From Stable Standing to Rock and Roll Walking (Part 1)
The Importance of Alignment, Proportion and Profiles
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Introduction
Orthoses are one of the most commonly used interventions with children. All interventions should be prescribed optimally if they are to achieve the desired outcomes in the required domains of the International Classification of Function Disability and Health, Children and Youth Version (ICF-CY) (World Health Organisation, 2007; Majnemer 2012). To prescribe orthotic interventions optimally they need to be determined and described in a manner analogous to drug interventions (Morris and Condie 2009). Firstly, by the name of the orthosis, as defined by the International Standards Organisation (ISO 8549-3 1989); secondly, by the dosage, which in the case of orthoses will include the design, alignments, proportions and profiles of the prescription; and finally by the frequency of administration, which is a description of the activities for which the orthosis will be used and for how long it will be worn each day or week.

Many aspects of orthotic provision are defined by the International Standards Organisation. ISO 8549-1:1989 gives the following definitions:

ORTHOTICS is the science and art involved in treating patients by the use of an orthosis.

AN ORTHOSIS OR ORTHOTIC DEVICE is an externally applied device used to modify the structural and functional characteristics of the neuromuscular and skeletal systems.

AN ANKLE FOOT ORTHOSIS (AFO) is one that encompasses the ankle joint and the whole or part of the foot. This definition includes a range of AFO designs including: fixed ankle designs where the ankle joint alignment is set at one angle within the AFO; flexible, hinged or jointed AFO designs which allow full or a limited range of movement into dorsiflexion or plantarflexion; and supramalleolar orthoses. Integral to the function of any AFO is the design of the footwear that is worn with the AFO, so the overall orthosis is now called an AFO Footwear Combination (AFOFC), to give equal emphasis to both parts of the prescription.

Describing the features of orthoses in all three planes is essential but this paper concentrates on some key sagittal plane features of AFOFC prescriptions. These will include principal alignments, principal proportions and principal footwear design features, which are pitch, stiffness and profiles.

There has been much debate in the literature about which AFOFC designs to use. The optimum AFOFC design should be selected according to desired outcomes for the patient. Clinical algorithms can help determine optimal designs and several are available. A clinical algorithm for designing, aligning and tuning AFOFCs based on shank kinematics is published elsewhere (Owen 2005; Owen 2010). An algorithm for determining the optimum Angle of the Ankle in the AFO (AA-AFO) in a fixed ankle AFOFC (Owen 2005; Owen 2010) is reproduced in this paper. An algorithm for determining whether a dorsiflexion free AFOFC is optimal (Owen, 2013) is also presented here. In order to become confident in using the latter two algorithms it is easier to start with determining the alignments of fixed ankle AFOs and then look at the criteria for dorsiflexion-free AFO designs.

Principal Alignments
Definitions of alignments are given in ISO 8551:2003

ALIGNMENT - establishment of the position in space of the components of the prosthesis or orthosis relative to each other and the patient.

ALIGNMENT OF A JOINT - the spatial relationship between the skeletal segments, which comprise the joint.

ALIGNMENT OF A SKELETAL SEGMENT - the spatial relationship between the ends of a segment.

There are many alignments in all three planes within an AFOFC. Two principal sagittal alignments are the Angle of the Ankle in the AFO (AA-AFO) and the Shank to Vertical Angle of the AFOFC (SVA-AFOFC) (Owen, 2002; Owen, 2004; Owen, 2005; Owen, 2010; Bowers and Roos, 2009; Ridgewell, 2010; Eddison and Chockalingam, 2013). Figure 1 illustrates the nine possible configurations of these two alignments (Owen 2004, 2010).
Until recently these two alignments have been largely confused or ignored in orthotic science (Owen, 2004; Ridgewell et al, 2010). This may be because similar language was used to describe these alignments, the terms dorsiflexion, plantigrade and plantarflexion being applied to both. Reviews of the literature reveal that only a very small proportion of publications from the 1990s to present have differentiated between the two alignments, included information about alignments used and described how those alignments were optimised (Owen, 2004; Bowers and Ross, 2009; Ridgewell et al, 2010; Edisson and Chockalingam, 2013). However optimising these alignments alone would not necessarily produce optimum kinematics and kinetics in standing, stepping or gait. At our centre, which uses a video vector gait laboratory to evaluate the effects of orthoses, we have found that for this to occur all the other alignments, designs, proportions and profiles of the AFOFC in the sagittal plane need to be optimum, as do those in the coronal and transverse plane. MTU length may be available in the definition, for the ankle joint alignment when the measure is taken.

Optimising the AA-AFO and SVA-AFOFC is essential to any orthotic prescription (Owen, 2004; Owen, 2010; Bowers and Ross, 2009; Ridgewell et al, 2010; Edisson and Chockalingam, 2013). These reviews acknowledged that differentiating between and stating both alignments, and also how they were acknowledged that differentiating between the two alignments, included information about alignments used and described how those alignments were optimised (Owen, 2004; Bowers and Ross, 2009; Ridgewell et al, 2010; Edisson and Chockalingam, 2013).

Determining the Optimal AA-AFO

The sagittal AA-AFO describes the alignment of the foot segment relative to the shank segment within the AFO. The optimal sagittal AA-AFO should be determined for each leg of each patient. To be able to do this we need to be conversant with the factors that might help us best determine this angle, which are the length and stiffness of musculoskeletal units (MTUs) and the desired triplanar bony alignment of the foot (Owen, 2005). In addition leg lengths come into the consideration and also the activity for which they will be used and whether that activity requires knee extension.

Calf MTU length

AFOFCs are most often used in circumstances when the knee will be extended, in standing or walking, so the length and stiffness of the gastrocnemius should be taken into account. Gastrocnemius is a tri-rected MTU crossing the knee, ankle and subtalar joints. Setting the AA-AFO without due regard for the available gastrocnemius length will result in insufficient length of gastrocnemius being available to allow knee extension, or pronation/supination of the foot will occur to release gastrocnemius length, or both these scenarios will occur. None of these are desirable as they will compromise gait, prevent optimum development of the bony alignment of the foot and prevent the MTU being used at optimal length. If AFOFCs are only being used with flexed knees, an assessment of soleus length alone is sufficient.

MTU stiffness

MTU stiffness will also determine if knees will extend or bony alignment of the foot will be compromised (Sanger et al, 2003; Lieber, 2010). On clinical examination, MTU length may be available in the definition, for the ankle joint alignment when the measure is taken.

Bony alignment of the foot

It is essential that children’s feet develop to acquire optimum triplanar bony alignment. All feet, as the knee is plantarflexed, will ‘escape’ to triplanar pronation or supination, in order to achieve greater degrees of dorsiflexion, if there is insufficient MTU length to achieve reverse plantarflexion. This dominant view has prevailed in the literature for many years (Nuzzo, 1980, 1983, 1986) but the stiffness or hypertonia may be such that the AA-AFO has to be adjusted to obtain knee extension and/or maintain bony alignment of the foot. As we know, hypertonia is speed dependent so when AFOs will be in use, taking hypertonia into account is very important. Even when walking slowly joint movements and consequent stretch on MTUs can be fast.

Fixed dorsiflexed ankles

Some children with myelomeningocele, and other rare disorders, may have fixed dorsiflexions angles at the ankles. If this is the case then this must be taken into account when determining the AA-AFO.

The algorithm for determining the optimum AA-AFO (Figure 2) gives consideration to all these factors and any risks associated with using chosen alignments (Owen 2005; Owen, 2010). In addition there are opportunities for interventions if required throughout the algorithm. An optimally designed and aligned AFOFC may be the chosen intervention to increase MTU length, reduce MTU stiffness and develop optimal bony alignment of the foot. To be able to determine whether intervention is needed to increase calf MTU length, metatarsal MTU lengths for age are required. Reimers et al (1995) documented the length of the triceps surae MTU, measured as the angle of the lateral border of the calcaneus to the axis of the lower leg. They measured ‘with the knee extended and the hindfoot in a neutral position and the foot/forefoot sufficiently adducted to bring the talus into a neutral position relative to the calcaneus’. They measured 279 typically developing children aged 3 to 17 years. The proportion of children with one or both MTU lengths surae that could only be brought to plantargrade rose from 24% to 62% between the ages of 3 and 17 years. In 13% of adolescents one or both feet could only achieve 5° plantarflexion. They also found an association between short triceps surae and flat feet in the older group.

If the algorithm for determining the AA-AFO is followed, a plantarflexed AA-AFO is the only recommendation when patients have a short or excessively stiff gastrocnemius or a foot that will only align in neutral pronation/supination when the ankle is plantarflexed. Any alternative would compromise the triplanar bony alignment of the foot or prevent the knee from extending. Compromising the foot has adverse consequences for the development of normal bony structure of the foot, comfort and skin viability. Also if the bony alignment of the foot is compromised the calf MTUs will not be optimally plantarflexed, and foot progression angles may become excessively rotated, leading to reduced toe levers and adverse kinematics and kinetics at the knee and hip.

Despite all these good reasons to use a plantarflexed AA-AFO its use remains controversial. It is essentially a last resort for patients when all else has failed. But the stiffness or hypertonia may be such that the AA-AFO has to be adjusted to obtain knee extension and/or maintain bony alignment of the foot. As we know, hypertonia is speed dependent so when AFOs will be in use, taking hypertonia into account is very important. Even when walking slowly joint movements and consequent stretch on MTUs can be fast.

ANGULAR SIGNIFICANCE OF THE ANKLE-FOOT ORTHOSIS

The angle between the line of the shank relative to the line of the foot. The line of the foot is defined as the line between the base of the heel and the most inferior point of the foot under the fifth metatarsal head. It is described in degrees of plantarflexion, dorsiflexion or as plantigrade (Owen, 2004).

SHANK TO VERTICAL ANGLE OF THE AFO

FOOTWEAR COMBINATION (SVA-AFOFC) - the angle of the line of the shank relative to the vertical when standing in the AFOFC with weight equally distributed between the heel and forefoot. When measured in the sagittal plane the SVA is described as inclines if the shank is leaning forward of the vertical and reclined if it is leaning backwards from the vertical. It is described in degrees from the vertical, 0° describing the vertical (Owen, 2004).

These definitions refer to AFOFCs with fixed ankle designs. The SVA of a flexible or hinged AFOFC can be measured but as the SVA can vary, because of the variability of ankle joint alignment possible in these designs, additional specification is required in the definition, for the ankle joint alignment when the measure is taken.

Optimising the AA-AFO and SVA-AFOFC is essential to any orthotic prescription (Owen, 2004; Owen, 2010; Bowers and Ross, 2009; Ridgewell et al, 2010; Edisson and Chockalingam, 2013). However optimising these alignments alone would not necessarily produce optimum kinematics and kinetics in standing, stepping or gait. At our centre, which uses a video vector gait laboratory to evaluate the effects of orthoses, we have found that for this to occur all the other alignments, designs, proportions and profiles of the AFOFC in the sagittal plane need to be optimum, as do those in the coronal and transverse plane. MTU length may be available in the definition, for the ankle joint alignment when the measure is taken.
Until recently these two alignments have been largely confused or ignored in orthotic science (Owen, 2004; Ridgewell et al, 2010). This may be because similar language was used to describe these alignments, the terms dorsiflexion, plantigrade and plantarflexion being applied to both. Reviews of the literature reveal that only a very small proportion of publications from the 1990s to present have differentiated between the two alignments, including information about alignments used and described how those alignments were optimised (Owen, 2004; Bowers and Ross, 2009; Ridgewell et al, 2010; Eddison and Chockalingam, 2013). However optimising these alignments alone would not necessarily produce optimum kinematics and kinetics in standing, stepping or gait. At our centre, which uses a video vector gait laboratory to evaluate the effects of orthoses, we have found that for this to occur all the other alignments, designs, proportions and profiles of the AFO in the sagittal plane need to be optimum, as do those in the coronal and transverse plane. MTU length may be available in the definition, for the ankle joint angle when the measure is taken.

Optimising the AA-AFO and SVA-AFO is essential to any orthotic prescription (Owen, 2004; Owen, 2010; Bowers and Ross, 2009; Ridgewell et al, 2010; Eddison and Chockalingam, 2013). These reviews acknowledged that differentiating between and sating both alignments, and also how they were optimised, is essential for both clinical practice and future research trials.

New terminology has recently emerged and the following terms and definitions are now accepted internationally (Owen, 2004; Meadowos et al, 2008; Owen, 2010; Ridgewell et al, 2010; Eddison and Chockalingam, 2013). These definitions refer to AFOCs with fixed ankle designs. The SVA of a flexible or hinged AFOC can be measured but as the SVA can vary, because of the variability of ankle joint alignment possible in these designs, an additional specification is required in the definition, for the ankle joint angle when the measure is taken.

Determining the Optimal AA-AFO

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Calf MTU length

AFOCs are most often used in circumstances when the knee will be extended, in standing or walking, so the length and stiffness of the gastrocnemius should be taken into account. Gastrocnemius is a tri-jointed MTU crossing the knee, ankle and subtalar joints. Setting the AA-AFO without due regard for the available gastrocnemius length will result in insufficient length of gastrocnemius being available to allow knee extension, or pronation/supination of the foot to occur to release gastrocnemius length, or both these scenarios will occur. None of these are desirable as they will compromise gait, prevent optimum development of the bony alignment of the foot and prevent the MTU being used at optimal length. If AFOCs are only being used with flexed knees, an assessment of soleus length alone is sufficient.

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The determination of optimum AA-AFO is largely made from clinical examination, which is not the case for determining the optimal SVA alignment of an AFOFC. This is made by undertaking trials of the activity for which the AFOFC is intended to be used (Owen, 2004; Owen, 2010; Eddisson and Chockalingam, 2013).

**Figure 2** - Clinical algorithm for determining the sagittal angle of the ankle in an ankle-foot orthosis footwear combination (Owen 2005; Owen, 2010).

**Figure 3** - Shank kinematics dictate proximal segment kinematics and GRF alignment (Owen, 2004; Owen, 2010).

**Determining the Optimal SVA-AFOFC**

The optimal SVA-AFOFC should be determined for each leg and the activities for which the AFOFC will be used. The SVA-AFOFC used for weight bearing activities has been defined. Determining the optimal SVA is done by trials of the required activities. A number of terms have been used in the literature in regard to optimising, tuning and aligning orthoses. To establish clarity definitions are required.

**TUNING** - the dictionary definition of the word ‘tuning’ is ‘to adjust for optimum performance’, such as tuning a car engine or a musical instrument. A definition of tuning an AFOFC can be derived from this.

**TUNING AN AFOFC** - the process whereby fine adjustments are made to the design and alignment of the AFOFC in order to optimise its performance during a particular activity such as sitting, standing, transferring, stepping, walking, running, climbing stairs (Owen, 2010; Eddisson and Chockalingam, 2013).

**BIOMECHANICAL OPTIMISATION** - the process of designing, aligning and tuning an AFOFC in order to optimise its performance (Owen, 2010; Eddisson and Chockalingam, 2013).

ISO 8549-1(1989) gives definitions of three terms commonly used in prosthetic science but, until recently less used in orthotic science.

**BENCH ASSEMBLY AND ALIGNMENT** - assembly and alignment of the components of a prosthesis or orthosis in accordance with the characteristics and with previously acquired data regarding the patient.

**STATIC ALIGNMENT** - process whereby the bench alignment is refined while the prosthesis or orthosis is being worn by the stationary patient.

**DYNAMIC ALIGNMENT** - process whereby the alignment of the prosthesis or orthosis is optimised by using observations of the movement pattern of the patient.

Static alignment is therefore the process of setting or resetting the SVA of the AFOFC while the patient is static in standing, and dynamic alignment is the process of assessing whether the set SVA alignment has produced the optimal results. The terms ‘tuning’ and ‘biomechanical optimisation’ also apply to the process of setting and determining the optimal SVA alignment, but they have a wider context. Biomechanical optimisation has the broadest context as it covers designing, aligning and tuning in all three planes. Tuning has the next broadest context as it involves fine adjustment of any part of the design or any alignment during activities and it also refers to any adjustment in any plane. Static and dynamic alignment usually only refer to optimally aligning the sagittal SVA.

It is essential to optimise the SVA-AFOFC because SVA alignment affects more proximal segment alignments, in both standing and walking. Figure 3 shows nine standing conditions, all with accurate human segment proportions and the foot horizontal on the floor (Owen, 2004; Owen, 2010).
the AFOFC intervention is not sufficiently successful in itself. Secondly, the AA-AFO and SVA have not been differentiated well and, coupled with a belief that a vertical alignment of the AFOFC is required for both standing and gait, this has lead to a belief that 90° AA-AFO is the only way to achieve a vertical alignment. It has not been well understood that any SVA alignment can be achieved with any AA-AFO and that inclined alignments of SVAs offer the best chance of achieving optimum standing balance, kinematics and kinetics in standing, stepping and gait, especially if knee and hip extension are goals of interventions (Owen 2004; Owen, 2010).

The determination of the optimum AA-AFO is largely made from clinical examination, which is not the case for determining the optimal SVA alignment of an AFOFC. This is made by undertaking trials of the activity for which the AFOFC is intended to be used (Owen, 2004; Owen, 2010; Eddison and Chockalingam, 2013).

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It is essential to optimise the SVA-AFOFC because SVA alignment affects more proximal segment alignments, in both standing and walking. Figure 3 shows nine standing conditions, all with accurate human segment proportions and the foot horizontal on the floor (Owen, 2004; Owen, 2010).
Homo sapiens evolved a more efficient gait, which enabled walking over longer distances and carrying of objects. We evolved longer legs and shorter trunks, a gait that has extension at both knees and hips or ‘strider gait’, a stable mid-foot, a toe lever and valgus at the knees. The proportion of the segments of the lower limb and the trunk dictate the kinematics and kinetics of normal human gait. The lengths of all the body segments at all ages are documented (Tilley, 2002). It is interesting to note that the segment proportions do not remain the same at all ages. The foot length of a 2-3 year old is 30% of overall leg length but by adulthood it is 31%. So when young children are at the stages of balance and gait maturation they have a longer foot in proportion to the leg length, and overall height, which gives them an increased base of support.

Short heel and toe levers can have an adverse effect on the quality of gait. The reduction of heel lever affects first rocker and the reduction of toe lever affects third rocker, in particular the ability of the ground reaction force to align itself anterior to the knee to create knee extending moments. Short heel and toe levers are not only the result of a short anatomical foot, they are also created when an anatomically correct length foot has an excessive external or internally rotated ‘foot progression angle’. Many children have a combination of a short foot and abnormal foot progression angles compromising their length of toe lever. When normalising gait in AFOFCs an essential task is to normalise segment lengths, which includes normalising the length of the overall ‘effective leg’, equalising leg lengths and normalising the ‘effective heel and toe lever’. Circumstances it may be helpful to increase heel and toe levers beyond those of normative data to create additional stability. Optimising heel and toe lever lengths in AFOFCs is part of the ‘trochoidal moment’ when tuning for standing, stepping and whole gait cycle. To do this the optimum stiffness and profile of the heel and sole of the footwear should be determined (Owen, 2004; Owen, 2008; Owen, 2010).

Principal Proportions

Homo sapiens evolved from early hominids who were the first non feathered bi-pedals. Early hominids had long trunks, short legs, walked with a flexed gait, had an unstable mid-foot and no valgus alignment at the knees. All these elements meant that walking on two limbs required a lot of energy. Homo sapiens evolved a more efficient gait, which was the first non feathered bi-pedals. Early Homo sapiens evolved from early hominids who...
Homo sapiens evolved a more efficient gait, which hominids had long trunks, short legs, walked with a were the first non-feathered bipedals. Early Homo sapiens evolved from early hominids who Ridgwell et al., 2010; Eddison and Chockalingam, 2008; Meadows et al., 2008; Bowers and Ross, 2009; pathology, and that the optimum footwear designs for each leg of each patient as it will be dependant on a theoretical perspective or observational gait analysis rather than from actual kinematic and kinetic tuning, and usually just one SVA alignment was suggested. Only recently is there an emerging need to be determined for each leg of each patient as it will be dependant on the clinical condition and the type of gait pathology, and that the optimum footwear designs are also required (Owen, 2004; Owen et al., 2004; Meadows et al., 2008; Bowers and Ross, 2009; Ridgwell et al., 2010; Eddison and Chockalingam, 2013). Homo sapiens evolved from early hominids who were the first non-feathered bi-pedals. Early hominids had long trunks, short legs, walked with a flexed gait, had an unstable mid-foot and no valgus alignment at the knees. All these elements meant that walking on two limbs required a lot of energy. Homo sapiens evolved a more efficient gait, which enabled walking over longer distances and carrying of objects. We evolved longer legs and shorter trunks, a gait that has extension at both knees and hips or ‘strider gait’, a stable mid-foot, a toe lever and valgus at the knees. The proportion of the segments of the lower limb and the trunk dictate the kinematics and kinetics of normal human gait. The proportions of all the body segments at all ages are documented (Tilley, 2002). It is interesting to note that the segment proportions do not remain the same at all ages. The foot length of a 2-3 year old is 38% of overall leg length but by adulthood it is 31%. So when young children are at the stages of balance and gait maturation they have a longer foot in proportion to the leg length, and overall height, which gives them an increased base of support. Short heel and toe lever can have an adverse effect on the quality of gait. The reduction of heel lever affects first rocker and the reduction of toe lever affects third rocker, in particular the ability of the ground reaction force to align itself anterior to the knee to create knee extending moments. Short heel and toe levers are not only the resultant of a short anatomical foot, they are also created when an anatomically correct length foot has an excessive external or internally rotated ‘foot progression angle’. Many children have a combination of a short foot and abnormal foot progression angles compromising their length of toe lever. 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Only recently is there an emerging evidence for optimal SVA adjustments obtained from gait laboratories. There is also an increasing understanding that the SVA needs to be determined for each leg of each patient as it will be dependant on the clinical condition and the type of gait pathology, and that the optimum footwear designs are also required (Owen, 2004; Owen et al., 2004; Meadows et al., 2008; Bowers and Ross, 2009; Ridgwell et al., 2010; Eddison and Chockalingam, 2013). Principal Proportions Stiffness refers to the ability of the material and design to resist bending. Profile is the shape of the sagittal view of the distal surface of the footwear. Both the stiffness and profile of heels and soles of footwear can be designed and optimised for the required activity (Figure 6) (Owen, 2004; Owen, 2005; Owen, 2010). The optimised sole design may be flexible or stiff. If it is stiff it should have a rocker sole profile. Whether the optimum design is a rounded rocker or point-loading rocker the optimum position of the rocker for the desired activity needs to be determined. The position of the rocker dictates the length of the ‘toe lever’ and an optimum toe lever is required for standing, stepping and in full gait cycles for both ‘temporal midstance’ and the ‘exit from temporal midstance’. If a patient has a short foot it may be necessary to optimise foot proportion by use of a stiff rocker sole to create a false longer toe lever. Optimising heel design has effects on the ‘heel lever’ for the ‘entrance to midstance’. Pitch or heel sole differential This paper concentrates on the sagittal plane designs of AFOFCs and has previously distinguished, defined and discussed two of the principal sagittal alignments in any AFOFC, the AA-AFO and the SVA-AFOC. The optimal AA-AFO for each leg is determined by a clinical algorithm and then the optimal SVA is determined by trials of the activity for which the AFOFC is required. When using a fixed ankle AFOFC or one with a plantarflexion stop function, the desired SVA is set by adjusting the ‘pitch’ or more specifically the ‘heel sole differential’ (HSD) of the footwear and any accompanying internal wedges (Figure 1) (Cook and Cozzens, 1976; Owen, 2004; Owen, 2010). The HSD describes the difference in height between the heel and sole of the footwear. Heel height alone does not describe pitch. Heel Sole Differential The measured difference between the depth of the heel at mid-heel and the depth of the sole at the metatarsal heads. The term ‘final heel sole differential’ can be used to describe the overall HSD when it includes the HSD of the footwear and HSD of any internal wedges. The HSD is generally measured in centimetres in clinical practice. Degrees of pitch may be used in research or when explaining the linkage between AA-AFO and SVA alignments. Adjusting the HSD of the footwear to adjust the SVA is a key element in static and dynamic alignment and tuning AFOFCs. Optimising the SVA is essential to optimise standing balance, swaying, and stepping and ‘temporal mid-stance’ of the gait cycle (Owen, 2010). Heel and Sole Designs – Stiffness and Profile The design of heels and soles of footwear also affects standing balance, swaying, stepping and the three rehabilitative subdivisions of the gait cycle, ‘entrance to midstance’, ‘temporal midstance’ and ‘exit from temporal midstance’ (Figures 4 & 5) (Owen, 2004; Owen, 2005; Owen, 2010). Stepping is different to walking with full gait cycles. Stepping has a ‘temporal midstance’, as does a full gait cycle but it has an abbreviated ‘entrance’ and ‘exit’. The first 10% of stance and the last 10% of single stance are not present. Young children start walking with abbreviated gait cycles and then develop full gait cycles and, as we get older, we often regress to ‘stepping’. Entrance to midstance Midstance Exit from midstance

Figure 5 - Temporal midstance 30% gait cycle (Owen, 2010)

SVA Guidelines

Figure 4 - Producing normal foot, shank and thigh kinematics with an AFOFC (Owen, 2004; Owen, 2010)
An Algorithm for Determining Whether a Dorsiflexion Free AFOFC is Appropriate

Like the decision about the optimal AA-AFO alignment in a fixed ankle AFO, the decision as to whether it is appropriate to use a dorsiflexion free function in an AFO design is based on calf MTU length and stiffness and triplanar bony alignment of the foot, and an additional consideration is also required, which is the strength of the calf MTU. An AFOFC with a dorsiflexion free function, often combined with a 90° plantarflexion stop function, has been a commonly investigated orthosis. The research to date has a number of problems, particularly when related to gait (Owen, 2013; Bowers and Ross, 2009):

1. Research often seeks to determine whether a fixed ankle or hinged/dorsiflexion free AFO design is optimum for diagnostic groups or categories, which is inappropriate;
2. Dorsiflexion free AFOs have been investigated with study subjects who have contraindications to their use;
3. AFOFCs with dorsiflexion free functions have been coupled with fixed metatarsal phalangeal joints (MTPJs) which may adversely affect ankle joint kinematics;
4. Some literature states that movement at the ankle joint is essential for gait which is incorrect (Owen, 2013).

An algorithm to determine whether an AFOFC with a dorsiflexion free function is likely to be the optimal prescription for gait can be created (Figure 8) if a few key requirements for normal barefoot gait are considered (Owen, 2013):

- At 40% gait cycle maximum stance phase knee extension occurs and at this time the ankle is dorsiflexed 10-12° (Figure 7) - there must be sufficient gastrocnemius length available to allow both these kinematics;
- The ankle dorsiflexes to 10-12° during mid-stance - there must be sufficient length and sufficiently low tone in soleus and gastrocnemius to allow this movement;
- The ankle is prevented from excessively dorsiflexing in mid-stance and is maintained in a quasi-stiff position of dorsiflexion in terminal stance by the actions of the calf muscles - there must be sufficient strength of the calf muscles to achieve this;
- Ankle dorsiflexion in gait is coupled with stable bony alignment of the foot.

* An AFOFC with an MTPJ free design is required to allow MTPJ extension during third rocker for two reasons. Firstly, restriction in MTPJ extension may produce excessive ankle dorsiflexion. This compensatory response is required to enable normal shank kinematics if MTPJs are fixed and not compensated for by a rocker sole profile. Secondly, patients who meet the criteria for a dorsiflexion free AFO should also meet the criteria for an MTPJ free design AFOFC. If they do not then a rocker sole profile is required on the footwear.

** To obtain 10-12° of ankle joint dorsiflexion in gait the dorsiflexion free AFO needs to be combined with footwear that has a 0mm Heel Sole Differential (HSD) or 0 degree pitch. For each degree of pitch in the footwear there will be a reduction of one degree of ankle dorsiflexion. This is because gait requires normal shank kinematics and ankle joint kinematics adjust to the pitch of the footwear to achieve this. In normal gait the shank is 10-12° inclined by the end of MST and a 10-12° pitch in the footwear negates the need for ankle joint movement to achieve this.

Figure 7 - 40% gait cycle - maximum knee extension, ankle dorsiflexion, maximum gastrocnemius length (Owen, 2010)

Figure 8 - Proposed algorithm for determining whether a dorsiflexion free AFO is an appropriate prescription (Owen 2013)
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Conclusion

Research about biomechanical optimisation of AFOFCs is still at an early stage of development (Owen, 2004; Owen, 2010; Meadows et al, 2008; Bowers and Ross, 2009; Ridgewell, 2010, Eddison and Chockalingam, 2013). One of the problems with the emerging evidence is that only the SVA seems to have been manipulated in some trials with lack of detail about the AA-AFO and whether it was optimised prior to tuning trials. The designs at the metatarsal phalangeal joints and the heels and soles of the footwear are also not stated as being optimised. The pre-requisites for determining the optimal SVA alignment for each leg of each patient are that all the other design features of the AFOC are optimal, which includes optimisation of AA-AFO, designs of the AFO, heel and toe levers, design of the footwear heel and sole stiffness and profile and having leg lengths equalised in prescriptions (Owen, 2010). The process of optimising prescriptions is therefore multi-faceted. In future research it would preferable if AFOFC prescriptions were optimised in all parameters and then just one parameter varied, rather than vary one parameter while other parameters may not be optimum. A recent editorial (Fatone, 2010) has suggested that there are many challenges in lower limb orthotic research due to the heterogeneity of the mechanics of the device; the individual and each leg of the individual; the interaction of the device with the individual; and the required outcomes for the individual. The comments that customisation produces confounding variables, standardisation limits the population for the study and single subject research and case studies are perhaps too frequently undervalued by practitioners and transferred into clinical practice.

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References


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Appendix 1

Publications detailing a recommended or optimised SVA for fixed ankle AFOFCs.

*Children included in all except one (*). Adapted from Owen E (2004) MSc Thesis

<table>
<thead>
<tr>
<th>YEAR</th>
<th>AUTHOR</th>
<th>SVA</th>
<th>COMMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>1970</td>
<td>Jebsen, Corcoran, Simon</td>
<td>10° Incline</td>
<td>• Theoretical justification</td>
</tr>
<tr>
<td>1972</td>
<td>Glancy &amp; Lindseth</td>
<td>3-5° Incline</td>
<td>• Visual gait analysis</td>
</tr>
<tr>
<td>1978</td>
<td>Fulford &amp; Cairns</td>
<td>Slight Incline</td>
<td>• Theoretical justification</td>
</tr>
<tr>
<td>1983</td>
<td>Nuzzo</td>
<td>Knee cap over MTPJs</td>
<td>• Theoretical justification from kinematic gait analysis</td>
</tr>
<tr>
<td>1984</td>
<td>Meadows</td>
<td>4-17° Incline</td>
<td>• SVA deducible from other data given in Rosenthal et al. 1975</td>
</tr>
<tr>
<td>1986</td>
<td>Nuzzo</td>
<td>7-10° Incline</td>
<td>• Theoretical justification and kinematic gait analysis</td>
</tr>
<tr>
<td>1990</td>
<td>Cusick</td>
<td>5° Incline</td>
<td>• Theoretical justification</td>
</tr>
<tr>
<td>1992</td>
<td>Hullin, Robb, Loudon</td>
<td>0° with a rocker sole or 10° incline without a rocker sole</td>
<td>• SVA deducible</td>
</tr>
<tr>
<td>2002</td>
<td>Owen E</td>
<td>7-15° Incline Mean 11.4° Inc</td>
<td>• SVA tuned to optimum</td>
</tr>
<tr>
<td>2009</td>
<td>Jagadamma et al</td>
<td>10.8° Inc (SD 1.8)</td>
<td>• SVA are best of selected SVA trails and may not be fully optimised</td>
</tr>
<tr>
<td>2010</td>
<td>Jagadamma et al *</td>
<td>14° Inc</td>
<td>• SVA and sole design tuned to optimum</td>
</tr>
</tbody>
</table>

Introduction

For children who have physical disabilities, physiotherapy is often one of the first therapeutic treatments that parents encounter, and usually continues throughout the child’s life (Pigott et al, 2003). Physiotherapists work with the child and their carers through therapy techniques and with equipment (Tétreault et al, 2003; Wiart et al, 2010). Physiotherapists in today’s health service integrate HEPs at home, nursery and school. Parents are asked to consent to physiotherapy involvement and expected to implement HEPs (Novak & Cusick, 2006).

Physiotherapists will use knowledge of the child’s condition, motor planning and evidenced treatments to make decisions about HEPs. Collaboration is intricately entwined in multifactoral personal, social and clinical reasoning. In applying collaborative practice it is assumed that physiotherapists are meeting family preferences.

FCC requires excellent communication and teaching skills. The physiotherapist needs to appreciate family systems, cultural differences and wider socio-economic factors and the abilities of the parents (Case-Smith & Nastro, 1993). The belief is that families are better placed to carry out HEPs in the context of their life, and prioritise their child’s health needs (Novak & Cusick, 2006). For HEPs to be successful, however, families need to be

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ABSTRACT

Background and purpose
Parents of children with complex physical disabilities are expected to be active partners in delivering Home Exercise Programmes (HEPs). Their role involves them acquiring a range of techniques for administering exercise, facilitating therapeutic activities, donning and doffing orthotics and using multiple pieces of equipment that potentially change over time as their child grows. Little is known about the needs and experiences of parents who are responsible for carrying out HEPs for their child with long term physiotherapy needs.

Methods
Six parents responsible for a physiotherapy HEP for their child were selected through convenience sampling. Experiences of learning from paediatric physiotherapists were explored through unstructured interviews applying Colaizzi’s framework to interpret audio recorded and transcribed data.

Results
Three major themes emerged:
1. the relevance of roles and responsibilities;
2. the relevance of learning physiotherapy, its meaning and context;
3. doing physiotherapy - enabling and influencing, practicalities, barriers, and tangible things.

Conclusions
The implications of the phenomena are discussed. In light of the results, questions regarding the delivery of care in today’s NHS, recommendations and implications for current practice are raised.

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The Learning Experiences of Parents with Children Requiring Physiotherapy Intervention
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