Classification of gait patterns in spastic hemiplegia and spastic diplegia: a basis for a management algorithm

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Classifications of gait and postural patterns in spastic hemiplegia and spastic diplegia are presented, based on the work of previous authors. The classifications are used as a biomechanical basis, linking spasticity, musculoskeletal pathology in the lower limbs, and the appropriate intervention strategies. The choice of target muscles for spasticity management, the muscle contractures requiring lengthening and the choice of orthotics are then linked to the underlying gait pattern.

Introduction

Gait patterns in spastic motor disorders have been described by a number of authors, but only two classifications are widely used. Winters \textit{et al.} described four gait patterns in spastic hemiplegia and Sutherland and Davids described four patterns of knee motion in spastic diplegia (Winters \textit{et al.}, 1987; Sutherland and Davids, 1993). The widespread use of these classifications and the frequency with which they are quoted in the literature is evidence for their utility and the need felt by many researchers to describe the complexities of spastic gait disorders in a manageable format. The classification of gait patterns in this article is based on the above studies. Management recommendations are made on the basis of the classification, drawing from many sources but essentially reflecting the author’s biases and experiences. The majority are not supported by randomized trials and there is ample scope for further clinical trials in this challenging area.

Management options are for convenience grouped as ‘spasticity management’ or ‘contracture management’. This is overly simplistic but is based on the simple premise that there is a reversible type of muscle stiffness and a more fixed type of stiffness. The former is sometimes referred to as spasticity or dynamic contracture and may respond to oral medications, injections of phenol or botulinum toxin type A, selective dorsal rhizotomy or administration of intrathecal baclofen. The latter is referred to as fixed or myostatic contracture and is traditionally addressed by lengthening of contracted muscle tendon units. Management strategies are complex and, almost invariably, more than one method is required to achieve optimal outcomes. For example, injection of the gastrocnemius muscle with botulinum toxin type A may improve the range of ankle dorsiflexion in the younger child with spastic hemiplegia but on its own may have little impact on gait or function. Gait is more likely to improve if an ankle foot orthosis is used to manage the deficiency in ankle dorsiflexor function.

Focal vs. generalized spasticity

In considering spasticity management options, a primary issue is whether the spasticity is focal, regional or generalized (Boyd and Graham, 1997; Graham \textit{et al.}, 2000; Gormley \textit{et al.}, 2001). Oral medications are absorbed and act systemically and equally on all muscle groups. Selective dorsal rhizotomy (SDR) affects mainly the lower limbs although beneficial changes are sometimes found in the upper limbs (Loewen \textit{et al.}, 1998). Intrathecal baclofen (ITB) acts mainly on the lower limbs, although the effects on the upper limbs and trunk can be varied according to the siting of the catheter tip and the concentration and rate of delivery of the drug (Albright \textit{et al.}, 1995; Albright, 1996; Muhonen, 2001). Intramuscular injection of botulinum toxin type A (BTX-A) to the gastrocnemius is a focal intervention. The BTX-A heavy chains bind quickly and irreversibly to the cholinergic nerve terminals, so that there is little spread to neighbouring muscles (Dolly \textit{et al.}, 1984; Graham \textit{et al.}, 2000). Fine wire EMG studies confirm changes in muscles remote to the injection site, but these effects are usually of little consequence.

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There is no precise definition as to what constitutes focal, regional and generalized spasticity. We have previously suggested that focal intervention with BTX-A should be restricted to four large muscle groups at one time because of concerns about systemic spread and toxicity (Boyd and Graham, 1997; Graham et al., 2000). Others have used higher doses and injected more muscles with benefit and few side-effects (Molenaers et al., 1999). It is strongly recommended that multilevel injections and high doses be used only by experienced clinicians. Recommended doses and dilutions for the management of spasticity in children with cerebral palsy have been previously published (Graham et al., 2000).

Selective dorsal rhizotomy is usually reserved for a highly selected group of children with spastic diplegia who have significant lower limb spasticity and good underlying strength and selective motor control (Peacock and Arens, 1982). Ideally, SDR should be undertaken before there are fixed contractures or the child may require an extensive deformity correction programme, in addition to spasticity management. SDR requires an intensive rehabilitation programme and some children may be unable to cope because of cognitive or behavioural problems. Functional outcomes of SDR were studied in three randomized trials with the control group receiving physical therapy (PT) only. Two of the three studies confirmed functional benefits from the addition of rhizotomy to a programme of physical therapy, but the third and largest found an equal improvement in the PT only compared to the SDR and PT group (Steinbok et al., 1997; McLaughlin et al., 1998; Wright et al., 1998). A recent meta-analysis of the three trials confirmed a functional benefit, as judged by the Gross Motor Function Measure (McLaughlin et al., 2000). In all three studies and in numerous uncontrolled studies, SDR has been shown to permanently reduce spasticity and to improve gait (Vaughan et al., 1991, 1998; Park and Owen, 1992; Thomas et al., 1996). There are some reports that indicate increased SDR-associated musculoskeletal deformities including scoliosis, lordosis, hip migration and foot deformities (Green, 1991).

Intrathecal baclofen is an increasingly widely used option for spasticity management in cerebral palsy and the criteria are less strict than for SDR. Because the dose of baclofen can be adjusted or even discontinued, ITB can be offered as a fully reversible intervention, to more severely involved children, including those with severe spastic quadriplegia or generalized dystonia (Krach, 1999; Gormley et al., 2001). After ITB, there is good evidence for reduced spasticity, improved joint range of motion and improved comfort, and less robust evidence for improved function (Albright et al., 1995; Albright, 1996). Improvements in gait have been reported on subjective criteria, but have not been confirmed using motion analysis (Gerszten et al., 1998; Piccinini et al., 1999; Motta et al., 2000).

The most widely used interventions in spastic cerebral palsy are therefore injections of BTX-A for focal spasticity and orthopaedic surgery for fixed deformities. A small number of children who satisfy stringent criteria may benefit from SDR. The indications for ITB therapy are evolving and may well expand with further study (Krach, 1999; Gormley et al., 2001).

**Postural and gait patterns: management algorithm (Figures 1 and 2)**

Although gait and posture are variable in children who have cerebral palsy, there are certain patterns that can be identified and recognized by clinicians using a variety of tools. In general, spastic motor patterns are reasonably consistent from stride to stride and from day to day (Gage, 1991). However, over the longer term, there are often changes with age and as the result of intervention. The most common change with age is from a pattern of ‘toe walking’ (because the gastrocnemius is dominant) to a pattern of increasing hip and knee flexion and eventually, ‘crouch gait’ with hip and knee flexion and ankle dorsiflexion (Rab, 1991). The transition from equinus gait to crouch gait is seen in many children with severe spastic diplegia or spastic quadriplegia as a normal progression, but it may be accelerated by an injudicious isolated lengthening of the heel cord (Sutherland and Cooper, 1978; Borton et al., 2001). Variations in gait patterns related to the topographical type of cerebral palsy are best seen in the contrast between unilateral spastic cerebral palsy (spastic hemiplegia) and bilateral spastic cerebral palsy (spastic diplegia and spastic quadriplegia). Although there are at least four types of gait patterns seen in hemiplegia, in general, there is more involvement distally and therefore true equinus is the basis of the most common patterns (Winters et al., 1987). In diplegia and quadriplegia, more proximal involvement is typical and therefore apparent equinus and crouch gait are frequently seen.

Gait patterns can only be precisely identified and accurately categorized by the use of instrumented motion analysis (Gage, 1991). The purpose of this article is to draw attention to common postural patterns that can be recognized by a combination of careful inspection of gait and clinical examination. Observational gait analysis can be greatly enhanced by the use of two-dimensional video recording, especially if...
there is the facility for slow motion replay (Boyd and Graham, 1999b). These common patterns are more accurately referred to as postural patterns rather than gait patterns. Although the pattern will vary according to the precise part of the gait cycle, the postural patterns referred to here are usually most clearly seen during the middle and end of the stance phase of gait. Given that the focus of this classification are postural patterns caused by spasticity or contracture of the principal sagittal plane motors, the classification is largely based on sagittal plane observation of gait. However, reference to the coronal and transverse planes are necessary in Type 4 hemiplegia and also in diplegia/quadriplegia.

Introduction

The most widely accepted classification of gait in spastic hemiplegia is that reported by Winters et al. (1987). They subdivided hemiplegia into four gait patterns based on sagittal plane kinematics. The classification has direct relevance to understanding the gait pattern and management. Given that spasticity in hemiplegia is unilateral, management with SDR and ITB is not appropriate, but BTX-A is very useful for spasticity, and orthopaedic surgery for fixed deformity.

Figure 1 Gait patterns and management algorithm spastic hemiplegia. © Rodda and Graham, Royal Children’s Hospital, Melbourne, Australia.

Figure 2 Gait patterns and management algorithm spastic diplegia. © Rodda and Graham, Royal Children’s Hospital, Melbourne, Australia.
**Type 1 hemiplegia**

In Type 1 hemiplegia there is a ‘drop foot’ which is noted most clearly in the swing phase of gait, due to inability to selectively control the ankle dorsiflexors during this part of the gait cycle. There is no calf contracture and therefore during stance phase, ankle dorsiflexion is relatively normal. In our experience, this gait pattern is rare, unless there has already been a calf lengthening procedure. The only management required is a leaf spring ankle foot orthosis (AFO). Spasticity management and contracture surgery are clearly not required.

**Management summary**
- Spasticity management: Not applicable.
- Contracture management: Not applicable.
- Orthotic management: Leaf spring or hinged AFO.

**Type 2 hemiplegia**

- 2a Equinus plus neutral knee and extended hip.
- 2b Equinus plus recurvatum knee and extended hip.

Type 2 hemiplegia is by far the most common type in clinical practice. True equinus is noted in the stance phase of gait because of spasticity and/or contracture of the gastroc-soleus muscles. There is a variable degree of drop foot in swing because of impaired function in tibialis anterior and the ankle dorsiflexors. A pattern of true equinus is seen, with the ankle in the plantar flexion range through most of the stance phase. The plantar flexion-knee extension couple is over active and the knee may adopt a position of extension or recurvatum (Boyd and Graham, 1997).

Gastroc-soleus spasticity can be managed by intramuscular botulinum toxin type A injections, especially in the younger child (Cosgrove et al., 1994; Koman et al., 1994, 2000; Corry et al., 1998; Flett et al., 1999). If there is a mild contracture, supplemental casting can be very effective (Boyd and Graham, 1997; Molenaers et al., 1999). The majority of children will also require orthotic support, both to control the tendency to ‘drop foot’ during the swing phase of gait but also to augment and prolong the response to botulinum toxin type A chemodenervation.

Once a significant fixed contracture develops, lengthening of the gastrocnemius and soleus may be indicated. Type 2 hemiplegia with a fixed contracture of the gastroc-soleus constitutes the only indication for isolated lengthening of the tendo achillis (Graham and Fixsen, 1988; Borton et al., 2001). If the knee is fully extended or in recurvatum, then a hinged AFO with an appropriate plantar flexion stop is the most appropriate choice of orthosis.

**Management summary**
- Spasticity management: BTX-A dose 4–8 U/kg, divided between 2 and 4 sites.
- Contracture management: Tendo Achilles lengthening, Strayer calf lengthening, if the contracture is confined to the gastrocnemius.
- Orthotic management: Hinged AFO or leaf spring AFO.

Equinovalgus deformities can be managed by concomitant injection of tibialis posterior at the time of calf injection or by split transfer of tibialis posterior (Green, 1991; Boyd and Graham, 1997; O’Byrne et al., 1997). Equinovalgus deformities can be managed initially by calf injection and an AFO. Calf injection often improves AFO tolerance and efficacy. Older children with progressive valgus deformities are likely to become brace intolerant and require bony surgery such as os calcis lengthening or subtalar fusion (Miller et al., 1995).

**Type 3 hemiplegia**

Type 3 hemiplegia is characterized by gastroc-soleus spasticity or contracture, impaired ankle dorsiflexion in swing and a flexed, ‘stiff knee gait’ as the result of hamstring/quadriceps cocontraction.

Management may consist of botulinum toxin type A injections for gastroc-soleus spasticity and at a later stage, muscle tendon lengthening for gastroc-soleus contracture. In addition, lengthening of the medial hamstrings with transfer of rectus femoris to the semitendinosus is the most effective long-term solution for the stiff knee (Sutherland et al., 1990; Chambers et al., 1998). A solid or hinged AFO may also be helpful; the choice should be according to the integrity of the ‘plantar-flexion, knee-extension couple’.

**Management summary**
- Spasticity management: BTX-A injections to the calf and hamstrings, dose 4 U/kg per muscle, 8 U/kg body weight. BTX-A injections to rectus femoris have been tried with little clinical or motion analysis evidence of success.
- Contracture management: tendo achillis lengthening combined with lengthening of the medial hamstrings and transfer of the rectus femoris to the gracilis or semitendinosus.
- Orthotic management: solid or hinged AFO, according to the pre and post intervention integrity of the plantar-flexion, knee-extension (PF–KE) couple.
Type 4 hemiplegia (Figure 3)
In Type 4 hemiplegia there is much more marked proximal involvement and the pattern is similar to that seen in spastic diplegia. However, because involvement is unilateral, there will be marked asymmetry, including pelvic retraction. In the sagittal plane there is equinus, a flexed stiff knee, a flexed hip and an anterior pelvic tilt. In the coronal plane, there is hip adduction and in the transverse plane, internal rotation. Management is similar to Type 2 and Type 3 hemiplegia, in respect of the distal problems. However, there is a high incidence of hip subluxation and careful radiographic examination of the hip is important (Simmons et al., 1998). The adducted and internally rotated hip will usually require lengthening of the adductors and an external rotation osteotomy of the femur. Failure to address the hip adduction and hip internal rotation will usually mean that any distally focused intervention will fail and the overall outcome will be poor.

Management summary
- **Spasticity management:** multilevel injections of BTX-A, including the calf and hamstrings, sometimes the hip adductors and hip flexors, according to the clinical indications and experience of the injector. Dose 4 U/kg/muscle, total dose 12–16 U/kg body weight.
- **Contracture/deformity management:** lengthening of the calf, medial hamstrings (with rectus femoris transfer when indicated), hip adductors and iliopsoas. External rotation osteotomy of the femur;
- **Orthotic management:** ground reaction (Saltiel) AFO, solid AFO or hinged AFO, according to the integrity of the PF–KE couple.

Common postural/gait patterns spastic diplegia/quadriceps: a management algorithm (Figure 2)
The patterns of knee involvement in spastic diplegia described by Sutherland and Davids are an excellent basis for classifying postural and gait patterns in spastic diplegia (Sutherland and Davids, 1993). The following classification draws heavily on their work but has some important differences:
- The sagittal plane is considered as a whole; i.e. pelvis, knee, and ankle;
- The stiff-knee pattern may be present as part of the other sagittal plane patterns and is therefore not included as a separate entity;
- The classification starts with equinus/calf dominance and ends with crouch/hamstring/hip flexor dominance; and;
- The classification follows the commonly observed changes with age and intervention.

Torsional deformities of the long bones and foot deformities are frequently found in spastic diplegia, in association with musculo-tendinous contractures. These are collectively referred to as ‘lever arm disease’ (Gage, 1991). Muscles work most effectively on rigid bony levers, which are in the line of gait progression. Maldirected or bent levers reduce the effectiveness of muscle action. The most common bony problems are medial femoral torsion, lateral tibial torsion and mid

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**Figure 3** Gage Type IV hemiplegia: this boy has a severe left-sided spastic hemiplegia, Winters and Gage Type IV. He has a fixed equinus at the ankle, a flexed knee, a flexed adducted and internally rotated hip. His motion analysis showed that all of these deformities had the expected effect on gait and that the knee was both flexed and very stiff throughout the gait cycle. His management consisted of lengthening of the tendo Achillis, lengthening of the medial hamstrings and transfer of rectus femoris to semitendinosus, lengthening of adductor longus, lengthening of psoas at the brim of the pelvis and a left proximal femoral derotation osteotomy. Postoperatively he was managed in a solid AFO for the first 6 months and after his gastroc-soleus regained strength, a hinged AFO allowed a more normal gait pattern.
foot breaching, with foot valgus and abduction. Rotational osteotomies and foot stabilization surgery are often required, in association with the spasticity and contracture management.

The PF–KE couple is a critical biomechanical concept in understanding interrelationships between the foot-ankle and knee levels. A stable foot in the line of progression, when acted on by a competent gastrosoleus, controls the progression of the tibia over the planted foot during the stance phase of gait. The ground reaction vector is directed anterior to the knee joint, providing an extensor moment at the knee and reducing demands on the quadriceps. A weak or overlengthened gastrosoleus and a maldirected, breached foot, may contribute to crouch gait (Figure 4a,b). The integrity of the PF–KE couple can be improved by correcting foot deformity, correcting external tibial torsion and using a ground reaction ankle foot orthosis (Gage, 1991).

1. True Equinus

When the younger child with diplegia begins to walk with or without assistance, calf spasticity is frequently dominant resulting in a ‘true equinus’ gait with the ankle in plantar flexion throughout stance and the hips and knees extended. True equinus may be hidden by the development of recurvatum at the knee. The patient can stand with the foot flat and the knee in recurvatum (Miller et al., 1995). The equinus is real, but hidden. Botulinum toxin type A can be very effective for gastrocnemius spasticity, to improve stability in stance. A more stable base of support can be enhanced by the use of hinged AFO’s (Buckon et al., 2001). A few children with diplegia remain with a true equinus pattern throughout childhood and, if they develop fixed contracture, may eventually benefit from isolated gastrocnemius lengthening. The persistence of this pattern is unusual and seen in only a small minority of children with diplegia. It is more common in children with spasticity, secondary to spinal lesions (e.g. hereditary spastic paraparesis).

Management summary
• Spasticity management: BTX-A injections to the calf; 4 U/kg each side, 8 U/kg total.
• Contracture management: lengthening of the gastrocnemius.
• Orthotic management: solid or hinged AFO, according to the integrity of the PF-KE couple.

2. Jump Gait (with or without stiff knee) (Figure 5a,b,c,d)

The jump gait pattern is very commonly seen in children with diplegia, who have more proximal involvement, with spasticity of the hamstrings and hip flexors in addition to calf spasticity. The ankle is in equinus, the knee and hip are in flexion, there is an anterior pelvic tilt and an increased lumbar lordosis. There is often a stiff knee, because of rectus femoris activity in the swing phase of gait. This is the description given by Sutherland and Davids, although Miller et al. describe the ankle as being neutral in jump gait (Sutherland and Davids, 1993; Miller et al., 1995). We prefer the former description and to use the term ‘apparent equinus’ for flexed hip, flexed knee and plantigrade ankle/foot (Boyd et al., 1999a).
In younger children, this pattern can be managed effectively by botulinum toxin type A injections to the gastrocnemius and hamstrings and the provision of an AFO. A more extensive multilevel approach, with BTX-A injections may also be appropriate, but is not for the inexperienced practitioner (Molenaers et al., 1999). SDR may be the best solution to achieve a permanent reduction in tone, provided the appropriate indications are observed (Peacock and Arens, 1982; Gormley et al., 2001).

In older children musculotendinous lengthening of the gastrocnemius, hamstrings and iliopsoas may be indicated with transfer of the rectus femoris to semitendinosus for co-contraction at the knee (Gage, 1991; Molenaers et al., 2001). The jump knee pattern and stiff knee pattern described by Sutherland and Davids, in our experience, frequently coexist.

**Management summary**
- **Spasticity management:** in younger/less involved children BTX-A injections to the calf and hamstrings. Multilevel injections of BTX-A may be useful. Selective dorsal rhizotomy may be the optimum choice for small group of children, following previously reported selection criteria.
- **Contracture/deformity management:** single event multilevel surgery, addressing all contractures and lever arm dysfunction.
• Orthotic management: ground reaction (Saltiel) AFO, solid AFO or hinged AFO according to the integrity of the PF–KE couple.

Apparent equinus (with or without stiff knee) (Figure 6a,b)

As the child gets older and heavier, a number of changes may occur which may render the calf muscle and the PE–KE couple less competent. Equinus may gradually decrease as hip and knee flexion increase (Rab, 1991; Sutherland and Davids, 1993; Molenaers et al., 2001). There is frequently a stage of ‘apparent equinus’ where the child is still noted to be walking on the toes and simple observational gait analysis may mistakenly conclude that the equinus is real, when it is in fact apparent (Miller et al., 1995; Boyd and Graham, 1997). Sagittal plane kinematics will show that the ankle has a normal range of dorsiflexion but the hip and knee are in excessive flexion throughout the stance phase of gait. At this stage, weakening the gastrocnemius by injections of botulinum toxin type A or lengthening of the gastrocnemius muscle will only provoke a crouch gait and result in impaired function (Sutherland and Cooper, 1978; Borton et al., 2001). Management should be focused on the proximal levels, where the hamstrings and iliopsoas may benefit from spasticity treatment or musculotendinous lengthening (Corry et al., 1999). Redirection of the ground reaction vector in front of the knee can best be achieved by the use of a solid or a ground reaction AFO.

Management summary
• Spasticity management: in younger/less involved children, BTX-A injections to the hamstrings and iliopsoas.
• Contracture/deformity management: single event multilevel surgery, addressing all contractures and lever arm problems.
• Orthotic management: ground reaction (Saltiel) AFO, solid AFO or hinged AFO according to the integrity of the PF–KE couple.

Crouch gait (with or without stiff knee gait) (Figure 7)

Crouch gait is defined as excessive dorsiflexion or calcaneus at the ankle in combination with excessive flexion at the knee and hip. This pattern is part of the natural history of the gait disorder in children with more severe diplegia and in the majority of children with spastic quadriplegia. Regrettably, the commonest cause of crouch gait in children with spastic diplegia is isolated lengthening of the heel cord in the younger child (Sutherland and Cooper, 1978; Borton et al., 2001). Once the heel cord has been lengthened, if the spasticity/contracture of the hamstrings and iliopsoas has not been recognized and is not managed adequately, there will be a rapid increase in hip and knee flexion (Miller et al., 1995). The result is an unattractive, energy expensive gait pattern, followed by anterior knee pain and patellar pathology in adolescence. Frequent BTX-A injections to the gastroc-soleus, without addressing the hamstrings/iliopsoas or providing adequate orthotic support can also lead to

![Figure 6](image) (a) This 4-year-old girl stands on her toes with her heels off the ground. There is also increased hip and knee flexion. This is apparent equinus. The foot is at 90° to the leg, the heel is off the ground because of the hip and knee flexion. (b) In addition to the contractures of the iliopsoas and hamstrings she has an intoed stance and gait because of bilateral medial femoral torsion, another type of lever arm dysfunction.
progressive crouch gait. Crouch gait is always difficult to manage and usually requires lengthening of the hamstrings and iliopsoas, a ground reaction AFO and adequate correction of bony problems such as medial femoral torsion, lateral tibial torsion and stabilization of the foot. By the time it is recognized, the musculoskeletal pathology is usually too advanced to respond to intramuscular BTX-A.

Management summary
- **Spasticity management**: in younger/less involved children BTX-A injections to the hamstrings and hip flexors.
- **Contracture/deformity management**: single event multilevel surgery, addressing all contractures, bony torsional abnormalities and joint instability.

- **Orthotic management**: long-term use of a ground reaction (Saltiel) AFO until the integrity of the PF–KE couple is clearly re-established.

**Coronal and transverse plane issues**

The simple classification above concentrates on observation and examination of the sagittal plane motors, the gastrocnemius, hamstrings-rectus femoris and iliopsoas. However, the majority of children with spastic diplegia have also coronal plane and transverse plane problems. In the coronal plane, spasticity or contracture of hip adductors may be evident, as well as such issues as limb length discrepancy and hip subluxation.

The transverse plane is the most difficult to appreciate on visual inspection and three-dimensional gait analysis is always required for a full evaluation (Gage, 1991). In the transverse plane the common problems are pelvic rotation, medial femoral torsion, lateral tibial torsion, and foot deformity. Management of sagittal plane problems such as spasticity or contracture will usually fail if there are significant transverse plane problems that are not dealt with. The use of twister cables attached to an AFO may help the younger child for a short period of time but these orthoses are neither particularly effective nor well tolerated. The definitive answer to lever arm disease is bony surgery.

With optimal management of spasticity and muscle length in early childhood, the requirement for muscle-tendon surgery is decreasing but the requirement for bony surgery remains unchanged. Fortunately, the outcome of bony surgery in cerebral palsy is in general more predictable, more durable and more effective than soft tissue surgery.

**Summary and conclusions**

The postural and gait patterns in this algorithm can be most accurately identified by using a combination of clinical examination, video recording of gait and instrumented gait analysis. The critical role of clinical examination in the assessment of dynamic and fixed contracture is outside the scope of this article but has been covered comprehensively elsewhere (Boyd et al., 1998).

When instrumented gait analysis is unavailable, pattern recognition may help inform clinicians where to look for associated spasticity or contracture and not to focus on a single problem or anatomic level. The doses of botulinum toxin used by the author are found in detail in previous publications and need not be repeated here (Cosgrove et al., 1994; Corry et al., 1998; Graham et al., 2000). The orthotic recommendations...
are necessarily general rather than specific. This should not be misconstrued to imply that orthotic prescription is unimportant. Appropriate orthotic use is critical to the magnitude and duration of response to spasticity and contracture management. The principal issue is that the degree of orthotic support is predicated on the integrity of the PE–KE couple before intervention. The PF–KE couple is invariably altered and is frequently unstable after intervention. Thus, orthoses must be regularly evaluated as an integral part of spasticity management in children with cerebral palsy. Despite some excellent recent studies, the precise indications for the posterior leaf spring AFO, hinged AFO, solid AFO and ground reaction or Saltiel AFO, have not been fully established (Harrington et al., 1984; Ounpuu et al., 1996; Abel et al., 1998; Buckon et al., 2001).

Many questions remain unanswered and there is ample scope for more clinical trials with objective outcome measures. Many of the existing studies have small numbers, short-term follow up and the outcome measures are neither comprehensive nor sufficiently objective.

References


McLaughlin JF, Bjornson KF, Astley SJ et al. (1998). Selective dorsal rhizotomy: efficacy and safety in an


