Research Article

Different Types of Orthoses in the Management of Genu-recurvatum, What are the Best Choices?

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Abstract

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

Methods: An extensive search was performed in ISI Web of Knowledge, PubMed, Embase, EBSCO, Google Scholar and Scopus. Hyperextension of knee joint and genu-recurvatum, were used in combination with brace, orthoses and assistive devices in a period between 1960 and 2018. The quality of identified paper was assessed using Black and Down tool. The maximum score of this scale was 28.

Results: Fourteen papers were identified in which six papers focused on using AFO, six papers focused on using KAFO, and two papers focused on using knee orthoses. The quality of papers varied between 14 and 20. The external validity of papers varied between 1 and 3. Moreover, the reporting score was between 4 and 9, and internal validity (confounding) was between 2 and 6. Finally, the internal validity (bias) score varied between 3 and 4.

Conclusion: Although there is not enough evidence on the efficiency of different orthotic interventions on genu-recurvatum, it can be concluded that use of orthoses is depending on severity of the disease and presence of concurrent valgus deformity. It seems that both AFO and KAFO are good orthotic interventions which can be used to manage genu-recurvatum, depends on the severity of the disease. More studies should be done on this topic.

Keywords

Genu-Recurvatum; Knee Joint Hyperextension; Orthosis; Review

Introduction

Knee joint hyper extension, which is also named as genu-recurvatum has been reported in approximately one half of hemiplegic subjects. It is also occurred in other neurological diseases such as cerebral palsy, poliomyelitis and other complex lower limb deformities [1]. Three distinct types of genu-recurvatum could be identified based on mechanical pattern of lower limb deformities, including: genu-recurvatum with excessive external rotation, genu-recurvatum with excessive internal rotation and uniplanar genu-recurvatum. Genu-recurvatum is frequently with knee pain during daily
activities, which may restrict the abilities of the subjects especially during walking and running. It may be due to several parameters including: weakness of the knee extensors, spasticity of knee extensors, weakness of 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 quadriceps associated with proprioceptive disorder [2].

Although various types of treatment approaches such as use of orthoses, physical therapy and surgery have been used for these patients, clinicians usually prefer to treat it by use of different types of orthoses. However, the main question posted here is that which type of orthoses is most suitable to be used?

Ankle Foot Orthoses (AFO) set in various degrees of dorsiflexion, Knee Orthoses (KO) and Knee Ankle Foot Orthoses (KAFO) have been used for treatment of this deformity [3-7]. However, the type of selected orthoses is depending on severity of this deformity and type of deformity. AFO may be used for stroke subjects with spasticity or contracture of triceps muscles. For spasticity or weakness of knee extensors, KAFO orthosis should be used [8]. Although, use of KAFO orthoses may improve the stability and kinematic of the stroke subjects while walking, it is assumed that practicing with this orthosis may delay recovery of normal movement and increase spasticity. Problems with donning and doffing of KAFO orthoses should be considered in this regard [4,9-11].

Robotic Knee Orthosis (RKO) is another type of orthosis used for stroke subjects. Actually, this orthosis has been designed and used for mobility training. This orthosis seems to regulate the co-contraction of quadriceps and hamstring. The results of preliminary evaluation of this orthosis showed an improvement in knee flexor and extensor moments and a decrease in the severity of pain [12].

Various orthoses have been used for the subjects with genurecurvatum. However, it is not well understood which one is more effective. Therefore, the aim of this review was to detect the best orthoses used to manage genu-recurvatum. Moreover, it was aimed to determine the parameters important to consider when treat this deformity by use of orthoses.

**Methods**

An extensive search was performed in ISI web of knowledge, PubMed, Embase, EBSCO, Google Scholar and Scopus. Keywords such as hyperextension of knee joint, genu-recurvatum were used in combination with braces, orthoses and assistive devices. The search period was between 1960 and 2018. The first round of paper selection was based on titles and abstracts. In other words, if titles and abstracts of identified papers addressed the research questions of interest, they were included for further investigation. The papers which were published in English and only focus on use of orthoses for genu-recurvatum were selected for final analysis.

The quality of each paper was assessed using Black and Down tool. This tool is a reliable measure to evaluate the quality of papers and consists of reporting, internal validity (bias), internal validity (confounding), and external validity. The maximum score of this scale was 28. The method and outputs of the selected studies were summarized based on PICO style (population, intervention, comparison and outcomes).

**Results**

Based on the mentioned key words, 14 papers were identified in which 6 papers focused on using of AFO orthoses, 6 papers focused on using KAFO, and 2 papers focused on using KO. 10 papers focused on the effects of orthoses in hyperextension of knee joint in stroke subjects. 2 papers focused on using orthoses in hyperextension of knee joint in cerebral palsy subjects and 2 papers focused on using orthoses in hyperextension of knee joint in poliomyelitis subjects. Table 1-3, summarize the results of the studies on use of various orthoses on knee hyper extension. The quality of papers varied between 14 and 20. The external validity of papers varied between 1 and 3. Moreover, the reporting score was between 4 and 9, and internal validity (confounding) was between 2 and 6. Finally, the internal validity (bias) score varied between 3 and 4. Table 4 shows the results of quality assessment.
| Author                  | Method                                                                 | Outcome                                                                                                                                 |
|-------------------------|------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------|
| Morinaka Y et al. [13]  | 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 ability of most of the subjects improved following the use of orthoses. |
| Morinaka Y et al. [4]   | A KAFO orthoses named as Subottohollen 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. |
| Boudahm J et al. [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 joint 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 influence knee flexor moment, ankle plantar flexor and hip flexion moments. |
| Rahul A et al. [14]     | The aim of this study was to check the effectiveness of an articulated knee hyperextension orthoses (KAFO) in severe genu-recurvatum. Gait parameters and energy consumption were evaluated in this study. | 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 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. |
| Requier B et al. [15]   | 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. | 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. |
| Jagadamma KC et al. [16] | A 63 years old male diagnosed with PPRP with 40 degrees of knee hyperextension moderate, flexible ankle varus and foot drop participated in this study. Energy consumption was evaluated by use of PCI (Physiological Cost Index). An articulated knee hyper extension orthosis was used in this study. | There was no difference between energy consumption of the subjects while walking with and without orthoses based on PCI. |

Table 1: The results of the studies done on use of KAFO orthoses to correct genu-recurrence.
| Author                  | Method                                                                 | Outcome                                                                                                                                                       |
|------------------------|------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Jagadamma KC et al. [16]| 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 shank 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 broaden the results. |
| Fatone et al. [17]     | The effects of three types of AFOs (full length and ¾ foot length, and 90 degree 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 follow 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. |
| Kobayashi T et al. [18]| 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. |
| Buckon CE et al. [19]  | 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 to 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 knee flexed 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. |
| Appasamy M et al. [20] | 22 subjects with hemiparesis and genu-recurvatum who received Botulin toxin injections also in conjunction with orthoses participated in this study. Orthotic intervention: 1. AFO with heel lift 2. Hinged AFO with adjustable posterior stop + heel lift 3. AFO with dual channel ankle joint + heel lift KAFO with offset knee joint | More than one biomechanical factor contributed to genu-recurvatum in all patients. 1. Botulin toxin used for the patients with significant plantar flexion spasticity and or clonus. 2. AFO (solid) for the patients with severe ankle dorsiflexion+plantar flexion weakness or clonus. 3. Hinged AFO with adjustable plantar flexion stop in the patients with less severe ankle dorsiflexion weakness in the absence of clonus. 4. AFO with dual-channel ankle joint for quadriceps weakness or sever proprioceptive deficient. KAFO with offset knee joint in the patients with Achilles tendon contracture or severe proprioceptive deficient. |
Ohsawa S et al. [21]  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.

Mao Y et al. [12]  The purpose 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.

Portnoy S et al. [22]  31 adults with 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, Borge 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.

Discussion
Knee joint hyperextension, which is also known as genu-recurvatum, influences the abilities of the subjects during walking. Various kinds of treatment approaches have been used to restore the abilities of the subjects. This deformity usually occurs in some neurological conditions such as stroke, poliomyelitis and cerebral palsy as a result of muscular imbalance. The aim of this review was to compare the effectiveness of various orthoses used for this disease based on the available literature.
Based on the aforementioned key words 14 papers were found in which 6 papers focused on using AFO orthoses, 2 papers focused on using KO orthoses and 6 papers focused on using KAFO. The quality of the studies varied between 14 and 20.

The effects of using AFO on knee joint hyperextension

Actually, there were 6 studies focused on use of AFO with various designs on knee joint hyperextension. The quality of the studies was low due to small number of subjects in each study and also due to the method of assessment, table 4. 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 done by Ohsawa et al., it was shown that walking speed of stroke subjects improved following the use of AFO. Moreover, Genu-recurvatum was modified in 21 of the subjects [21]. The effects of using AFO with stop, with heel high compensation and with ¾ length foot plate for the patients with post stroke hemiplegia was investigated by Fatone S et al. Based on the results of their study, use of AFO did not influence the walking speed [17]. However, it increased the knee extensor moment in early stance phase and increased dorsiflexion during swing phase. They recommended using full length AFO in conjunction with plantar flexion stop for this group of the subjects.

Buckon CE 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 stance phase [19]. The following results have been achieved from different studies on use of AFO for genu-recurvatum:

1. AFO is light weight, easy to use and could control the motion of knee and ankle joints
2. Increase in ankle plantar flexion resistance increases knee flexion in stance phase
3. Increase in ankle plantar flexion resistance may influence stability while walking
4. Ankle dorsiflexion at initial contact increased in all kinds of AFO but mostly occurred in Hinged AFO (HAFO) and flexible AFO.
5. Knee hyper extension during stance phase significantly decreased follow the use of AFO in combination with footwear.

Based on the results of different studies on use of AFO orthoses for genu-recurvatum, it can be concluded that it can be used for the subjects with moderate genu-recurvatum. Stiffness of ankle joint and resistance of the orthoses to dorsiflexion also influence the effect of the orthoses on knee hyperextension.

The effect of knee orthoses on genu-recurvatum

Use of KO is another orthotic solution recommended for the subjects with genu-recurvatum. There were only 2 studies on use of KO on genu-recurvatum. In one study which was done on 31 subjects with stroke it was shown that genu-recurvatum was controlled with increase in knee flexion during swing phase. Moreover, use of knee orthoses influence the ability of the subjects during walking. It was also emphasized that KO orthoses can be used only for subjects with a deformity of less than 20 degrees and with coronal deformity of less than 10 [22].

A new Robotic Knee Orthosis (RKO) was also developed for the stroke subjects with genu-recurvatum. The results of this study showed that the RKO provided co-contracture training of 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 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 was evaluated [15]. The results of their study showed that the severity of pain decreased significantly follow the use of orthoses. Moreover, most of the patients were satisfied with using KAFO orthoses.

Boudarham J et al., showed that wearing KAFO improved gait parameters in the patients with genu-recurvatum (walking speed improved due to an increase in cadence and stride length) [8]. Use of KAFO orthoses decreases knee extension angle and improved knee stability while walking [14]. Based on the results of the studies on use of KAFO (mostly done on stroke subjects) it was shown that 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 spatiotemporal gait parameters [4,8,15,23].

Using KAFO in the management of genu-recurvatum raises a couple of questions which should be answered here:

The first question posted here is that, for which severity of genu-recurvatum KAFO should be used?

And the second question is that, what are the benefits of using these orthoses compared to other designs of orthoses.
Based on the available literature KAFO should be used for the subjects with genu-recurvatum greater than 20 degrees, and with coronal plane deformity greater than 10 degrees. In contrast to KO and AFO, KAFO have more abilities to control genu-recurvatum. However, its weight and cosmetics are the two main issues associated with use of KAFO [8,10]. KAFO orthoses improved gait velocity by improving both cadence and stride length and improve gait symmetry. However, donning and doffing the orthoses is a big challenge. There is also unsupported thought that use of KAFO orthoses could delay recovery of normal movement and increase spasticity [8].

Based on the reviewed study, unfortunately there was not enough evidence regarding the efficiency of various orthotic interventions. Most of the studies were done on small number of subjects with simple analysis methods. The quality of most of the studies was low and there was no study to evaluate the efficiency of various types of orthoses on a big number of subjects with genu-recurvatum due to various diseases. However, based on the available studies, it can be concluded that use of orthoses could influence the genu-recurvatum and decrease the effects of this deformity on the gait performance of the subjects with stroke, cerebral palsy and poliomyelitis. However, it is recommended to use AFO and knee orthoses for genu-recurvatum with severity of less than 10 degrees.

**Conclusion**

Although there is not enough evidence on the efficiency of various orthotic interventions on genu-recurvatum, it can be concluded that the efficiency of use of orthoses for genu-recurvatum depends on severity of the disease. It seems that both AFO and KAFO are good orthotic interventions which can be used to manage genu-recurvatum. More studies should be done on this topic.

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