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Approach to rehabilitation treatment of gait disorders in patients with genu recurvatum

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Abstract

Background. The definition of genu recurvatum is the presence of more than 5° hyperextension of the knee. Biomechanically, genu recurvatum appears during the stance phase, with the ground reaction force line passing anterior to the knee. From a practical point of view, retraining the gait in patients with genu recurvatum is relatively complex because of diverse etiologies.

Aims. To present multiple approaches of rehabilitation strategies and their outcomes for treating patients with genu recurvatum.

Methods. We performed a systematic literature review in different databases, PubMed, Science Direct, using the following key words: "genu recurvatum", "knee hyperextension", "rehabilitation".

Results. Ten articles met our selection criteria. Three assessed retraining methods (functional electric stimulation or electrogoniometric feedback), five articles focused on orthoses and two articles on botulinum toxin.

Conclusions. Genu recurvatum has a multifactorial etiology mechanism such as spasticity, muscle weakness and many others, and among post-stroke patients almost half of them develop genu recurvatum. Genu recurvatum is a disability factor, affecting gait, the quality of life of patients, generating pain and increasing the risk of fall-related injuries.

Key words: genu recurvatum, rehabilitation, stroke.

Introduction

The definition of genu recurvatum is the presence of more than 5° hyperextension of the knee (Appasamy et al., 2015). Biomechanically, genu recurvatum appears during the stance phase, with the ground reaction force line passing anterior to the knee. Genu recurvatum increases the stance phase duration and promotes gait asymmetry (Woolley, 2001; Bleyenheuft et al., 2010).

From a practical point of view, retraining the gait pattern in patients with genu recurvatum is relatively complex because of diverse etiologies (Bleyenheuft et al., 2010).

Among hemiparetic post-stroke patients, genu recurvatum affects between 40 and 68% of them (Ota et al., 2010). In patients with post-stroke genu recurvatum, the gradual knee hyperextension can cause limitation of functional mobility and joint pathology (Cooper et al., 2012).

From a pathophysiological point of view, different causes of genu recurvatum have been described:

- knee extensor weakness, in which the patient maintains a hyperextension of the knee, keeping the ground reaction force anterior to the knee, preventing the normal lower limb from collapsing. The same mechanism is used by patients with quadriceps weakness after peripheral paralysis (neuropathy);
- knee extensor spasticity, causing an abnormal extension of the knee during the stance phase;
- gluteal muscle weakness, promoting a forward pelvic tilt, hyperlordosis of the lumbar spine, increased hip flexion and compensatory knee hyperextension;
- knee flexor weakness;
- ankle dorsiflexion range of motion reduction, due to spasticity and/or retraction of the posterior structures of the leg, in which the reduction of ankle dorsiflexion promotes the knee in a hyperextension position due to its inability to move the tibia anteriorly during the stance phase. To avoid this type of hyperextension, the patient has to adopt an equinus gait pattern;
- spasticity and/or retraction of posterior musculo-tendinous structures of the leg restricts the advance of the tibia, generating a hyperextension of the knee (Bleyenheuft et al., 2010).

Loss of proprioception in the lower limb, mostly in post-stroke patients, has also been associated with genu recurvatum, because the patients direct their knee into hyperextension during the late swing phase, locking the knee in extension, or by leaning their trunk forward at heel strike, preventing the collapse of the joint (Ota et al., 2010).

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Weak ankle plantar flexors, in particular the gastrocnemius, may have an important role in the presence of knee hyperextension (Cooper et al., 2012).

Material and method

We performed a literature review in different databases: PubMed, Science Direct, using the following key words: *genu recurvatum*, *knee hyperextension*, *stroke*, *rehabilitation*.

Results

Using external devices such as ankle-foot orthosis (AFO), knee orthosis (KO), knee-ankle-foot-orthosis (KAFO), several studies have described the importance of these types of devices for managing patients with genu recurvatum.

In patients with genu recurvatum and foot drop of the ankle, AFOs are largely used, improving the gait pattern and gait speed (Gok et al., 2003). Early stance knee moments in post-stroke patients with genu recurvatum have been improved using an articulated AFO (Fatone et al., 2009).

AFOs have been shown to be effective for the treatment of genu recurvatum in stroke patients when the main cause is spasticity or contracture of the triceps surae muscle (Jagadamma et al., 2010).

In a study on post-stroke patients associating genu recurvatum (n=6), using an articulated ankle-foot orthosis whose plantarflexion resistance was adjustable at four levels using 4 different spring rates (S1–S4), the authors investigated the individual responses to plantarflexion resistance of this device on knee joint kinematics and kinetics, evaluating clinical tests such as: Timed-Up and Go Test (TUG), Modified Ashworth Scale (MAS) of the affected ankle, Manual Muscle Testing (MMT) of the ankle and knee joints, and gait analysis using a Bertec split-belt treadmill and gait parameters from the leg with the AFO in each subject, peak ankle plantarflexion angle, peak ankle dorsiflexion moment, peak knee extension angle and peak knee flexion moment in the second rocker of stance (Kobayashi et al., 2016).

Table I

The range and mean (SD) of ankle and knee joint angle and moment parameters under four spring conditions (S1, S2, S3 and S4) of the ankle-foot orthosis

Knee	Peak knee extension angle	
	Range (^{0})	Mean (SD) (^{0})
S1	(-20.51, -2.62)	-10.41 (6.75)
S2	(-18.75, -0.57)	-8.67 (6.39)*
S3	(-17.80, 2.71)	-7.11 (7.55)*
S4	(18.85, 7.54)	- 4.92 (9.27)*

An asterisk (*) indicates a significant difference at $P < 0.05$ from S1 with the *post-hoc* Wilcoxon signed-rank test.
Abbreviations: SD, standard deviation

Their results suggested that by individually adjusting the amount of plantarflexion resistance of an articulated AFO under four spring conditions, genu recurvatum in patients with stroke could be improved (Table I). The ankle and knee joint angle and moment parameters showed statistically significant differences among the spring conditions of the AFO. However, individual analyses showed that the responses to the changes in the plantarflexion resistance of the AFO were not necessarily linear and unique to each subject (Kobayashi et al., 2016).

Knee orthoses (KOs) are prescribed to control genu recurvatum and to provide mediolateral stability (Frontera & DeLisa, 2010). An 8-week prospective, randomized, controlled study on 31 post-stroke patients with chronic symptoms and knee hyperextension was conducted, evaluating the effect of a hinged soft knee orthosis on the gait pattern and symmetry.

Multiple measurements such as spatiotemporal gait parameters and symmetry of the paretic knee angle, muscle activation patterns evaluated with and without the orthosis, were made. In addition, the Berg Balance Scale (BBS), 6-Minute Walk Test, 10-Meter Walk Test (10 MWT), and Timed Up and Go Test were used (Portnoy et al., 2015) (Table II).

Their results showed that improved BBS scores after the subjects ambulated for 4 weeks with the orthosis may indicate a reduced risk of falling, improving quality of life and other fall-related injuries.

Significant improvements in the 10MWT, 6MWT, and TUG scores were also seen. Specifically, in the 6MWT, the increase in distance was greater than 20 m for 13 subjects (41.9%) and greater than 50 m for 8 subjects (25.8%). In the TUG, 7 subjects (22.6%) improved their timing by more than 23%. Additionally, 21 subjects (67.7%) increased their gait velocity by more than 0.1 m/s, as calculated from the 10MWT. In ten subjects (32.3%), gait velocity increased in the 10MWT by at least 0.16 m/s, which is the minimally clinically important difference in stroke patients (Portnoy et al., 2015).

The use of a KAFO in chronic post-stroke hemiplegic subjects (N = 11) resulted in a significant reduction in the knee hyperextension angle when measured by gait analysis (Table III) (Boudarham et al., 2013).

Gait velocity was significantly greater in the KAFO condition than in the control condition (+21%,). Stride length and cadence were also significantly greater in the KAFO condition (+15% and +11% respectively). There was no significant difference between the two conditions for step width. Step length of the non-paretic limb was greater in the KAFO condition (14%) and the swing phase duration of the paretic limb was significantly shorter in the KAFO condition (−29%) (Boudarham et al., 2013).

In the stance phase, the peak knee extension (knee hyperextension) of the paretic limb was significantly lower in the KAFO condition compared to the control condition. Peak hip flexion and peak ankle dorsiflexion were significantly greater in the KAFO condition, whereas peak ankle plantarflexion was significantly lower. There were no significant differences between conditions for peak hip extension (or peak knee flexion of the paretic limb or for any of the kinematic parameters of the non-paretic limb) (Boudarham et al., 2013).

As expected, KAFO significantly decreased the primary outcome measure: knee hyperextension of the paretic limb (from −16.2 (11.9)° to −7.6 (7.4)°) during the stance phase. However, the genu recurvatum was not totally resolved (Boudarham et al., 2013).

Table II

Mean and standard deviation of the Berg Balance Scale, 6-Minute Walk Test, 10-Meter Walk Test, Timed Up and Go Test, spatiotemporal gait data, symmetry indices, and the sagittal angle of the paretic knee while the subjects (n =31) walked at baseline without the knee orthosis and after 1 month of ambulating with the orthosis

Indicators	Without the Knee Orthosis		With the Knee Orthosis	
	Mean (Median value)	SD	Mean (Median value)	SD
BBS	36.8	11.4	39.4	10.9
6MWT, m	182.1	102.6	212.1	123.6
10MWT, s	22.9 (18.0)	16.6	21.3 (15)	16.6
TUG, s	26.3 (18)	17.6	23.5 (18)	15.5
Velocity, m/s	0.38 (0.32)	0.25	0.45 (0.44)	0.31
Cadence, steps/min - Temporal data, s	68.7 (75.4)	23.5	73.2 (72.9)	32.1
Stride time	2.37 (1.63)	2.69	2.05 (1.67)	1.28
Step time	1.16 (0.82)	1.24	1.00 (0.83)	0.62
Stance duration	1.83 (1.26)	2.49	1.55 (1.16)	1.30
Swing duration	0.50	0.12	0.50	0.12
Double support	0.73 (0.36)	1.59	0.49 (0.28)	0.52
Single support - Temporal data, % GC	0.50	0.12	0.50	0.12
Stance duration	72.1 (69.4)	9.3	70.7 (69.2)	8.9
Swing duration	27.9 (30.6)	9.3	29.3 (30.8)	8.9
Double support	22.6 (19.3)	10.1	21.7 (18.1)	11.3
Single support	27.8 (31.8)	9.6	29.3	8.6
Stride length	62.4	26.3	69.4	32.8
Step length	32.8	14.1	34.8	14.5
Base width	15.4 (14.7)	6.3	16.2 (15.7)	7.1
Foot progression, degree SI	12.8	9.4	13.3	10.2
Step time	37.2 (32.6)	32.6	36.8 (29.2)	32.8
Stance duration	15.3 (13.9)	11.9	16.0 (13.8)	13.9
Swing duration	34.5	21.5	33.1	15.4
Double support	43.4 (25.4)	41.7	49.5 (36.1)	47.1
Step length	48.2 (23.9)	56.1	39.4 (19.4)	48.5
Base width - Sagittal angle of the paretic knee	18.6 (9.7)	35.2	20.2 (12.7)	18.4
Maximum	32.7	12.4	40.5	12.7
Minimum	8.2 (9.7)	7.2	10.1	9.5
At preswing		10.6	24.9	9.5

Abbreviations: SD, standard deviation; BBS, Berg Balance Scale; 6MWT, 6-Minute Walk Test; 10MWT, 10-Meter Walk Test; TUG, Timed Up and Go Test; GC, gait cycle

Table III

Spatiotemporal and kinematic parameters

Spatiotemporal parameters	Without KAFO		With KAFO	
	Non-paretic side	Paretic side	Non-paretic side	Paretic side
Stance phase duration (%)	78.6 [75.8 (10.2)]	62.3 [62.6 (7.3)][c]	68.9 [72.3 (8.4)]	59.5 [62.2 (6.2)][c]
Swing phase duration (%)	21.4 [24.2 (10.2)]	37.7 [37.4 (7.3)][c]	31.1 [27.7 (8.4)]	40.5 [37.8 (6.2)][c]
Stance phase duration (s)	0.94 [1.26 (0.70)]	0.77 [1.01 (0.53)][c]	0.88 [1.08 (0.71)]	0.75 [0.91 (0.58)][c]
Swing phase duration (s)	0.36 [0.33 (0.10)]	0.60 [0.59 (0.20)][c]	0.37 [0.36 (0.10)]	0.48 [0.46 (0.20)][c,a]
Stance phase Peak hip extension (°)	−2.7 [−4.6 (12.8)]	−2.6 [−3.0 (10.4)]	−7.2 [−7.5 (10.5)]	−0.9 [−2.9 (8.4)]
Peak hip flexion (°)	40.1 [41.5 (9.2)]	28.7 [26.9 (10.0)][c]	41.2 [38.9 (11.2)]	31.3 [30.6 (9.3)][c,a]
Peak knee extension (°)	7.0 [5.1 (7.4)]	−11.8 [−16.2 (11.9)][c]	0.6 [2.2 (6.1)]	−7.8 [−7.6 (7.4)][c,a]
Peak knee flexion (°)	35.3 [40.0 (9.1)]	9.1 [13.2 (9.5)][c]	37.4 [38.3 (6.4)]	14.7 [14.5 (9.3)][c]
Peak ankle plantarflexion (°)	0.1 [−0.8 (7.6)]	−12.1 [−13.4 (9.7)][c]	1.0 [0.2 (7.2)]	−3.1 [−5.3 (5.1)][c,a]
Peak ankle dorsiflexion (°)	19.4 [18.3 (7.1)]	0.9 [1.4 (10.4)][c]	21.0 [19.4 (5.4)]	8.1 [8.2 (5.3)][c,a]
Swing phase Peak hip extension (°)	14.5 [7.6 (17.0)]	8.9 [7.2 (12.1)]	5.5 [4.3 (12.3)]	4.7 [4.2 (12.3)]
Peak hip flexion (°)	41.9 [42.5 (10.1)]	32.8 [31.9 (9.5)]	42.7 [41.9 (11.5)]	30.1 [32.8 (9.3)]
Peak knee extension (°)	26.0 [22.7 (15.2)]	0.6 [1.7 (6.7)][c]	17.4 [15.3 (11.9)][b]	6.8 [5.5 (7.5)][c,a]
Peak knee flexion (°)	69.0 [64.2 (9.8)]	28.0 [26.9 (16.2)][c]	68.2 [64.9 (9.7)]	29.5 [28.9 (16.8)][c]
Peak ankle plantarflexion (°)	8.7 [11.0 (6.3)]	−3.8 [−3.6 (8.1)][c]	11.9 [11.4 (7.1)]	2.8 [2.6 (5.3)][c,a]
Peak ankle dorsiflexion (°)	−7.3 [−3.5 (10.0)]	−11.4 [−13.3 (8.5)][c]	−6.9 [−6.1 (9.2)]	−2.6 [−2.4 (4.5)][a]
Velocity	0.48 [0.57 (0.36)]		0.80 [0.73 (0.34)][a]	
Stride length (m)	0.82 [0.78 (0.33]		1.06 [0.92 (0.35)][a]	
Cadence (step/min)	72.0 [79.2 (25.4)]		65.1 [88.9 (23.4)][a]	
Width length (cm)	22.3 [21.8 (6.3)]		20.4 [20.9 (5.5)]	
Step length non-paretic limb (m)	0.36 [0.35 (0.18)]		0.44 [0.40 (0.20)][b]	
Step length paretic limb (m)	0.46[0.42 (0.16)]		0.52 [0.48 (0.15)]	

Median values for the gait parameters of non-paretic and paretic limbs, without and with KAFO (mean and standard deviation in brackets). [a] Significant difference between the two conditions for the paretic limb ($P < 0.05$). [b] Significant difference between the two conditions for the non-paretic limb ($P<0.05$). [c] Significant difference between the two limbs ($P<0.05$).

Despite the fact that a degree of genu recurvatum remained, the mean decrease of around 8° of hyperextension during stance confirmed that the KAFO evaluated in this study is clinically useful for the reduction of genu recurvatum in hemiplegic patients (Boudarham et al., 2013).

The changes in spatiotemporal parameters were mainly due to a decrease in the genu recurvatum during the stance phase and to an increase in paretic limb ankle dorsiflexion during both phases (Boudarham et al., 2013).

In a case series study on hemiparetic post-stroke patients with genu recurvatum, multiple types of orthotic devices were used (ankle-foot orthosis ± heel lift, hinged AFO with an adjustable posterior stop ± heel lift, AFO with dual-channel ankle joint ± heel lift), including KAFO with offset knee joint and injection with botulinum toxin A in case of plantar flexor spasticity (Appasamy et al., 2015).

If the aforementioned measures did not adequately manage the patient's GR, a KAFO with offset knee joints was provided to control the knee and prevent GR. KAFO was prescribed when the aforementioned interventions failed to adequately reduce GR and placed the subject at risk for the development of sagittal plane deviations in the future. One subject who had a severe Achilles tendon contracture required a KAFO after GR failed to improve with botulinum toxin A injections and distal orthotic modifications, including heel lifts. A second subject required a KAFO after a hinged AFO with an APS failed to reduce GR in the setting of a severe proprioceptive deficit at the knee (Appasamy et al., 2015).

In the case of patients with GR associated with pain, a retrospective study (27 patients with 31 knee-ankle-foot orthoses) was conducted on patients who had been fitted with KAFOs in order to alleviate posterior knee pain resulting from GR. Patients included in the study were classified under 3 headings: upper motor neuron pathologies (stroke, multiple sclerosis, Neuro-Behçet's disease, compressive medullary tumors from T1 to T5, spastic hemiparesis after surgery on an epidermoid cyst in the 4th ventricular cavity, Strumpell-Lorrain disease), lower motor neuron pathologies (poliomyelitis, Charcot-Marie-Tooth disease, post-radiotherapy plexitis in L3–S1, Becker's disease, and traumatic musculoskeletal lesions (articular destruction after multiple falls, articular destruction after motorcycle accidents: posterior knee luxation, gunshot to the femur) (Requier et al., 2018).

The mean time spent wearing the orthosis per 24 h was 9.8 h (SD 4.4; range: 2–17) (Requier et al., 2018).

The main outcome was scored using a verbal numeric pain rating scale (VNRS), giving a score out of 100 (where 0 means "no pain at all" and 100 means "worst imaginable pain") and a verbal rating scale (VRS), where each response option consisted of descriptions of pain. Scores were attributed to the various responses corresponding to different levels of pain intensity: "no pain", "mild pain", "moderate pain", "severe pain", and "extreme pain". Secondary outcomes were rated with the Quebec User Evaluation of Satisfaction with assistive Technology (QUEST) (Requier et al., 2018).

After fitting the knee-ankle-foot orthosis, the median VNRS pain score decreased from 85/100 to 25/100 and the description of pain on VRS decreased from "extreme" to "mild". The QUEST total score was 4.0. Using a KAFO showed an important improvement in reducing genu recurvatum and alleviating pain (Requier et al., 2018).

Treating a painful genu recurvatum with a knee-ankle-foot orthosis reduced the pain efficiently regardless of patients' diagnosis, and high scores were obtained for patient satisfaction (Requier et al., 2018).

To evaluate the electrical muscle activity and inspect the neuromuscular control system, electromyographic signal or EMG is used (Frontera & DeLisa, 2010).

In Biofeedback (BF) retraining, EMG is the most used form to down-train hyperactive muscles or up-train flaccid or weak muscles in patients with various sensorimotor deficits, thus further improving patients' control over joints (Frontera & DeLisa, 2010).

Joint angle BF can be efficient for improving joint movement control, even more than EMGBF. When active joint motion is present but limited in patients with neuromotor deficits, compared to EMGBF, joint angle BF might be promising for effective and expeditious recovery of joint control. In addition, angle BF is indicated when the goal of training is the regulation of joint movement, such as correction of genu recurvatum or the control of movement with appropriate timing and coordination (Frontera & DeLisa, 2010).

A prospective, no control group study was conducted on 15 patients; 11 of them performed a full program using multichannel functional stimulation, and only 8 of them had post-stroke knee hyperextension in the stance phase (3–48 months after stroke). The stimulated muscles were the ankle dorsiflexors and flexors, knee flexors and extensors and hip extensors or abductors, and a qualitative gait analysis was made. After the full program ended, 7 of 8 patients had improved knee hyperextension (Stanic et al., 1978).

In the case of electrogoniometric feedback retraining, a prospective, no control group study evaluating the number of beeps after therapy was carried out. After 20 days of electrogoniometric feedback retraining, of which 15 with a physiotherapist and 5 days without one, a decrease in the number of beeps was seen (Hogue & McCandless, 1983).

It is well known that spasticity represents an important disability factor in patients with cerebral palsy. Many studies demonstrated the efficacy of botulinum toxin A (BtA) for the treatment of spasticity affecting the lower limb. In the case of spastic cerebral palsy, genu recurvatum was linked to an equinus deformity (Davis et al., 2000).

A well-known mechanism that explains the influence between equinus deformity and knee extension during the stance phase is that of plantar flexion-knee extension couple (PFKE couple). Authors have demonstrated a correlation during the stance phase of gait between knee extension and ankle plantar flexors (Baddar et al., 2002). Injection of botulinum toxin A into the triceps surae muscles is a well-accepted treatment in the case of dynamic equinus deformity (Baddar et al., 2002). The presence of gastrocnemius and soleus muscle shortening, which occurs in high degrees of spasticity, favors the development of equinus foot and genu recurvatum (Simon et al., 1978; Aiona & Sussman, 2004; Svehli et al., 2010).

Using BtA to reduce the shortening caused by spasticity of the surae muscles could alleviate the knee hyperextension, despite no increase in knee flexion during the early and midstance phase. Unfortunately, the development of genu recurvatum in subjects with equinus foot is not yet fully understood (Baddar et al., 2002). In a retrospective study, which included 13 children (five female, eight male) with spastic diplegic cerebral palsy, the mean age of the patients was 5 years, before the injection. Examination was performed using a three-dimensional (3-D) gait analysis and clinical examination before BtA injections and at 6 and 18 weeks after BtA injections, according to a standardized protocol (Klotz et al., 2013).

After 18 weeks post-BtA injection into the calf muscles, a reduction of genu recurvatum was observed although patients maintained a mean knee hyperextension of 6.2° (Klotz et al., 2013).

Although maximum dorsiflexion during the stance phase improved at 6 weeks post-BtA treatment (maximum ankle dorsiflexion before treatment was −3.0°, SD, 14.3°; at 6 weeks, maximum ankle dorsiflexion was 6.2°, SD, 14.2°; $p < 0.05$), genu recurvatum did not improve during the stance phase at 6 or 18 weeks post-injection. A significant improvement of knee hyperextension (6.2°) was seen, but genu recurvatum was present in most patients in the stance phase between baseline and 18 weeks after BtA treatment (Table IV) (Klotz et al., 2013).

Table IV

Knee kinematics before and 6 and 18 weeks after BtA injection

Kinematics	Before injections		6 weeks after injections		18 weeks after injections	
	Maximum angle	SD	Maximum angle	SD	Maximum angle	SD
Ankle dorsiflexion in the stance phase	- 3.0^0	14.3^0	6.2*	14.2^0	4.5^0	10.4^0
Ankle dorsiflexion during the gait cycle	1.9^0	13.7 ^{0}	7.2*	10.7^0	4.8^0	9.8^0
Genu recurvatum during midstance	12.4^0	9.4^0	10.2^0	11.4^0	6.2^0	6.0^0

BtA = botulinum toxin; * significant difference ($p<0.05$ in t-test) compared with the values before injection.

No significant differences were observed at 18 weeks with the numbers available and, as mentioned, the improvements in equinus did not result in relevant improvement of knee hyperextension with the numbers available. None of the patients showed an equinus deformity greater than 20°. Eighteen weeks after the BtA injection, there was significant improvement in ankle dorsiflexion (Klotz et al., 2013).

Discussions

Despite the multiple etiologies of genu recurvatum, almost all rehabilitation approaches show an improvement of it, mainly by using orthotic devices. Using an AFO for reducing genu recurvatum in post-stroke patients with spastic triceps surae or a drop foot etiology has been demonstrated to the efficient. However, in patients with severe knee recurvatum, caused by spasticity or weakness of the knee extensor muscles, the AFO may not be effective (Woolley, 2001). Also, using an adjusted non-articulated AFO-footwear combination and an articulated AFO with plantarflexion stop was effective in alleviating genu recurvatum (Jagadamma et al., 2010).

In the case of knee orthosis, more than 50% of the subjects increased their gait velocity and stride length while walking with the orthosis, while the differences were not statistically significant. In addition, no significant differences were found in the gait symmetry indices. Temporal parameters were the least affected by the orthosis (Portnoy et al., 2015).

In the instance of knee-ankle-foot-orthosis (KAFO), studies have recommended the usage of this orthotic device for persons who have genu recurvatum with sagittal plane deviations of more than 20^0 (Fish & Kosta, 1998). KAFOs were initially developed to counteract quadriceps weakness in patients with poliomyelitis (Genêt et al., 1998). Indeed, this type of orthosis mechanically reduces genu recurvatum by preventing knee hyperextension during the stance phase of the gait cycle through a stop in the metal joint, without interfering with knee flexion during the swing phase (Farncombe, 1980; Morinaka et al., 1982; Morinaka et al., 1984).

However, KAFOs are bulky and noticeable, and although they are effective in controlling the knee, they have a significant weight, cosmetic drawbacks, and lack of patient compliance (Bleyenheuft et al., 2010).

Although the onset time of genu recurvatum has not yet been described, in patients with chronic genu recurvatum, using KAFOs showed an important improvement in reducing genu recurvatum and alleviating pain (Boudarham et al., 2013; Requier et al., 2018). Despite the fact that a degree of genu recurvatum remained, the decrease in hyperextension during stance confirmed that KAFO is clinically useful for the reduction of genu recurvatum in hemiplegic patients (Boudarham et al., 2013).

In the case of BtA efficacy on genu recurvatum, studies (Baddar et al., 2002; Klotz et al., 2013) demonstrated a relation between equinus foot and genu recurvatum, mainly in spastic diplegia. After treatment with BtA injection, an improvement of ankle dorsiflexors was seen; nevertheless, genu recurvatum did not show an important improvement at 6 or 18 weeks. Authors took into consideration other causes of genu recurvatum because in most patients, knee hyperextension was maintained. Gastrocnemius muscle weakness induced by BtA injection may explain why genu recurvatum gait did not improve (Klotz et al., 2013).

In post-stroke patients with genu recurvatum of spastic etiologies, studies remain to be conducted on the efficacy of BtA, with or without the usage of an orthosis.

Regarding physical therapy and other physiotherapy rehabilitation treatments, no studies were performed on patients with genu recurvatum irrespective of the etiology.

A few questions remain to be answered: first, the onset of genu recurvatum has not yet been established; secondly, can genu recurvatum be prevented in post-stroke patients in their early gait training; thirdly, once genu recurvatum is present, could it be delayed using multiple rehabilitation approaches, preventing the complications that might occur.

Conclusions

1. Genu recurvatum has a multifactorial etiology mechanism such as spasticity, muscle weakness, and many others. Among post-stroke patients, almost half of them develop genu recurvatum.
2. The use of orthoses was shown to result in a reduction of genu recurvatum despite the etiology, especially in the case of KAFO.
3. Studies show a reduction of genu recurvatum regardless of the management strategies.
4. The association of genu recurvatum and spastic equinus gait, although present in patients with cerebral palsy, has been demonstrated and injection with BtA shows important benefits.
5. In post-stroke patients with lower limb spasticity associated with equinus foot and genu recurvatum, no studies have investigated the effects of BtA.
6. There are no recent studies describing prevention strategies for genu recurvatum.
7. Genu recurvatum is a disability factor, affecting the gait, the quality of life of patients, generating pain and increasing the risk of fall-related injuries.

Conflicts of interest
Nothing to declare.

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