

## Use of an Ankle-Foot Orthosis to Optimize Hip and Knee Biomechanics Following Stroke

Roy Bowers, Orthotist  
Barry Meadows, Bioengineer

### Abstract

An appropriately "tuned" solid ankle-foot orthosis (AFO), designed to accommodate gastrocnemius length, successfully realigned the ground reaction force (GRF) to the knee and hip in the late midstance and terminal stance phases of gait in a patient following stroke. Appropriate external moments were created at both joints, improving kinematics and the weight bearing ability of the affected limb.

### Background

While non-articulated AFOs are commonly employed to improve gait following stroke,<sup>1</sup> the importance of accommodating gastrocnemius length when casting the limb is not always recognized. Too often practitioners opt for a 90-degree angle as a matter of course, failing to recognize the detrimental consequences of ignoring gastrocnemius shortening. Specifically, if gastrocnemius length is not sufficient to allow ankle dorsiflexion to 90 degrees with the knee extended, then dorsiflexing the ankle to this angle in an AFO will actually limit knee extension in gait.<sup>2</sup>

Alternatively, some orthotists cast the ankle in plantarflexion so that the shank is maintained in a vertical alignment when the shoe is worn, ignoring the fact that in normal gait, the shank is actually inclined in midstance and terminal stance.<sup>3</sup> Importantly, at this stage of normal gait, GRF alignment generates simultaneous external extension moments at the knee and hip. This requires thigh inclination, which in the presence of a vertical shank would cause unacceptable knee hyperextension. Therefore, some shank inclination is also necessary.

Generation of simultaneous external extension moments at knee and hip in late stance has been demonstrated to improve stability and weight bearing through the limb in patients with cerebral palsy. It has also been found to be sensitive to small changes in tibial inclination angle;<sup>4</sup> i.e., "shank to vertical angle" (SVA). Solid AFOs must therefore be tuned to optimize gait, a fact not universally appreciated. Tuning involves fine adjustment of the SVA by adding or removing thin wedges under the heel of the AFO, with the intention of improving the kinematics of the limb segments and the kinetics at the knee and hip.<sup>2,4,5</sup>

The ability of an AFO to influence the kinetics and kinematics of the *hip* is not always recognized, nor is it evidenced in the stroke literature.<sup>1</sup> Many fail to recognize the importance of establishing this as an objective of orthotic treatment.<sup>4</sup>

### Case Study

The subject was a 67-year-old male with a right-sided hemiplegia following stroke. Unbraced gait demonstrated swing-phase equinus and poor knee flexion, and was markedly asymmetrical with poor contralateral stride length. Tibial kinematics throughout stance was abnormal, with insufficient shank inclination and poor hip extension in mid to terminal stance. Physical examination revealed gastrocnemius shortening (five-degree plantarflexion with knee extended). Passive range-of-hip joint extension, however, was good.



**Figure 1** shows an image captured from a video-vector recording of the terminal stance of the subject walking without an AFO. GRF alignment is far in front of the knee, resulting in an excessive external knee-extension moment. Significantly, it is also in front of the hip, generating an abnormal and undesirable external hip-flexion moment at this stage of gait.

With an AFO (**Figure 2**) the GRF is aligned more appropriately to the knee (reducing the external extension moment) and, importantly, is now behind the hip, generating the desired external hip-extension moment. The increase in height of the GRF indicates the improved ability of the affected limb to bear weight, with consequent improvement in contralateral step length.

### Methods



The subject was fitted with a homopolymer polypropylene AFO with carbon-fiber reinforcement at the ankle. Due to gastrocnemius shortening, the subject was cast in plantarflexion consistent with muscle length. In line with our normal clinical practice, wedges were progressively added under the heel to tune the AFO, using slow-motion video replay to confirm appropriate inclination of the shank and thigh in mid to terminal stance. Video-vector gait analysis subsequently confirmed successful GRF realignment.

## Discussion

Experience with the use of solid AFOs in children with cerebral palsy has demonstrated the clinical significance of realignment of the GRF to the knee and the hip in late stance. Specifically, the achievement of simultaneous external extension moments at *both* joints facilitates the generation of an appropriately high second vertical peak of GRF, demonstrating improved weight bearing.<sup>4</sup> This case study suggests that achieving similar results in adults with stroke may be possible and of equal clinical significance. Tuning the

AFO is necessary to achieve this but requires prior selection of an appropriate plantarflexion/dorsiflexion angle consistent with gastrocnemius length.

Following stroke, many patients face excessive biomechanical challenges due to poor segment kinematics and the abnormal relationship of the GRF to the proximal joints, particularly the hip. Paradoxically, they must respond with an impaired neurological system to biomechanical challenges that are greater than in their pre-morbid state. It could be argued that appropriate early orthotic intervention might reduce these biomechanical challenges, with consequent reduction in the required neuromuscular response facilitating and accelerating the rehabilitation process. This exciting possibility requires further investigation.

## Conclusion

When appropriately tuned, a solid polypropylene AFO was shown to have clinically important biomechanical effects on the gait of a stroke survivor, particularly in relation to the kinetics and kinematics of the hip, and the ability of the affected limb to bear weight. Correct plantarflexion/dorsiflexion angle in the AFO and appropriate adjustment of SVA are critical to this process.

## References

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*Roy Bowers, orthotist, is a senior lecturer at the National Centre for Training and Education in Prosthetics and Orthotics NCTEPO, University of Strathclyde, Glasgow, Scotland. He can be reached at [r.j.bowers@strath.ac.uk](mailto:r.j.bowers@strath.ac.uk).*

*Barry Meadows, bioengineer, is head of Neurobiomechanics at the WESTMARC location (West of Scotland Mobility and Rehabilitation Centre), Southern General Hospital, Glasgow, Scotland. He can be reached at [barry.meadows@sgh.scot.nhs.uk](mailto:barry.meadows@sgh.scot.nhs.uk).*

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