FROM STABLE STANDING TO ROCK AND ROLL WALKING
A SEGMENTAL KINEMATIC APPROACH TO GAIT REHABILITATION

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REFERENCES
Owen E (2013) A proposed clinical algorithm for dorsiflexion free AFO footwear combinations based on calf muscle length, strength, stiffness and skeletal alignment. ISPO UK NMS Scientific Meeting 2013, BLESMA prize award.
Owen E (2009) How should we define the rockers of gait and are there three or four. Gait & Posture. 30:S 94
**Stepping – Abbreviated Gait Cycle**

Walking can be divided into ‘walking with full gait cycles and ‘stepping’ (Owen 2014). This is helpful because when children develop walking skills they first stand, then sway in standing, then start stepping and finally they develop full gait cycles. This developmental sequence is, therefore, useful for rehabilitation. Also, walking with full gait cycles may never be a possibility for some patients so stepping is a safe and sustainable alternative walking style.

Stepping is defined as walking with an abbreviated gait cycle, single stance finishing at 40% of the normal full gait cycle and swing phase ending at 90%. It is different from strolling, or walking slowly with a full gait cycle and a heel strike. In stepping, initial contact is with a horizontal foot, not the heel, and the shank is vertical not reclined. By the end of single stance the shank and thigh are inclined, there is maximum stance phase knee extension and knee extending moments combined with almost maximum stance phase hip extension and hip extending moments. The stance phase of stepping, as defined, would have some heel rise but in rehabilitation it may be helpful in some circumstances to achieve stepping with the stance foot in full contact until contralateral initial contact.
When standing and walking the feet act as the ‘base of support’. In the sagittal plane the foot has what are considered to be a ‘heel lever’ and a ‘toe lever’. The length of the heel and toe levers dictates the sagittal length of the base of support. The length of the heel and toe levers of the normal foot have evolved such that the foot can provide a stable ‘base of support’ in standing while also providing sufficient stability and mobility during walking, running and other activities. The levers are set anthropometrically to be at optimum distances from the ankle joint to ensure optimal placement of the ‘point of application’ of the ‘ground reaction force’ at the foot, and optimal alignment of GRF to knee and hip joints during standing and walking.
## ACTUAL AND RELATIVE LENGTHS OF LOWER LIMB SEGMENTS BY AGE

<table>
<thead>
<tr>
<th>Age</th>
<th>Height mm</th>
<th>Thigh mm</th>
<th>Shank mm</th>
<th>Foot mm</th>
<th>Equivalent Shoe size with no additions for growth etc</th>
<th>Whole leg mm</th>
<th>Sh/Th %</th>
<th>F/Th %</th>
<th>F/Sh %</th>
<th>F/Leg %</th>
</tr>
</thead>
<tbody>
<tr>
<td>18-18.5 yrs</td>
<td>1718</td>
<td>417</td>
<td>406</td>
<td>252</td>
<td>38</td>
<td>823</td>
<td>97%</td>
<td>60%</td>
<td>62%</td>
<td>31%</td>
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<tr>
<td>17</td>
<td>1683</td>
<td>406</td>
<td>394</td>
<td>247</td>
<td>37</td>
<td>806</td>
<td>97%</td>
<td>61%</td>
<td>61%</td>
<td>31%</td>
</tr>
<tr>
<td>16</td>
<td>1685</td>
<td>409</td>
<td>404</td>
<td>249</td>
<td>38</td>
<td>813</td>
<td>99%</td>
<td>61%</td>
<td>62%</td>
<td>31%</td>
</tr>
<tr>
<td>15</td>
<td>1636</td>
<td>396</td>
<td>394</td>
<td>246</td>
<td>37</td>
<td>790</td>
<td>99%</td>
<td>62%</td>
<td>62%</td>
<td>32%</td>
</tr>
<tr>
<td>14</td>
<td>1594</td>
<td>388</td>
<td>384</td>
<td>244</td>
<td>37</td>
<td>772</td>
<td>99%</td>
<td>63%</td>
<td>64%</td>
<td>32%</td>
</tr>
<tr>
<td>12</td>
<td>1490</td>
<td>363</td>
<td>364</td>
<td>232</td>
<td>35</td>
<td>727</td>
<td>100%</td>
<td>64%</td>
<td>64%</td>
<td>32%</td>
</tr>
<tr>
<td>11</td>
<td>1431</td>
<td>346</td>
<td>345</td>
<td>223</td>
<td>34</td>
<td>691</td>
<td>100%</td>
<td>65%</td>
<td>65%</td>
<td>32%</td>
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<tr>
<td>10</td>
<td>1380</td>
<td>328</td>
<td>327</td>
<td>216</td>
<td>33</td>
<td>655</td>
<td>100%</td>
<td>66%</td>
<td>66%</td>
<td>33%</td>
</tr>
<tr>
<td>9</td>
<td>1331</td>
<td>310</td>
<td>310</td>
<td>206</td>
<td>31</td>
<td>620</td>
<td>100%</td>
<td>67%</td>
<td>67%</td>
<td>33%</td>
</tr>
<tr>
<td>8</td>
<td>1267</td>
<td>292</td>
<td>292</td>
<td>197</td>
<td>30</td>
<td>584</td>
<td>100%</td>
<td>68%</td>
<td>68%</td>
<td>34%</td>
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<tr>
<td>7</td>
<td>1217</td>
<td>278</td>
<td>274</td>
<td>188</td>
<td>28</td>
<td>552</td>
<td>99%</td>
<td>68%</td>
<td>69%</td>
<td>34%</td>
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<tr>
<td>6</td>
<td>1153</td>
<td>257</td>
<td>257</td>
<td>176</td>
<td>27</td>
<td>514</td>
<td>100%</td>
<td>69%</td>
<td>69%</td>
<td>34%</td>
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<tr>
<td>5</td>
<td>1092</td>
<td>239</td>
<td>236</td>
<td>170</td>
<td>26</td>
<td>475</td>
<td>99%</td>
<td>71%</td>
<td>72%</td>
<td>36%</td>
</tr>
<tr>
<td>4</td>
<td>1019</td>
<td>218</td>
<td>216</td>
<td>160</td>
<td>24</td>
<td>434</td>
<td>99%</td>
<td>73%</td>
<td>74%</td>
<td>37%</td>
</tr>
<tr>
<td>2.5-3yrs</td>
<td>942</td>
<td>195</td>
<td>193</td>
<td>147</td>
<td>22</td>
<td>388</td>
<td>99%</td>
<td>75%</td>
<td>76%</td>
<td>38%</td>
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<tr>
<td>20-23m</td>
<td>825</td>
<td>125</td>
<td>120</td>
<td>107</td>
<td>19</td>
<td>188</td>
<td>99%</td>
<td>75%</td>
<td>76%</td>
<td>38%</td>
</tr>
<tr>
<td>16-19m</td>
<td>790</td>
<td>120</td>
<td>116</td>
<td>109</td>
<td>19</td>
<td>154</td>
<td>99%</td>
<td>75%</td>
<td>76%</td>
<td>38%</td>
</tr>
<tr>
<td>12-15m</td>
<td>737</td>
<td>116</td>
<td>116</td>
<td>109</td>
<td>19</td>
<td>154</td>
<td>99%</td>
<td>75%</td>
<td>76%</td>
<td>38%</td>
</tr>
<tr>
<td>9-11m</td>
<td>730</td>
<td>107</td>
<td>107</td>
<td>105</td>
<td>19</td>
<td>146</td>
<td>99%</td>
<td>75%</td>
<td>76%</td>
<td>38%</td>
</tr>
<tr>
<td>6-8m</td>
<td>687</td>
<td>99</td>
<td>99</td>
<td>99</td>
<td>19</td>
<td>128</td>
<td>99%</td>
<td>75%</td>
<td>76%</td>
<td>38%</td>
</tr>
<tr>
<td>3-5m</td>
<td>633</td>
<td>90</td>
<td>90</td>
<td>90</td>
<td>19</td>
<td>120</td>
<td>99%</td>
<td>75%</td>
<td>76%</td>
<td>38%</td>
</tr>
<tr>
<td>2m</td>
<td>555</td>
<td>81</td>
<td>81</td>
<td>81</td>
<td>19</td>
<td>120</td>
<td>99%</td>
<td>75%</td>
<td>76%</td>
<td>38%</td>
</tr>
</tbody>
</table>

**Definitions of Segment Lengths:**

- **Foot:** Posterior of heel to end of toes
- **Shank:** Knee joint to ankle joint
- **Thigh:** Hip Joint to knee joint

**References:**


Shoe sizes and relative percentages are derived from raw data, from same source, by Elaine Owen.

ALLOCATION OF SEGMENTS AND JOINTS

DEFINITIONS

ALIGNMENT OF A JOINT
The spatial relationship between the skeletal segments which comprise the joint (ISO 8551: 2003)

ALIGNMENT OF A SKELETAL SEGMENT
The spatial relationship between the ends of a segment (ISO 8551:2003)

SEGMENT TO VERTICAL ANGLE
SHANK TO VERTICAL ANGLE, THIGH TO VERTICAL ANGLE, TRUNK
The angle of the segment relative to the vertical, measured in the sagittal plane. The angle is described as inclined if the segment is leaning forward from the vertical and reclined if leaning backward from the vertical. It is described in degrees from the vertical, vertical being 0 degrees. (Owen 2004, 2010, 2014, 2015)

SEGMENT TO HORIZONTAL ANGLE
PELVIS TO HORIZONTAL ANGLE, FOOT TO HORIZONTAL ANGLE
The angle of the segment relative to the horizontal, measured in the sagittal plane. Described in degrees from the horizontal, horizontal being 0 degrees. (Owen 2010, 2014, 2015)

Winters (1990)
with permission
JOINT AND SEGMENT ALIGNMENTS
IN AFO FOOTWEAR COMBINATIONS

ANGLE OF THE ANKLE IN THE AFO (AAAFO)
The angle of the line of the shank relative to the base of the lateral border of the foot i.e. a line drawn from the most inferior point of the heel pad on its lateral side to the most inferior point of the foot under the fifth metatarsal head. Described in degrees of plantarflexion or dorsiflexion or plantigrade.

SHANK TO VERTICAL ANGLE (SVA)
The angle that the line of the shank makes with the perpendicular to the ground, in the sagittal plane, when the patient is wearing the ankle-foot orthosis footwear combination. This is measured in standing with weight equally distributed between heel and sole. It is measured as angles relative to the vertical and named inclined or reclined to define whether there is a forward lean from the vertical or backward lean from the vertical.
**Relationsip of Shank, Thigh, Pelvis and Trunk Segments in Standing**


<table>
<thead>
<tr>
<th>Shank Angle to Floor</th>
<th>Thigh Reclined</th>
<th>Thigh Vertical</th>
<th>Thigh Inclined</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shank 0° Vertical</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shank 11° Inclined</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shank 20° Inclined</td>
<td></td>
<td>(Not Possible)</td>
<td></td>
</tr>
</tbody>
</table>

- It is only possible to achieve an inclined thigh with an inclined shank.
- The optimum Shank to Vertical Angle for this is 10-12° incline, the range is probably 7-15° inclined.
- It is not possible to achieve an inclined thigh with a vertical shank/SVA 0° unless the knee hyperextends.
- It is not possible to achieve an inclined thigh with a shank that is inclined 20°/SVA 20° as this requires movement of the centre of mass outside of the base of support.
- It is only possible to achieve both hip and knee extension combined with a vertical trunk when both shank and thigh are inclined.
- The row of images with a Shank to Vertical Angle of 10-12° inclined show that this is the only SVA where it is possible for the thigh to move from reclined to vertical to inclined, translating a vertical trunk over a stable base.
- Shank to Vertical Angle 10-12° inclined places the knee caps over the MTPJs.
- Shank to Vertical Angle 20° inclined places the knee caps over the end of toes.
- Shank to Vertical Angle 0° vertical places the knee joint centre over the ankle joint.
ALIGNMENT OF FOOT & SHANK AT TEMPORAL MIDSTANCE
PRODUCING STABILITY IN STANCE

Shank 10-12° inclined at temporal midstance
Knee over middle of foot

Knee over middle of foot and slowing of shank
‘Stability in Stance’

HOW SHOULD WE DEFINE THE ROCKERS OF GAIT AND ARE THERE THREE OR FOUR?
Owen E, Child Development Centre, Bangor, UK

SUMMARY
A three-event ankle model of the rockers in gait is inadequate. A four-event model is preferable.

CONCLUSION
Definitions of four rockers are proposed: The mechanisms of the ankle and foot that produce shank kinematic during stance phase of the gait cycle (GC); First rocker during loading response (LR), heel is the pivot, movement at the ankle joint; Second rocker during mid-stance (MST), ankle is the pivot, movement at the ankle joint; Third rocker during terminal stance (TST), forefoot is the pivot, movement at the metatarsal-phalangeal joints; Fourth rocker during pre-swing (PSW), forefoot is the pivot, movement at the metatarsal-phalangeal and ankle joints.

INTRODUCTION
Perry first described the three rockers of gait, ascribing them to three subdivisions of the GC; ‘Initial/first rocker’ in LR, ‘mid-stance rocker’ in MST and ‘terminal rocker’ in TST. She later renamed the rockers, according to the pivot of each rocker; ‘heel rocker’ during LR, ‘ankle rocker’ during MST and ‘forefoot rocker’ during TST and extended the description of the forefoot rocker to include PSW. She attributes the purpose of the rockers to production of tibial advancement during stance, an essential element in forward progression. Perry has renamed the forefoot rocker in PSW as ‘toe-rocker’. Perry’s three rockers have been reinterpreted as solely relating to ankle kinematic and they have been renamed ‘first, second and third ankle rockers’, first involving plantarflexion during LR, second involving dorsiflexion, and third involving plantarflexion or movement from dorsiflexion towards plantarflexion, with varying interpretations of the division between second and third rockers.

METHOD AND RESULT
Tabulation of kinematic data by subdivisions of the GC reveals four events and three pivots producing the normal shank kinematic of stance.

<table>
<thead>
<tr>
<th>PROPOSED NAME</th>
<th>LR</th>
<th>MST</th>
<th>TST</th>
<th>PSW</th>
</tr>
</thead>
<tbody>
<tr>
<td>PIVOT</td>
<td>1$^{st}$ ROCKER</td>
<td>2$^{nd}$ ROCKER</td>
<td>3$^{rd}$ ROCKER</td>
<td>4$^{th}$ ROCKER</td>
</tr>
<tr>
<td>JOINT producing tibial advancement</td>
<td>Heel</td>
<td>Ankle</td>
<td>Forefoot / MTPJs</td>
<td>Forefoot / toes</td>
</tr>
<tr>
<td>ANKLE JOINT</td>
<td>Plantigrade to 10º Plantarflex</td>
<td>10º Plantarflex to 10º Dorsiflex</td>
<td>Virtually locked in Dorsiflex 10-12-7º</td>
<td>7º Dorsiflex to 20º Plantarflex</td>
</tr>
<tr>
<td>MTPJs</td>
<td>Dorsiflex 25º to 0º</td>
<td>0º to 0º</td>
<td>0º to Dorsiflex 25º</td>
<td>Dorsiflex 25º-55º</td>
</tr>
</tbody>
</table>

SHANK KINEMATIC degrees relative to vertical
- 25º to 10º Recline
- 10º Recline to 10º Incline
- 10º to 25º Incline
- 25º to 50º Incline

FOOT KINEMATIC
- 25º Incline to Horizontal
- Horizontal
- Horizontal to 20º Recline
- 20º Recline to 60º Recline

DISCUSSION
Confining interpretation of the rockers to ankle kinematic does not recognise: 1) The original purpose of describing the rockers; to describe the pivot mechanisms by which normal shank kinematic is produced during stance. 2) The original differentiation between first and second rocker; heel rise, at 30% GC, at the start of TST, the pivot transferring from the ankle to the forefoot. More recent descriptions differentiate these rockers by the point at which the ankle starts to move towards plantarflexion, or the end of TST, rather than which coincide with the start of heel rise. 3) Four events of ankle kinematic in stance, rather than three. A four event model recognises that the ankle is not in motion throughout stance. During TST, the ankle is ‘virtually locked’, in dorsiflexion. The movement that advances the shank occurs at the metatarsal-phalangeal joints. The stiffness of the ankle in TST is essential for heel rise and the ability to achieve maximum knee extension at 40% GC, maximum hip extension at 50% GC. These omissions may lead to inappropriate or suboptimal interventions.

REFERENCES
HOW SHOULD WE DEFINE THE ROCKERS OF GAIT AND ARE THERE THREE OR FOUR? ANSWER: FOUR


FIRST ROCKER in loading response using ankle movement. Pivot at heel

SECOND ROCKER in midstance using ankle movement. Pivot at ankle
THIRD ROCKER in terminal stance using MTPJ movement. Pivot at forefoot / MTPJs

FOURTH ROCKER in preswing using ankle and MTPJ movement. Pivot at forefoot /

Refs:

Perry 2008, 2010
When walking in footwear that has a ‘Heel Sole Differential’ or Pitch the base of the footwear becomes the Effective Foot. The kinematics of the Effective Foot mimic the kinematics of the Actual Foot in barefoot gait. The actual foot shifts its kinematics by the degree of pitch in the footwear. The ankle shifts its kinematics by the degree of pitch in the footwear, so as to maintain normal barefoot shank, thigh and trunk kinematics. The ankle joint adjusts to maintain normal segment kinematics.
An importance of the rockers is that the distal segment alignments and kinematics dictate proximal kinematics and kinetics, ‘Normal distal produces normal proximal’ and ‘abnormal distal produces abnormal proximal’. Understanding each of the rockers of gait and incorporating normal segment alignment strategies into all rehabilitation and orthotic interventions for standing, stepping and walking with full gait cycles is essential.

The rockers of barefoot gait are dependent on movement at both the ankle and metatarsal phalangeal joints (MTPJs). If these joints are not able to move it is still possible to produce normal shank kinematics if the correct footwear or orthosis design is used, because joint kinematics and segment kinematics are independent of each other.

When walking in AFOFCs the design of the AFOFC needs to create most normal, foot and shank kinematics, subsequent most normal thigh kinematics and knee and hip kinematics and kinetics. For a number of reasons we often have to fix the ankle joint or MTPJs in orthotic designs. This prevents use of anatomical rockers, so normal shank kinematics must be replicated by the use of simulated rockers created by the design of the footwear that is combined with the ankle-foot orthosis.

Normal shank kinematics can be created by determining the optimal SVA alignment of the AFOFC and by optimising the designs of the heels and soles of the footwear to facilitate the foot and shank kinematics required for entry to and exit from temporal midstance. When using AFOFCs the base of the footwear becomes the ‘effective foot’. Designs of soles vary the timing and rate of heel rise and shank kinematics. Designs of heels vary the rate of foot kinematics from heel strike to foot flat and shank kinematics.

DEFINITIONS

BIOMECHANICAL OPTIMISATION is the process of designing, aligning and tuning and AFOFC to optimise its performance.

TUNING is the process whereby fine adjustments are made to the AFOFC, in order to optimise its performance during a particular activity, for example standing, stepping, walking, stairs, running.
NORMAL SHANK KINEMATIC IN STANCE PHASE?

20-25° REC

10° REC

10° INC

20-25° INC

YES → SWING PHASE / INITIAL CONTACT PROBLEM?

YES → Posterior Leaf Spring or Hinged AFOFC

NO → FIXED ANKLE AFOFC with appropriate Angle of Ankle in AFO

ABNORMALITY OF SHANK KINEMATIC = EXCESSIVE INCLINE IN MST AND/OR TST

ABNORMALITY OF SHANK KINEMATIC = INSUFFICIENT INCLINE IN MST AND/OR TST

AFO DESIGN AT ANKLE JOINT

Ankle joint fixed

Plantarfexion and recline resist design, A or B

AFO DESIGN AT METATARSAL PHALANGEAL JOINTS

MTPJs free to extend so as to enable inclination of shank through use of anatomical 3rd rocker, A

FOOTWEAR DESIGN

Design which permits inclination of shank in TST = Flexible sole and sole profile design which enables MTPJ extension and use of anatomical 3rd rocker

FOOTWEAR DESIGN

Design which resists excessive inclination of shank in TST = Stiff sole and sole profile design which provides simulated 3rd rocker

TUNE MIDSTANCE by adjusting Heel Sole Differential of the AFOFC to determine the alignment of the AFOFC (SHANK to VERTICAL ANGLE/ SHANK ANGLE to FLOOR), which produces optimal shank kinematic and GRF alignment. A useful starting point is 10-12° incline.

TUNE ENTRY TO MST (IC, LR) by adjusting heel design to optimise shank kinematic and GRF alignment

Plain heel produces optimal result?

YES → HEEL DESIGN

NO → TUNE EXIT FROM MST (TST) by adjusting sole design to optimise shank kinematic and GRF alignment

Flexible sole with flat or rounded sole profile produces optimal result?

YES → SOLE DESIGN

NO → Stiff sole with rocker sole profile (optimised position and toe spring angle) produces optimal result?

YES → SOLE DESIGN

NO → Stiff sole with point loading rocker (optimised position and toe spring angle) produces optimal result?

YES → SOLE DESIGN

Angular velocity of shank during entry to MST needs to be increased by use of a positive heel?

YES → HEEL DESIGN

NO → Angular velocity of shank during entry to MST needs to be reduced by use of a negative or cushion heel?

YES → HEEL DESIGN

NO →

NOTE:

See steps on MTPJ and sole design

AFO DESIGN AT ANKLE JOINT

Ankle joint fixed

Plantarfexion and incline resist design, B or C, depending on severity of gait abnormality

AFO not required unless other indications

TUNE EXIT FROM MST (TST) by adjusting sole design to optimise shank kinematic and GRF alignment

Flexible sole with flat or rounded sole profile produces optimal result?

YES → SOLE DESIGN

NO → Stiff sole with rocker sole profile (optimised position and toe spring angle) produces optimal result?

YES → SOLE DESIGN

NO → Stiff sole with point loading rocker (optimised position and toe spring angle) produces optimal result?

YES → SOLE DESIGN

Angular velocity of shank during entry to MST needs to be increased by use of a positive heel?

YES → HEEL DESIGN

NO → Angular velocity of shank during entry to MST needs to be reduced by use of a negative or cushion heel?

YES → HEEL DESIGN

NO →

AFO DESIGN AT ANKLE JOINT

Ankle joint fixed

Dorsiflexion and incline resist design, B or C, depending on severity of gait abnormality

AFO not required unless other indications

TUNE EXIT FROM MST (TST) by adjusting sole design to optimise shank kinematic and GRF alignment

Flexible sole with flat or rounded sole profile produces optimal result?

YES → SOLE DESIGN

NO → Stiff sole with rocker sole profile (optimised position and toe spring angle) produces optimal result?

YES → SOLE DESIGN

NO → Stiff sole with point loading rocker (optimised position and toe spring angle) produces optimal result?

YES → SOLE DESIGN

Angular velocity of shank during entry to MST needs to be increased by use of a positive heel?

YES → HEEL DESIGN

NO → Angular velocity of shank during entry to MST needs to be reduced by use of a negative or cushion heel?

YES → HEEL DESIGN

NO →

STABLE SHANK KINEMATIC IN STANCE PHASE?

10° REC

10° INC

10° INC

10° INC
NOTE: Some gaits have a combination of abnormalities within the same gait cycle

**CATEGORIES OF STANCE PHASE ABNORMALITIES OF SHANK KINEMATICS**
**CORRECTION BY ANKLE-FOOT ORTHOSIS FOOTWEAR COMBINATIONS**


**INSUFFICIENT SHANK INCLINE**

- **MST**
  - **TST**

- **a**

- **b**

- **c**

  **a and b** Shank insufficiently inclined in MST. Vector excessively anteriorly aligned at foot, knee and hip in MST. Vector vertical (1a) or forward leaning (1b).

  **c** AFOFC producing normal shank kinematics at MST and TST by increasing the inclination of the shank with resultant improvement of GRF alignment at foot, knee and hip.

**EXCESSIVE SHANK INCLINE**

- **MST**
  - **TST**

- **d**

- **e**

- **f**

  **d and e** Shank excessively inclined in MST. Vector aligned posterior to knee in MST and TST with variable alignment at hip and foot. Different foot kinematics in (1d) and (1e).

  **f** AFOFC producing normal shank kinematics at MST and TST by reducing shank inclination with resultant improvement of GRF alignment at foot, knee and hip.
Is there sufficient gastrocnemius length to allow knee extension with 10° ankle dorsiflexion and a non compromised arch?

YES

Is there sufficiently low tone in the calf muscles to allow 10° of ankle dorsiflexion during second rocker of gait cycle?

YES

Is there sufficient calf muscle strength to prevent excessive ankle dorsiflexion in stance and create a ‘quasi‐stiff’ ankle in dorsiflexion in 3rd rocker?

YES

Is the triplanar bony alignment of the foot sufficiently stable to be maintained during the dorsiflexion free function of the AFO?

YES

A dorsiflexion free AFOFC design is likely to be suitable. Determine plantarflexion function.

MTPJs free design usually required*

0° pitch/0mm Heel Sole Differential footwear required for full effect on ankle dorsiflexion**

Optimal heel design in footwear required

NO

NO

NO

NO

Fixed ankle or dorsiflexion stop AFOFC design required

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

** 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 at the end of mid-stance. A 10-12° pitch in the footwear negates the need for ankle dorsiflexion to achieve this.


1) MUSCLE LENGTH

2) MUSCLE STIFFNESS

3) TRIPLANAR BONY ALIGNMENT OF FOOT

4) RISK OF LOSS OF LENGTH OR OVERLENGTHENING GASTROCNEMIUS OR SOLEUS

NOTE: THERE ARE INTERVENTION OPPORTUNITIES THROUGHOUT
The optimum SVA of an AFOFC seems to be dependent on 2 main factors:

1. The primary neurology
2. The consequent stiffness of the muscles and joints at the hip and knee

GUIDELINES FOR OPTIMAL SVA ALIGNMENTS

SVA ALIGNMENT
GMFCS 1 2 3
Insufficient incline. No shank reversal

SVA ALIGNMENT
GMFCS 1 2 3
Insufficient incline with shank reversal

SVA ALIGNMENT
GMFCS 1 2 3
Excessive incline. No knee or hip stiffness

SVA ALIGNMENT
GMFCS 1 2 3
Excessive incline with knee or hip stiffness

Owen 2002
GMFCS 1&2
112 legs
Mean SVA 11.4° Inc

The optimum SVA of an AFOFC seems to be dependent on 2 main factors;
1. The primary neurology
2. The consequent stiffness of the muscles and joints at the hip and knee
Many children will require an MTPJ Free AFO design coupled with flexible footwear. However, some children with gait category ‘Insufficient shank incline’ and many children with gait category ‘Excessive shank incline’ will need fixed MTPJs coupled with stiff rocker soles. The length of the rocker position determines the ‘toe lever’ which influences the timing of heel rise. The heel of the footwear cannot rise until the GRF reaches the start of the rocker. The more distal the rocker is placed the longer the ‘toe lever’ and the greater the leverage to prevent heel rise. The MTPJs on a normal foot are at 72% of the length of the foot, which provides the necessary stability in standing and mobility in walking. When optimising AFOFCs the rocker positions may need to be more or less than 72% of the length of the footwear. The key to successful optimisation of rocker soles is to have 1) the optimum size of footwear to provide optimum effective foot length 2) a very stiff sole and 3) a flat sole profile to the start of the rocker. Rockers are optimised by trials.

**A GUIDELINE FOR ROCKER POSITIONS:**
WALKING WITH FULL GAIT CYCLES: Insufficient Shank Incline 75%; Excessive Shank Incline without significant stiffness at hips and knees, 75-95%, with stiff hips and/or knees 85-95%. STEPPING can tolerate rockers at 90-100%. STANDING can tolerate rockers of 100% or more.
TEACHING STANDING, FIRST OR SMALL STEPS, STEPPING WITH OR WITHOUT WALKING AIDS
Owen E 2014, 2015

Biomechanical optimisation of AFOFCs does not just apply to those who can ambulate with full gait cycles, it also applies to children or adults who are just starting to take their first steps and also to those who have significant problems and are therefore only able to take small steps.

When teaching first steps to children with significant problems of muscle stiffness, muscle weakness, balance or other disabilities, it is a useful to use the following sequence. It can also be applied when teaching walking with small steps or stepping.

A Teach standing in AFOFCs which have optimised inclined SVA, combined with footwear that provides a very stable base. This footwear would have a flat sole profile, with an appropriate rocker at the appropriate place, and may also include a back float. This footwear design will provide a good base of support.

B In standing, encourage them to then translate the trunk anteriorly and posteriorly, moving the thigh from a reclined to vertical and inclined positions. Initially, they may need distal support at the top of the shanks to be able to do this.

C Encourage small steps with the stance leg moving from an MST position to an early TST position, with the thigh inclined and the GRF becoming aligned anterior to the knee and posterior to the hip, providing stability in stance.

D As walking progresses, they can start to develop late TST, TSW and LR, if possible.

E Some children and adults will not develop the ability to achieve a full TST combined with contralateral TSW. However, achieving TST to 40% GC provides a good stable gait.