Diyala Journal of Medicine

ORIGINAL RESEARCH
Published: 25 December 2023
Doi: 10.26505/DJM.25027610601

Assessing the Impact of Posterior Leaf Spring Ankle Foot Orthosis on Knee Joint of Hemiplegic Stroke Patients Through Software Gait Analysis

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Received: 1 June 2023
Accepted: 2 August 2023
Published: 25 December 2023

Abstract

Background: Ankle Foot Orthoses (AFO) is mostly advised for a stroke patient who is complicated with plantarflexion deformity, to support and improve the alignments of the feet for reducing knee joint extension and promoting hip joint extension through stance-phase.
Objective: To provide deeper knowledge using software gait analysis for the biomechanical effects of PLS AFO for stroke patients.
Patients and Methods: We divided 42 participants into 3 groups (the first and second groups were 28 stroke participants that used AFO and with OUT-AFO and the third group was 14 normal participants without deformity. All participants walk 10 meters in a straight line for the same time their gait was captured at Comfortable Walking Speed (CWS). Temporal-spatial and kinematic parameters of the knee joint were compared in the study.
Results: The PLS AFO showed improvement in knee ROM in the AFO condition that has better knee flexion in the early stance (from 8.16 to 16.24 degrees in the AFO condition), a huge increase in the late stance of knee extension (from 0.16 to 3.82 degrees) and better knee flexion than the barefoot condition in the swing flexion (from 26.1 to 39.78 degrees). Also, the mean Time Up and Go (TUG) identically decreased in stroke participants (from 36.04 s in OUT-AFO to 22.6 s in AFO condition).
Conclusion: In this study, we showed that using a PLS AFO can be beneficial for improving knee ROM and progress walking speed, gait symmetry, balance, and reducing the risk of falls.
Keywords: Posterior leaf spring Ankle Foot Orthoses, hemiplegic stroke, software gait analysis

Introduction

Stroke, which accounts for 11% of all fatalities globally, is the second greatest cause of mortality, according to the World Stroke Organization (WSO) [1]. In 2019, there were between 196 to 218 strokes per 100,000 individuals in Iraq [2]. Stroke is produced by a disorder in a function of the brain as blood supply to the parts of the brain is disturbed because of one of two (Ischemic stroke) blockages caused by the clot in the blood vessel or (Hemorrhagic stroke) the hemorrhage in the brain [3].

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Strokes can damage several different neuronal procedures and can result in a variety of impairments, which includes difficulty with the control of muscular activity (motor impairment), difficulty with coordination, balance, sensory abnormalities, and cognitive impairment [4, 5]. A deformity of plantarflexion, which is characterized by an ankle joint rest in the plantarflexion posture, is caused by weakness in the dorsiflexor muscle and is the most common consequence that affects people who have had a stroke [6, 7, 8]. A plantarflexion deformity is caused by motor impairments, weakness of plantar flexor muscles which cause a problem with spasticity of Muscle, weakness, and paralysis are all fairly common stroke symptoms [9, 10, 11].

To improve walking in patients having plantar-flexion deformities, physical therapy is typically used in stroke rehab [12, 13, 14]. Though, prescription ankle foot orthoses (AFOs) as an adjunct to physical therapy in the treatment of stroke has been recommended by NHS Quality Improvements of Scotland and the International Societies of Prosthetic and Orthotic (ISPO)[15, 16]. PLS AFO is mostly advised for a stroke patient to encourage initial-contact in heel strike (by limiting the ankle's excessive plantarflexion position), to promote foot ground clearance in the swing phase, to the supports and improving the alignments of the feet (controlling equinovarus deformities) [15, 16].

There is limited literature available that specifically examines the use of Posterior leaf spring AFO on the knee joint of stroke patients. However, some studies have investigated AFO's effect on the kinematics and kinetics of the knee joint through gait in the stroke patients. A study by [17] found that AFO can significantly reduce knee hyperextension and increase flexion of the knee through the stance phase of gait in stroke patients. The study also demonstrated that AFO can improve gait symmetry and increase the speed of walking of stroke patients. However, another study by [18]found that AFO may not improve knee joint kinetics and kinematics in stroke patients with severe knee hyperextension and quadriceps weakness. Overall, much literature suggests that PLS AFO may have a positive impact on knee joint kinematics and gait function in stroke patients, and using software gait analysis (SGA) has a better outcome measure by giving more detailed joint ROM. However, more research is needed to determine the optimal design, fit, and use of AFO in stroke rehabilitation for knee joint improvement.

The current study aimed to provide deeper knowledge using software gait analysis for the biomechanical effects of PLS AFO for stroke patients while walking, and a better comprehension of how AFOs affect the joint range of motion.

Patients and Methods

This case-control study included forty-two participants in Iraq-Erbil, fourteen normal participants that had good general health, and twenty-eight participants diagnosed with a stroke had a drop-foot deformity. All participants voluntarily agreed to participate in the study. The stroke participants inclusion criteria were: patients suffering from a stroke (a minimum of six months ago), above the age of 18, capable of walking 10–15 meters without walking aids, no spasticity, and Able to provide notified consent. All participants were enlisted from the Europe rehabilitation center and PAR hospital in Iraq.

In the Procedure, all participants were requested to attend two sessions for each for a maximum of 2 hours. In the first session, The participants were thoroughly informed about the study, and every question they may have had were addressed. During this, we, check the orthosis fitting and take some exercises and gait training to the patients. The second session (ten days to two weeks later) recorded the participant's gait. The place that data collected from that study was within the Europe Rehabilitation Center. The second meeting was managed in the gait analysis laboratory, that we arranged at the Europe Rehabilitation Center.

The laboratory involves of Two-dimensional (2D) motion capture system consisting of Two cameras placed in the back and affected side of participants that record data in the sagittal plane and capture the location in markers positioned on the body of participant's during the assessment, Afterward, kinematic data were collected. Before each participant arrived, A gait lab was set up, and every piece of equipment was checked. Then After checking that the cameras could see all of the markers; asked all participants to walk 10 meters in a straight line at the same time their gait was captured at Comfortable Walking Speed (CWS). After each test condition, all participants were offered time to relax if necessary.

For the group of participants, two conditions were done first (barefoot) OUT-AFO condition Asked the participants to walk barefoot with OUT-AFO. Second AFO condition the stroke participants walk with AFO.

Statistical Analysis

The GraphPad Prism (Version 9.0) program was used to analyze the data. One-way analysis of variance (ANOVA) and post hoc Tukey's test were carried out for comparison among the three studied groups. All data were presented as Mean and Standard error. The significance level ($P<0.05$) was regarded as significant.

Results

The research focused on investigating the immediate benefits of using an AFO as compared to OUT-AFO on the gait of Stroke Participants (SP) regarding their knee joint efficiency and then compared to normal Participants (NP). Furthermore, this research focused on measuring the joint angle. The primary goal was to examine how stroke participants responded to AFO. We collect data from 42 participants and then divided them into 3 groups (the first and second groups were 28 stroke participants that used AFO and with OUT-AFO and the third group was 14 normal participants with good health). Time up and go (TUG): As shown in Figure(1) the mean TUG identical decreased in Stroke Participants and a highly significant ($P<0.0001$) was observed between both OUT-AFO condition (36.04±2.57 s) and AFO condition (22.6±1.46 s) in SPs, even though the normal participants' TUG is (10.24±0.09 s). Among the interesting findings of the current research displayed that walking with AFO in stroke participants nearly (13.4 s) faster as compared with OUT-AFO condition, that benefits the participants to have a better ADL that making their daily work easier and faster.

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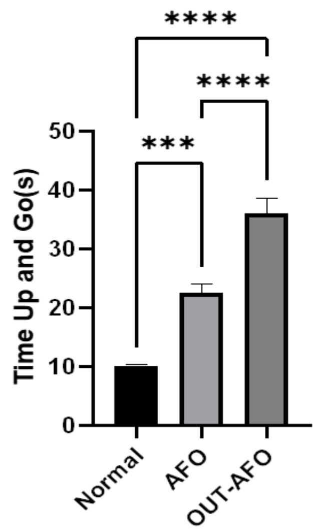

Figure (1): Comparison of TUG for (AFO, OUT-AFO, and normal groups)

Knee kinematic: knee kinematic parameters were used as a basis for the mean of the minimum/maximum peak values beyond fifteen Gait Cycles (GCs) for both stroke and good participants.

In Figure (2) we exhibit that demonstrated increased flexion peaks in the early stance phase and a highly significant difference (P<0.0001) was observed between both OUT-AFO conditions (8.16±0.65 degrees) and AFO condition (16.24±0.26 degrees) in SPs. While the normal participants' flexion peak is (13.54±0.96 degrees), likewise, there was significant difference (P=0.0138) between the AFO condition compared to Normal participants. The interesting results of this study exhibited that using AFO caused to have better knee flexion in early stance.

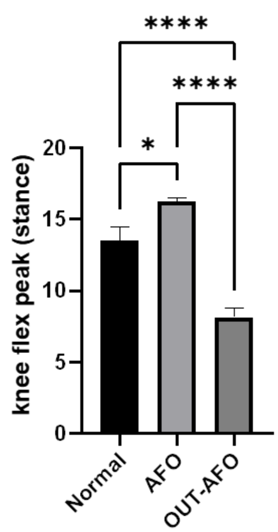

Figure (2): Comparison of knee flex peak (Stance) for (AFO, OUT-AFO, and normal groups)

As shown In Figure (3) we exhibit that increased extension in the late stance phase and a highly significant difference (P<0.0001) was noticed between both the OUT-AFO condition (0.16±0.27 degrees) and AFO condition (3.82±0.45 degrees) in SP. While the normal participants' extension peak is (5.65±0.57 degrees). also, there were significant difference (P=0.0184) between the AFO condition compared to NPs. At that point the interesting results of this study exhibited that using AFO has caused a huge increase in the late stance of knee extension, it helps to have a better GC in the stance phase.

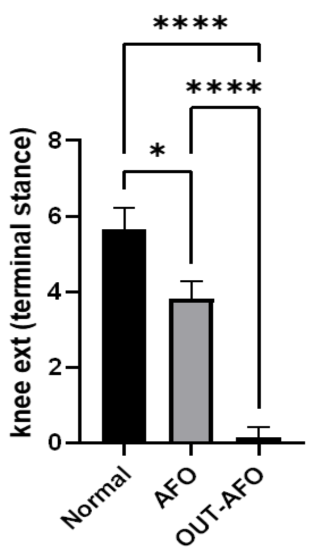

Figure (3): Comparison extension of knee (terminal stance) in the knee joint for (AFO, OUT-AFO, and normal groups)

As shown in Figure (4) identical increased flexion peak in the early swing phase and a highly significant difference(P<0.0001) was observed between both OUT-AFO condition (26.13±1.87 degrees) and AFO condition (39.78±2.43 degrees) in SP. while the normal participants' flexion peak is (64.37±0.53 degrees). The interesting results of this study displayed that using AFO produced better knee flexion than the barefoot condition, it helps to eliminate scratching the foot on the floor.

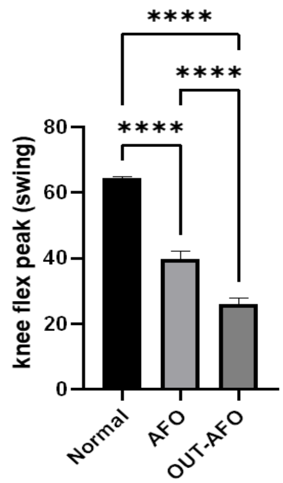

Figure (4): Comparison of knee flexion peak (swing) in the knee joint for (AFO, OUT-AFO, and normal groups)

Discussion

Knee joint kinematics has a major characteristic of knee motion during walking with OUT-AFO in stroke patients is a greatly diminished or missing knee flexion throughout the loading response, this is because of poor or not locking the ankle joint movement, that transfers the effect of the Ground Reaction Force (GRF) to the knee joint Typically, the foot is plantarflexed at initial contact, preventing knee flexion. At that point keeping the knee in its extended position during terminal swing [19]. This remains during stance and then even causes to prolong the stance phase as compared to control groups, this is because of very difficult to flex the knee. In the swing phase, decreased knee flexion is a characteristic of the typical knee motion in stroke patients. Two factors might cause this. Firstly, very difficult to flex the knee through the stance phase after it has been extended in the initial contact which reduces knee flexion in the initial swing and pre-swing in the stroke participants. Secondly, in the initial-swing and pre-swing flexion of the hip was decreased in stroke participants.

When compared the usage of AFO to OUT-AFO, causes a greater knee flexion throughout the loading response. AFO improves the knee flexion moment by reducing the plantarflexed position of a foot's initial contact. Re-establish initial contact is due to locking the ankle joint movement and move the tibia forward producing a knee flexion moment. According to the study's findings, all stroke patients had significantly reduced knee extension throughout the terminal stance and enlarged knee flexion peak through the swing phase [20].

Time up and go (TUG) is better when using AFO because the walking speed was faster and standing was easier with using an AFO compared to OUT-AFO in the all-stroke participants. TUG of the stroke patients in the current study ranged (from 17.4 to 54.6 s) when they were not using an AFO but improved clinically significantly to (ranging from 16.5 to 28.7 s) while wearing an AFO. Progresses in TUG in this study were caused by improving Temporal-spatial parameters and enhancing the kinematic alignment nearer to the normal leaning through the mid and terminal stance.

Conclusions

Overall, in this study, we showed that using a PLS AFO can be beneficial for improving knee ROM and progress walking speed, gait symmetry, and balance, and reducing the risk of falls. However, the effectiveness of AFOs may vary depending on the severity of stroke and individual patient's needs.

Recommendations

In the present research, we discuss the effects of AFO on the sagittal plane motion of the knee joints were investigated. In the future studies 3-D kinematic investigation of the hip and knee in the transverse and frontal planes should be considered.

Source of funding: This study received financial support in creating an AFO by Erbil Health and Medical Technical College / Orthosis and prosthesis department and by International Committee of the Red Cross.

Ethical clearance: Ethical approval was obtained from the College of Medicine / University of Diyala ethical committee for this study.

Conflict of interest: Nil

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DJM Diyala Journal of Medicine
ORIGINAL RESEARCH
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Doi: 10.26505/DJM.25027610601

تقييم تأثير posterior leaf spring ankle foot orthosis على مفصل الركبة لمرضى السكتة الدماغية المفلوجية من خلال تحليل مشية البرمجيات

محمود سوران عبدالرحمن[1] , غسان حسني علي [2]

الملخص

خلفية الدراسة: يُنصح في الغالب بأجهزة تقويم الكاحل للقدم (AFO) لمريض السكتة الدماغية الذي يعاني من تشوه ثني أخمصي لدعم وتحسين محاذاة القدم لتقليل تمديد مفصل الركبة وتعزيز تمديد مفصل الورك من خلال مرحلة الوقوف.

اهداف الدراسة: توفير معرفة أعمق باستخدام تحليل مشية البرمجيات للتأثيرات الميكانيكية الحيوية لـ PLS AFO لمرضى السكتة الدماغية.

المرضى والطرائق: قمنا بتقسيم 42 مشاركًا إلى 3 مجموعات (كانت المجموعتان الأولى والثانية 28 مشاركًا في السكتة الدماغية التي استخدمت AFO ومع OUT-AFO والمجموعة الثالثة كانت 14 مشاركًا عاديًا بدون تشوه.يمشي جميع المشاركين 10 أمتار في خط مستقيم في نفس الوقت الذي تم فيه التقاط مشيتهم بسرعة المشي المريحة (CWS). تمت مقارنة المعلمات الزمانية والمكانية والحركية لمفصل الركبة في الدراسة.

النتائج: أظهر PLS AFO تحسنًا في ROM الركبة في حالة AFO التي لديها ثني الركبة بشكل أفضل في الموقف المبكر (من 8.16 إلى 16.24 درجة في حالة AFO) ، وزيادة كبيرة في الموقف المتأخر لمد الركبة (من 0.16 إلى 3.82 درجة) وانثناء الركبة بشكل أفضل من حالة حافي القدمين في الانحناء المتأرجح (من 26.1 إلى 39.78 درجة). أيضًا ، انخفض متوسط Time Up and Go (TUG) بشكل مماثل في المشاركين في السكتة الدماغية (من 36.04 ثانية في OUT-AFO إلى 22.6 ثانية في حالة AFO).

الاستنتاجات: في هذه الدراسة ، أظهرنا أن استخدام PLS AFO يمكن أن يكون مفيدًا في تحسين ROM للركبة وإحراز تقدم في سرعة المشي ، وتماثل المشي ، والتوازن ، وتقليل مخاطر السقوط.

الكلمات المفتاحية: تقويم الكاحل للقدم ، السكتة الدماغية الفالجية ، تحليل المشي بالبرمجيات

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تاريخ استلام البحث: 1 حزيران 2023
تاريخ قبول البحث: 2 آب 2023

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