REVIEW

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Different Types of Orthoses in the Management of Genu Recurvatum: What are the Best Choices?

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SUMMARY

Background. Knee joint hyperextension, also known as genu recurvatum, has been reported in hemiplegic subjects, cerebral palsy, poliomyelitis, and other neurological conditions. Although various treatment approaches such as orthoses, physical therapy, and surgery have been used for these patients, clinicians usually prefer to treat it with different types of orthoses. Therefore, the aim of this review was to identify the best orthoses used to manage genu recurvatum.

Methods. An extensive search was conducted in ISI Web of Knowledge, PubMed, Embase, Ebsco, Google Scholar, and Scopus. Keywords such as hyperextension of the knee joint and genu recurvatum were used in combination with brace, orthoses, and assistive devices between 1960 and 2024. The quality of identified papers was assessed using the Black and Down tool.

Results. Fourteen papers were identified, with six focusing on ankle-foot orthosis (AFO), six on knee-ankle-foot orthosis (KAFO), and two on knee orthoses (KO). The quality of the papers ranged from 14 to 20. External validity varied between 1 and 3. Reporting scores ranged from 4 to 9, and internal validity (confounding) scores were between 2 and 6. Internal validity (bias) scores varied from 3 to 4.

Conclusions. While there is not enough evidence on the effectiveness of different orthotic interventions for genu recurvatum, it can be concluded that the selection of orthoses depends on the severity of the disease and the presence of concurrent knee valgus deformity. Both AFO and KAFO are effective orthotic interventions for managing genu recurvatum, depending on the disease's severity. More studies should be conducted on this topic.

KEY WORDS

Genu recurvatum; Knee joint hyperextension; orthosis; conservative treatment; ankle foot orthosis.

INTRODUCTION

Knee joint hyperextension, also known as genu recurvatum, has been reported in approximately half of hemiplegic subjects. It also occurs in other neurological diseases such as cerebral palsy, poliomyelitis, and other complex lower limb deformities (1). Three distinct types of genu recurvatum can be identified based on the mechanical pattern of lower limb deformities: genu recurvatum with excessive external rotation, genu recurvatum with excessive internal rotation, and uniplanar genu recurvatum. Genu recurvatum is often associated with knee pain during daily activities, which can restrict the abilities of the subjects, especially during walking and running. This may be due to several factors, including weakness of the knee extensors, spasticity of the knee extensors, weakness of the buttock muscles, weakness of the knee flexors, ankle dorsiflexion weakness, avoidance of painful pressure on the ball of the foot, proprioceptive disorders, combinations of ankle plantar flexor spasticity

and quadriceps weakness, and spasticity of the quadriceps associated with proprioceptive disorder (2).

Although various types of treatment approaches such as orthoses, physical therapy, and surgery have been used for these patients, clinicians typically prefer to use different types of orthoses. The main question here is: which type of orthosis is most suitable to use?

Ankle foot orthoses (AFO) are set at various degrees of dorsi-flexion, knee orthoses (KO), and knee ankle foot orthoses (KAFO) have been used to treat this deformity (3-7). The type of orthosis selected depends on the severity and type of deformity. AFO may be used for stroke patients with spasticity or contracture of the gastrocnemius muscles. For spasticity or weakness of the knee extensors, a KAFO orthosis should be used (8).

Although the use of KAFO orthoses may improve the stability and kinematics of stroke patients while walking, it is believed that using this orthosis may delay the recovery of normal movement and increase spasticity. Issues with donning and doffing KAFO orthoses should be considered in this regard (4, 9-11).

The Robotic KO (RKO) is another type of orthosis used for stroke patients. This orthosis has been specifically designed for mobility training and appears to help regulate the co-contraction of the quadriceps and hamstring muscles. Preliminary evaluations of this orthosis have shown improvements in knee flexor and extensor moments, as well as a decrease in the severity of pain (12). **Figure 1** shows AFO, KO and KAFO orthoses used for treatment of genu recurvatum.

Various orthoses have been used for patients with genu recurvatum, but it is not clear which is the most effective.

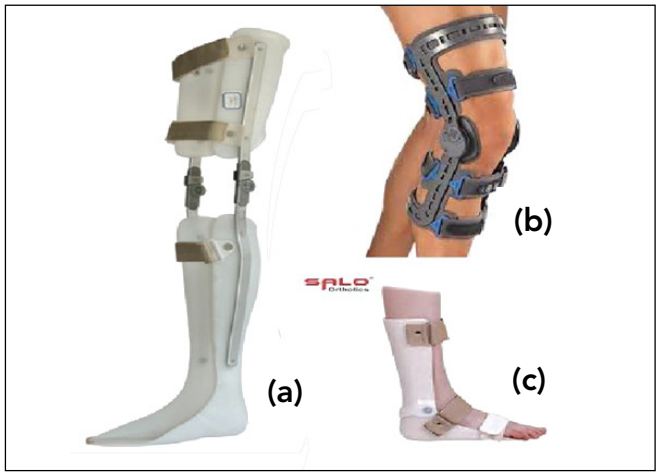


Figure 1. (a) KAFO; **(b)** KO; and **(c)** AFO orthoses used for genu recurvatum.

Therefore, the aim of this review was to determine the best orthoses for managing genu recurvatum. Additionally, the review aimed to identify the key parameters in treating this deformity using orthoses.

METHODS

Search strategy

An extensive search was conducted on ISI Web of Knowledge, PubMed, Embase, Ebsco, Google Scholar, and Scopus. Keywords such as hyperextension of the knee joint and genu recurvatum were used in combination with braces, orthoses, and assistive devices. The search period covered from 1960 to 2024. The initial selection of papers was based on titles and abstracts. If the titles and abstracts addressed the research questions of interest, the papers were included for further review. Only papers published in English that focused on the use of orthoses for genu recurvatum were chosen for final analysis.

Type of participants

The participants belonging to the selected studies were not categorized based on age and gender. However, only subjects with genu recurvatum were included in this study.

Type of interventions

The main interventions considered in the selected papers were orthoses. Therefore, the studies focusing on surgical interventions or comparisons between surgical procedures and orthoses were excluded from this study.

Type of outcome measures

The main outcome measures selected in this study include functional assessment and anatomical assessments. In anatomical assessment, the alignment of bones was determined based on X-rays of knee joint (AP and lateral X-rays). Regarding functional assessments, parameters such as range of motion of knee joint were evaluated.

Selection of the studies

The suitability of the papers based on inclusion criteria was determined by two independent researchers. This was mostly done based on abstracts and titles. If there was any source of disagreement, a third researcher was consulted.

Data extraction and management

Data extraction in this review was based on the PICO style (population, intervention, comparison, and outcomes).

Table I. The results of the studies done on the use of KAFO orthoses to correct genu recurvatum.

Reference number	Method	Outcome
(19)	From 120 hemiplegic subjects, 82 subjects were fitted with KAFO. Results were classified in three groups: Group A: cases who could not ambulate without the KAFO. Group B: cases who could ambulate more effectively and dynamically with the KAFO. Group C: cases who could ambulate with only an AFO. Electromyography evaluation was carried out for a small group of the subjects.	The KAFO is light weight, easy application and could control the motion at knee and ankle joints. There was no limitation for hip and knee motions with these orthoses. The walking ability of most of the subjects improved following the use of orthoses.
(4)	A KAFO orthoses, named Subottholen, was used in this study. The efficiency of the orthoses was evaluated on 36 hemiplegic patients with knee hyperextension. The patients were graded based on Brunnstrom functional classification of hemiplegia. Parameters evaluated include time necessary to walk around a straight L-shaped and S-shaped lines.	Only 25 subjects were followed continuously. The continued usage of the orthoses without rejection provides an effective and dynamic ambulation for the subjects due to its light weight, easy application and due to its flexibility of thigh and lower leg cuffs.
(8)	The effect of using KAFO to reduce hyperextension of knee joint in stroke subjects was investigated in this study. 11 hemiplegic subjects participated in this study (age = 51 years) with time after stroke more than 6 months. Joint kinematics and spatiotemporal gait parameters were investigated in this study. Moreover, the moments of the joints were investigated.	Use of KAFO increased walking speed significantly. It also influenced the symmetry between paretic and non-paretic limbs. Peak knee extension of the paretic limb was significantly lower in KAFO condition. Wearing KAFO improved kinematic, kinetic and spatiotemporal gait parameters. Use of orthoses also influenced knee flexor moment, ankle plantar flexor and hip flexion moments.
(18)	The aim of this study was to check the effectiveness of an articulated knee hyperextension orthoses (KAFO) in sever genu recurvatum. Gait parameters and energy consumption were evaluated in this study.	63 years old male diagnosed as post-polio residual paralysis with excessive genu recurvatum. There was no difference in PCI for braced and unbraced conditions. The results confirmed that this orthosis may be effective in managing genu recurvatum.
(17)	27 patients with painful genu recurvatum participated in this study and were treated with KAFO. The pain was scored with the Numerical Verbal Scale (NVS) and the Simple Verbal Scale (SVS) of pain. The other outcomes were obtained using French version of the Quebec User Evaluation of Satisfaction with Assistive Technology (QUEBEC) and numerical scale of satisfaction.	From 7 subjects (31 KAFO were analyzed, 4 patients double side, 25 free KAFO and 6 locked knee joints.) NVS of pain decreased from a mean of 80/100 to 26.9. SVS changed from extreme to week. QUEBEC had a total score of 4.04 and NSS had a mean of 86/09. The results of this study showed that treating genu recurvatum with KAFO is efficient on pain. Patient's satisfaction was also good.

Quality assessment

The quality of each paper was evaluated using the Black and Down tool, a reliable measure that assesses reporting (11 items), internal validity (bias) (6 items), internal validity (confounding) (7 items), and external validity (3 items). The maximum score on this scale is 28. The selected studies were summarized following the PICO style (population, intervention, comparison, and outcomes) to outline the methods and results.

RESULTS

Based on the keywords mentioned, 14 papers were identified. Of these, 6 papers focused on the use of AFO ortho-

Table II. The results of the studies on the use of AFO on genu recurvatum.

References number	Method	Outcome
(20)	The effects of AFO and footwear combination (AFO-FO) were evaluated on 5 subjects with cerebral palsy by use of motion analysis system.	The results of this study showed that knee hyperextension during stance significantly decreased and shanking to vertical angle was closer to normal. The results of this study indicated the potential of utility of tuning using wedge to correct knee hyperextension. Due to low sample size, it is not too practical to broad the results.
(14)	The effects of three types of AFOs (full length and ¾ foot length, and 90 degrees stop) on the moments of knee joints in normal and the subjects with hemiplegia were investigated. Subjects (24 months post injury) with age between 40 to 70 years were recruited in this study.	The AFO conditions delayed the onset of knee hyperextension. It should be emphasized that it did not eliminate knee joint hyperextension entirely. Use of AFO did not influence walking speed. The extensor moment of knee joint increased following the use of full length AFO. The results confirmed that when an articulated AFO is to be used, a full-length foot plate in conjunction with a plantar flexion stop may be considered to improve early stance knee moments for people with post stroke hemiplegia.
(21)	The aim of this study was to investigate the effects of plantar flexion resistance AFO on knee flexion angle in stance phase of stroke subjects. 5 hemiplegic subjects (53±11 years) used an experimental AFO with damper type ankle joint. Gait parameters were evaluated in this study.	An increase in the plantar flexion resistance of AFO induced more knee flexion at early stance phase in the patients with stroke. It influenced the stability of walking, especially during first stage of stance phase.
(15)	The purpose of this study was to investigate the effects of hinged ankle foot orthosis (HAFO), PLS and SAFO on gait of the subjects with spastic hemiplegia. 30 children with spastic hemiplegia with age varied between 4 and 18 years were recruited. Gait parameters and energy consumption were evaluated in this study. Gross motor function performance and functional mobility were measured in this study.	Ankle dorsiflexion with flexed knee was not significantly changed by AFO use. Ankle dorsiflexion at initial contact was significantly increased in all AFO conditions compared to barefoot. But it was significantly greater in HAFO and SAFO compared to PLS. Spatiotemporal gait parameters increased in all 3 AFO configurations compared to barefoot, but no difference was seen between the AFOs. No difference between energy consumption under the mentioned conditions.
(22)	22 subjects with hemiparesis and genu recurvatum who received Botulin toxin injections also in conjunction with orthoses participated in this study. Orthotic intervention - AFO with heel lift: 1. Hinged AFO with adjustable posterior stop + heel lift 2. AFO with dual channel ankle joint + heel lift 3. KAFO with offset knee joint	More than one biomechanical factor contributed to genu recurvatum in all patients. 1. Botulin toxin was used for patients with significant plantar flexion spasticity and or clonus. 2. AFO (solid) was used for patients with severe ankle dorsiflexion+plantar flexion weakness or clonus. 3. Hinged AFO with adjustable plantar flexion stop was used in the patients with less severe ankle dorsiflexion weakness in the absence of clonus. 4. AFO with dual-channel ankle joint was used for quadriceps weakness or severe proprioceptive deficient. KAFO with offset knee joint was used in patients with Achilles tendon contracture or sever proprioceptive deficient

References number	Method	Outcome
(13)	The effect of FAFO (foot AFO) was tested in this research. Of 39 patients 23 had genu recurvatum mostly due to CVA. The spasticity and muscle activity of quadriceps, gastrocnemius tibialis anterior, and hamstring muscles were evaluated in this study. Gait was also evaluated in this research.	The greatest reduction in activity of hamstring and gastrocnemius was displayed when wearing the FAFO (II) with increase in quadriceps activity. The walking speed was also improved in this study. The main problem mentioned in this study was the limb discrepancy when using orthoses. Genu recurvatum was modified in 21 subjects.

Table III. The results of the studies done on the use of knee orthosis on genu recurvatum.

References number	Method	Outcome
(12)	The aim of this study was to investigate the impact of wearable RKO on knee hyperextension by use of 3D motion analysis system. A 57 years old female with history of brain tumor participated in this study. Kinematic data were collected. Balance and lower limb functions were evaluated in this study.	The orthoses provided co-contraction training between the quadriceps and hamstrings. This training improved knee flexion/extension and improved knee flexor extensor moments and alleviated pain. This may be effective for recovery of the subjects.
(16)	31 adults with a minimum of 3 months after their stroke participated in this study. A soft knee hinged knee orthosis was used for the subjects. Spatiotemporal gait parameters, knee angle, Berge balance scale test, TUG and 6 minutes walking test were evaluated before and after use of the knee orthosis.	No significant difference was seen between spatio-temporal gait parameters and synergy of muscles between walking with and without the orthosis. Use of this orthosis prevented knee hyper extension, increase knee flexion, and improve knee stability.

ses, 6 papers focused on the use of KAFO, and 2 papers focused on the use of KO. Additionally, 10 papers examined the effects of orthoses on hyperextension of the knee joint in stroke subjects. 2 papers looked at the use of orthoses in hyperextension of the knee joint in cerebral palsy subjects, and 2 papers focused on the use of orthoses in hyperextension of the knee joint in poliomyelitis subjects. **Tables I-III** provide a summary of the results from these studies on the use of various orthoses for knee hyperextension.

The quality of the papers ranged from 14 to 20 (out of 28), while the external validity scores ranged from 1 to 3 (out of 3). The reporting score fell between 4 and 9 (out of 11), and the internal validity (confounding) scores ranged from 2 to 6 (out of 7). Finally, the internal validity (bias) score varied between 3 and 4 (out of 6). **Table IV** displays the results of the quality assessment.

DISCUSSION

Knee joint hyperextension, also known as genu recurvatum, affects the abilities of individuals while walking. Various treatment approaches have been utilized to restore these abilities in affected individuals. This deformity typically occurs in neurological conditions such as stroke, poliomyelitis, and cerebral palsy due to muscular imbalance. The aim of this review was to compare the effectiveness of different orthoses used for this condition based on existing literature. After conducting a search using the key words mentioned, 14 papers were identified. Of these, 6 papers focused on AFO orthoses, 2 papers on KO orthoses, and 6 papers on KAFO orthoses. The quality of the studies ranged from 14 to 20 (out of 28).

The effects of using AFO on knee joint hyperextension

Actually, there were six studies focused on the use of AFO with various designs on knee joint hyperextension. The quality of the studies was low due to the small number of subjects in each study and due to the method of assessment (**table IV**). The effects of some parameters such as ankle stiffness, ankle angle and also the length of AFO were investigated in these studies.

In the study by Ohsawa *et al*., it was shown that the walk-

Table IV. The results of quality assessment of the selected studies in this review.

Reference number	Level of Evidence	Reporting	External Validity	Internal Validity (Bias)	Internal Validity (Confounding)
(19)	5	6	3	4	5
(4)	5	7	3	4	5
(8)	4	8	2	3	5
(18)	2	7	1	3	4
(17)	5	7	2	4	5
(20)	3	8	1	3	6
(14)	5	7	3	4	4
(21)	3	7	1	3	6
(15)	5	9	3	4	4
(22)	5	8	3	4	2
(13)	5	4	3	3	4
(12)	2	7	1	3	6
(16)	5	7	3	4	5

ing speed of stroke subjects improved following the use of AFO. Moreover, genu recurvatum was controlled in 21 of the subjects (13). The effects of using AFO with a 90-degree stop, with heel high compensation and with a ¾ length foot plate for patients with post stroke hemiplegia were investigated by Fatone *et al*. Based on the results of their study, the use of AFO did not influence walking speed (14). However, it increased the knee extensor moment in the early stance phase and increased dorsiflexion during the swing phase. They recommended using a full length AFO in conjunction with a plantar flexion stop for this group of subjects.

Buckon *et al*. also evaluated the effects of hinged AFO and posterior leaf spring (PLS) on the gait performance of children with spastic hemiplegia. They concluded that hinged AFO (HAFO) better controlled knee hyper extension during the stance phase (15). The following results have been achieved from different studies on the use of AFO for genu recurvatum:

1. AFO is lightweight, easy to use, and can control the motion of knee and ankle joints.
2. An increase in ankle plantar flexion resistance leads to an increase in knee flexion during the stance phase.
3. An increase in ankle plantar flexion resistance may affect stability while walking.
4. Ankle dorsiflexion at initial contact increased in all types of AFOs but was most prominent in hinged AFOs (HAFO) and flexible AFOs.
5. Knee hyperextension during the stance phase significantly decreased following the use of AFO in combination with footwear.

Based on the results of various studies on the use of AFO orthoses for genu recurvatum, it can be concluded that they can be beneficial for individuals with moderate genu recurvatum. The stiffness of the ankle joint and the resistance of the orthoses to dorsiflexion also play a role in influencing the effect of the orthoses on knee hyperextension.

The effect of knee orthoses (KO) on genu recurvatum

The use of KO is another orthotic solution recommended for individuals with genu recurvatum. There were only two studies on the use of KO for genu recurvatum. In one study, which was conducted on 31 subjects with stroke, it was shown that genu recurvatum was controlled with an increase in knee flexion during the swing phase. Additionally, the use of KO influences the subjects' ability during walking. It was also emphasized that KO can only be used for individuals

with a deformity of less than 20 degrees and a coronal deformity of less than 10 (16).
A new Robotic KO (RKO) was also developed for stroke subjects with genu recurvatum. The results of this study showed that the RKO provided co-contraction training of the quadriceps and hamstring muscles. Moreover, it improved the range of motion of the knee joint during walking (12).

Use of KAFO to align the knee joint in subjects with genu recurvatum

Actually, there were 6 papers on the use of KAFO for genu recurvatum. The quality of the studies varied between 2 and 5. In the study done by Requier *et al.* on 27 patients with painful genu recurvatum, the effects of using KAFO on pain severity and satisfaction of the subjects with severe genu recurvatum were evaluated (17). The results of their study showed that the severity of pain decreased significantly following the use of orthoses. Moreover, most of the patients were satisfied with using KAFO orthoses.
Boudarham *et al.* showed that wearing KAFO improved gait parameters in patients with genu recurvatum (walking speed improved due to an increase in cadence and stride length) (8). The use of KAFO orthoses decreases knee extension angle and improves knee stability while walking (18). Based on the results of the studies on the use of KAFO (mostly done on stroke subjects) it was shown that the use of KAFO orthoses improves the symmetry of gait, decreases the peak of knee extension, improves knee flexion moment (decreases knee extension moment), and improves spatio-temporal gait parameters (4, 8, 17, 18, 19).
Using KAFO in the management of genu recurvatum raises a couple of questions that should be addressed here:

1. The first question is: "for what severity of genu recurvatum should KAFO be used?"
2. The second question is: "what are the benefits of using these orthoses compared to other designs of orthoses?"

According to available literature, KAFO should be used for individuals with genu recurvatum greater than 20 degrees and coronal plane deformity greater than 10 degrees. In comparison to KO and AFO, KAFO has greater abilities to control genu recurvatum. However, weight and aesthetics are the two main issues associated with the use of KAFO (8, 10). KAFO orthoses have been shown to improve gait velocity by enhancing both cadence and stride length, as well as improving gait symmetry. However, donning and doffing the orthoses can be a significant challenge. There is also a concern that the use of KAFO orthoses could potentially delay the recovery of normal movement and increase spasticity (8).
Based on the reviewed studies, unfortunately, there was not enough evidence regarding the efficiency of various orthotic interventions. Most of the studies were conducted on a small number of subjects using simple analysis methods. The quality of most of the studies was low, and there was no study evaluating the efficiency of various types of orthoses on a large number of subjects with genu recurvatum due to various diseases. However, based on the available studies, it can be concluded that the use of orthoses could influence genu recurvatum and decrease the effects of this deformity on the gait performance of subjects with stroke, cerebral palsy, and poliomyelitis. It is recommended to use AFO and knee orthoses for genu recurvatum with a severity of less than 10 degrees.

CONCLUSIONS

Although there is not enough evidence on the effectiveness of various orthotic interventions for genu recurvatum, it can be concluded that the efficacy of orthoses depends on the severity of the condition. It appears that both AFOs and KAFOs are effective orthotic interventions that can be used to manage genu recurvatum. It should be emphasized that KO can only be used for individuals with a deformity of less than 20 degrees and a coronal deformity of less than 10 degrees. Further research should be conducted on this topic.

FUNDINGS

None.

DATA AVAILABILITY

Data are available under reasonable request to the corresponding author.

CONTRIBUTIONS

The authors contributed equally to this work.

CONFLICT OF INTERESTS

The authors declare that they have no conflict of interests.

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