs. A few instances of SCKAFOs include the Otto Bock Sensor Walk, Horton, UTX, swing phase lock (SPL), and knee joint for stance control orthosis (SCO). In order to go from stance to swing mode, several SCKAFOs need specific joint angles. To ensure broad market acceptability, new orthosis designs must incorporate important design considerations like size, weight, and noise level. (Arch, 2017) (Bapat, 2018) The acceptably strong and performing SCKAFO knee-joint allowed tests on a 90 kg subject at a regular walking pace. We conducted walking experiments on an able-bodied person to verify the new electromechanical knee joint's performance as planned. When in terminal stance and swing, eight KAFO users saw a reduction in hip abduction angle abnormalities and pelvic obliquity; nevertheless, during the swing, the three KAFO users experienced an average increase in sagittal knee motion (488%). (Irby, 2005) Hwang, 2008 Knee-ankle-foot stance regulation Orthoses, when compared to locked knee devices, accelerate walking. As anticipated, there was no reduction in energy consumption when walking under the stance control condition. Eleven Kim, 2016

This relates to an improvement in temporal and spatial gait characteristics, a reduction in compensatory motions to help with swing phase clearance, and an increase in knee flexion during the swing phase, which provides enough ground clearance. Research findings demonstrate the benefits of using a SCKAFO system in clinical settings. (Nakanishi, 2012) Rafiaei, 2016 The stance-control methods that facilitate or impede joint mobility at certain points in the gait cycle must be the foundation for the design (Rakib,2015) To enhance the brace's visual appeal, it would be ideal to create "SSCKAFOs" that have minimal dimensions, enabling the device to be worn beneath jeans. worn below jeans. "SCKAFOs" are pricey, which is another problem. People with disabilities cite cost as a primary reason for not meeting their demands for assistive devices. Patients who were walking with a SCKAFO had more symmetrical and natural gait patterns, as well as longer strides and steps, according to consistent assessments Rasmussen, 2007 Ross, 2013. This knee extension assistance may benefit patients who have excessive knee flexion at the end of the swing phase and struggle with the first heel. Tian, 2016 Despite extensive research on stance-control knee, ankle, and foot orthoses, I have developed cost-effective stance-control orthotic knee joints for KAFO users, which outperform more expensive SCKAFOs in terms of functionality and enhance patients' quality of life.f life.

Materials and Methods

The Pak Rehabilitation Center in Peshawar served as the site of the experimental case study. The study ran from March 2023 to September 2023. We used non-probability sampling as the sampling method. For this investigation, there was one sample size. We eliminated all users, except for those who joined KAFO and those over 60 who did not use orthotic equipment. The research participants were Stance Control KAFO device users aged 10 to 50. The patient presented with a paralyzed right leg due to polio at the age of 24. First, we obtained consent from the patient who met the inclusion criteria. We took the patient's history and inquired about symptoms associated with falling risk, dynamic balance, and other related issues. We used the Tinetti scale as an assessment tool and a customized questionnaire to gauge the patient's quality of life and satisfaction. We used SPSS version 26 for statistical analysis. Steps followed during the formation of the stance-control orthotic knee joint are listed below in Figure 1.

Figure: 1

Formation of stance control orthotic knee joint

Results

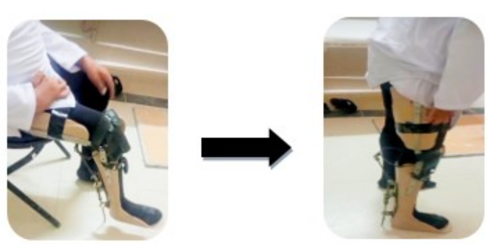
The study included a single patient with the age of 24 years having paralysis in his right leg due to polio. The patient was equipped with the Stance Control Knee-Ankle-Foot Orthosis (SCKAFO), a more modern design than standard KAFOs, which is also more useful and fairly priced.

Tools for Assessment

- **Tinetti Scale**: This tool was used to determine the patient's fall risk. The patient's pre-intervention score, which indicated a moderate/high fall risk, was 16 (placeholder) out of 28. Following the intervention, the score increased to 25, indicating a noteworthy decrease in the risk of falls.
- **Customized Questionnaire**
  This questionnaire was used to assess patient satisfaction after the use of Orthosis.
  The SCKAFO allowed the patient to achieve a more symmetrical and natural gait pattern, with an increase in step and stride length. The newly developed SCKAFO was found to be cost-effective compared to existing models like the Otto Bock Free Walk and Sensor Walk.

Figure: 2

Patient wearing SCKAFO



Data were analyzed using SPSS version 26. The results showed statistically significant improvements in all measured parameters post-intervention ($p < 0.05$).

Discussion

The case study's findings highlight the major benefits of Stance Control Knee-Ankle-Foot Orthosis (SCKAFO) over conventional KAFOs, especially for individuals with post-polio paralysis or weak quadriceps muscles.

According to Kim et al, 2016's study, the SCKAFO, which forbids knee flexion during the stance phase but permits it during the swing phase, greatly improves gait mechanics. The disadvantages of standard KAFOs, which lock the knee in its extended position and often result in aberrant gaits and increased energy consumption, are solved by this design. 20)

Arazpour et al, 2014.'s research discovered that wearing a powered orthosis greatly increased the amount of time spent in the stance phase but dramatically lowered walking speed and step length by 18% when compared to walking with a regular knee-ankle-foot orthosis. Cadence did not alter in a way that was statistically significant between the two testing conditions ($p = 0.751$). During the swing phase, the motorized orthosis significantly improved hip hiking and knee flexion. This novel-powered orthosis supported the knee during stance and allowed for active knee mobility throughout the gait cycle, all while improving the knee joint kinematics for patients using orthoses for the foot, ankle, and knee. Thus, unlike the locked knee-ankle-foot orthosis, the newly powered orthosis allowed its users to feel more natural knee flexion throughout the whole swing. Tian, 2015

Research by Rafiaei et al, 2016. shows that SCKAFOs provide good stance knee support and allow full knee mobility in the swing. SCKAFO prototypes have enabled KAFO users to use improved gait kinematics. Research has shown that the use of SCOs enhances both vertical and lateral displacement while walking, as well as pelvic obliquity. Although there are advantages to wearing a SCO, there hasn't been much of an improvement in terms of lower energy usage with this kind of orthosis. (Yakimovich, 2006).

The simple stance-control system (SSCS), created by Nankishi et al., is a unique device. "Carbon KAFO" is the term for the knee, ankle, and foot carbon fiber orthosis that is fastened to the upper lateral frame. All of the SSCS included a power source, an electrical circuit, a motor for the Swiss-lock knee joint, two pressure sensors connected to the metatarsal phalangeal and heel joints, and communication lines. When the knee joint with Swiss-lock is not in use, it automatically locks in the extended position. If an obstruction is detected during the swing phase by the pressure sensors, which activate the SSCS, the only way to release the Swiss-lock knee joint is to lift the lever. The Swiss-lock knee joint, which stopped the patient from bending their lower leg during the swing phase and held it under control throughout the stance phase, was not released by the SSCS connected to the carbon KAFO in five real-world situations.

Researchers Zissimopoulos et al, 2007. investigated the biomechanical and energy effects of a KAFO with the Horton SCOKJ on non-disabled people's stride. By recruiting healthy people without disabilities and observing their gait, they were able to measure the kinematic and energetic impacts of stance-control orthoses on a representative sample. In terms of kinematic and spatiotemporal data, there were hardly any noticeable differences between the locked and unlocked modes. Overall, the kinematics of the locked and auto modes were more similar to each other, indicating that the SCOKJ assisted the subjects in walking with a more normal gait. Zacharias, 2012

Researchers Arazpour et al, 2013. looked at how a knee-ankle-foot orthosis and a motorized stance control orthosis affected the kinematics and temporospatial aspects of walking in poliomyelitis patients. We originally designed a knee, ankle, and foot orthosis to assist a patient with poliomyelitis, combining drop-lock knee joints with specially made orthoses for the ankle and foot. Next, we fitted the orthosis with electrically activated motorized knee joints. This allowed the orthosis to produce torque in two directions: flexion during a swing and extension during a stance. We measured temporospatial characteristics, as well as the kinematics and kinetics of the lower limbs, by having each orthosis participant do three test walks. Findings from this study showed that using the new motorized SCKAFO instead of a regular KAFO while walking reduced compensatory displacements and let a volunteer with poliomyelitis control knee flexion and extension while walking. Zissimopoulos, 2007

Rakib et al, 2015. conducted a study about the creation of a prefabricated SCO using appropriate components and design. Compared to commercially available premade devices, it weighs 45% less. With its adjustable features, it can accommodate a broad range of patients' weights and heights (153–183 cm). The gait performance of the device was evaluated and contrasted with premade SCO that is sold commercially. A superior gait was revealed by the results. This orthotic device is lightweight, structurally stable, functionally appropriate, and user-acceptable in terms of appearance thanks to careful material selection and design

The research also highlighted the wider influence of the SCKAFO on the patient's quality of life. The notable advancements in physical and mental well-being, as assessed by the SF-36 questionnaire, indicate that the SCKAFO does not just improve movement but also plays a role in promoting general health. The SF PSQ 18 questionnaire shows that patients are highly satisfied with the device, highlighting its effectiveness and comfort as a valuable tool for enhancing the daily lives of those with mobility issues. In addition, the SCKAFO's design factors, like its small size enabling it to be worn inconspicuously underneath clothes, play a crucial role in ensuring patient adherence and societal approval. The research also emphasizes the cost-effectiveness of the newly created SCKAFO, showing that it is cheaper than other models on the market. This tackles a major obstacle hindering access, allowing the device to reach more patients and potentially enhancing the quality of life for many people with lower limb disabilities

The study's limitations stem from the limited sample size, notwithstanding the case study's encouraging outcomes. Future studies should include larger and more diverse participant cohorts to validate these results. Furthermore, to evaluate the SCKAFO's lifespan and its long-term effects on energy usage, a comprehensive study over an extended period of time is required. Further research into optimizing the transition from standing to moving phases and designing for various types of walking difficulties may provide even better outcomes for patients.

Conclusion

The SCKAFO greatly enhances walking and movement in comparison to standard KAFOs, enabling natural knee bending while walking and providing stability while standing. It improves equilibrium, evenness of walking, and overall well-being, all at an affordable price and in a subtle manner. While it did not significantly lower energy usage, the SCKAFO has potential as a viable orthotic option. Additional studies involving more participants are necessary to validate these advantages and enhance the device.

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