

# The effect of different shoes on functional mobility and energy expenditure in post-stroke hemiplegic patients using ankle-foot orthosis

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## Abstract

**Background:** Ankle-foot orthoses could be utilized both with and without shoes. While several studies have shown that ankle-foot orthoses improve gait abilities in hemiplegic patients, it remains unclear whether they should be used with shoes or without.

**Objectives:** The study purpose was to compare the effect of standard shoes and rocker shoes on functional mobility in post-stroke hemiplegic patients utilizing ankle-foot orthosis.

**Study design:** Randomized clinical study.

**Methods:** Thirty post-stroke hemiplegic patients participated in this study randomly assigned to two groups. Group I received standard shoes + ankle-foot orthosis and group II were provided with rocker shoes + ankle-foot orthosis. Their functional mobility and energy expenditure parameters including timed up and go, timed up stairs, timed down stairs, preferred walking speed, and oxygen (O<sub>2</sub>) cost (mL/kg/m) were measured.

**Results:** In group I, no significant changes were seen in outcome measures after wearing standard shoes. While in group II, O<sub>2</sub> cost and timed up and go time significantly decreased, and preferred walking speed increased when patients wore rocker shoes. Also, there was a significant difference between rocker shoes and standard shoes in improvement of timed up and go, preferred walking speed, and O<sub>2</sub> cost.

**Conclusion:** When patients using ankle-foot orthosis wore rocker shoes, their functional mobility improved and oxygen cost diminished. Also, rocker shoes was significantly more effective than standard shoes in improving functional mobility parameters.

## Clinical relevance

This study suggests that in post-stroke hemiplegic patients using ankle-foot orthosis, wearing rocker shoes can lead to much more improved functional mobility and decreased energy expenditure compared to ankle-foot orthosis only. Thus, in stroke patients, the combination of ankle-foot orthosis-rocker shoes is recommended for both rehabilitation programs and ankle-foot orthosis efficacy investigations.

## Keywords

Ankle-foot orthosis, shoes, functional mobility, energy expenditure, stroke

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## Background

Stroke is a major cause of death and disability worldwide.<sup>1–3</sup> Hemiplegia secondary to stroke may lead to decreased mobility,<sup>4</sup> altered gait pattern,<sup>5,6</sup> increased

energy consumption,<sup>7,8</sup> and un-coordinated movements.<sup>9</sup> Consequently, hemiplegic patients often face a lot of difficulties in their daily life activities.<sup>10</sup> Regarding the

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**Table 1.** Demographic characteristics of the patients (N = 30).

Gender	Age (mean and range)	Weight (mean)	Paretic side	Months after stroke (mean)	Ankle joint passive ROM (DF), ° (mean)
M: 19	59.3 (49–68)	64.7	L: 17	29.1	15 ± 5
F: 11			R: 13		

ROM: range of motion; DF: dorsi-flexion; M: male; F: female; L: left; R: right.

functional mobility is one of the most critical goals in rehabilitation of these patients.<sup>11</sup> Among different rehabilitation approaches, ankle-foot orthoses (AFOs) are widely prescribed to improve walking and functional mobility for patients with hemiplegia.<sup>8,12,13</sup>

Many studies have been conducted on the effect of AFOs on hemiplegic gait so far and most concluded that a suitable AFO could potentially improve function and increase gait velocity.<sup>7,14–17</sup> Moreover, energy expenditure is reported to be an important factor which can potentially affect the activities of daily living in stroke survivors. Although due to decreased gait velocity the rate of oxygen consumption in stroke patients is similar to healthy subjects, it is generally believed that their oxygen cost per distance walked is considerably higher than able-bodied persons, which could be decreased using an AFO.<sup>8</sup>

AFOs are usually utilized with shoes.<sup>18</sup> While several studies have shown that AFOs improve functional abilities in hemiplegic patients, it is still unclear that they are better to be used along with which type of shoes to have the most effect. On the other hand, normal function of the foot and ankle is described as three combined sequential rockers including heel rocker, ankle rocker, and forefoot rocker. Following hemiplegia, all three rockers are seriously damaged.<sup>19</sup> Previous studies conducted on the mechanism of the influence of AFOs have reported that AFOs improve heel and ankle rockers during walking; however, they did not seem to influence forefoot rocker in hemiplegic gait.<sup>10,18</sup> Also, it was demonstrated that rocker bars in shoes could result in improving rollover function of the foot and consequently, facilitating weight progression and push off or transferring weight from one limb to another. That is, the curvature of the rocker shoes (RS) leads to a better rolling of the body over the ground and reduces the need for foot movement.<sup>19–21</sup> Thus, it was hypothesized that wearing shoes with forefoot rocker modification while using AFO could improve walking ability and as a result functional mobility in hemiplegic patients.

The purpose of this study was to compare the effect of the standard shoes (SS) and RS on functional mobility and energy expenditure in patients with stroke utilizing AFO.

As the main objective of using various orthoses is to improve function and activities of daily living,<sup>22</sup> functional tests could be potentially useful indicators.<sup>23,24</sup> On the other hand, functional tests, which are considered to be valid and reliable,<sup>23–28</sup> seem to be cheap and easily

accessible so that clinicians will easily be able to evaluate the short-term effectiveness of the prescribed orthoses, without the need for voluminous and costly equipments. Hence, in this study, functional tests along with measurement of oxygen consumption per meter were used to evaluate the efficacy of the SS and RS on functional mobility and energy cost in hemiplegic patients secondary to stroke utilizing AFO.

## Methods

### Participants

Considering the confidence level of 95% and power of 80%, 30 hemiplegic patients secondary to stroke (both men and women) were recruited for the purpose of this study. Patients were randomly assigned into two groups through block randomization method. Inclusion criteria were having the age between 40 and 70 years, the spasticity score of 3 according to Modified Ashworth scale, the ability to walk with or without assistive device, and suffering from stroke for a period of at least 6 months. Patients were excluded if they had deformity in their spine or lower limbs, any history of surgery in their spine and lower limbs, cardiovascular problems or were unable to perform the tasks. Table 1 demonstrates demographic characteristics of the participants.

### Interventions

A prefabricated solid ankle-foot orthosis (SAFO), which was made of polypropylene, was prepared for each patient. The foot and ankle were kept at 90° to the lower leg (neutral plantigrade position) using orthosis. A rough (anti-slipping) rubber was attached to the bottom of the SAFO foot-plate in order to prevent slipping in AFO-only condition. As the attached rubber was thin (only 3-mm thick), and exactly the same rubber was used at the bottom of the shoes, it did not seem to affect the obtained results. Also, in order to put the foot and ankle in a secured position, four straps were used to tightly hold ankle-foot complex in the orthosis. Each orthosis was selected and fitted to the patient's limb by an expert orthotist.

Both SS and RS were custom fabricated (made of leather) based on anthropometric data obtained from the patients' foot and ankle. They were high top (extended to



**Figure 1.** Solid ankle-foot orthosis (SAFO).

lateral malleoli), in order to secure the AFO and foot properly, and had larger toe box to provide extra room for the AFO. At the sole of the SS and RS, ethylene vinyl acetate (EVA) rubber with standard hardness (shore-A 30–40) for midsole and a rough hard rubber (shore-A 50–60) were used. SS had almost flat footwear extended from heel to toe. In RS, rocker bar started at 65% of the full shoe length with respect to the posterior part of the heel with angle of 15°. The rest of the sole of the shoe was flat to provide maximum stability during standing and walking. As off-the-shelf RS are not usually high top and have heel-to-toe rockers which may potentially disturb hemiplegic patients' balance during walking, in this study, custom-made shoes were preferred to be utilized.

Patients were randomly assigned into two groups using block style randomization scheme. Group I received SS and group II were given RS while all participants used SAFO and wore the same shoes (Figure 1). Patients in each group were examined with and without their shoes in random sequences. Figure 2 shows flow chart of the study.

### Outcome measures

*Timed up and go (TUG) test.* Patients were asked to stand up from a standard chair, walk for 3 m, turn, walk back to the chair and sit down again. The time of this task was recorded in seconds.

*Timed up stairs (TUS) test.* Patients were instructed to go up to 10 steps of a stair that is produced for this test. Stairs included 10 stairs totally with 16.5 cm

high and 25 cm deep and 1 m wide with a rail on both sides. The total time of the task was recorded in seconds.

*Timed down stairs (TDS) test.* Patients were instructed to go down from the top to 10 steps, until they reached the land. The total time of the task was recorded in seconds.

*Preferred walking speed (PWS).* Patients were asked to walk 10 m in a straight line at self-selected speed. The time of the task was recorded in seconds and then divided to the distance (10 m).

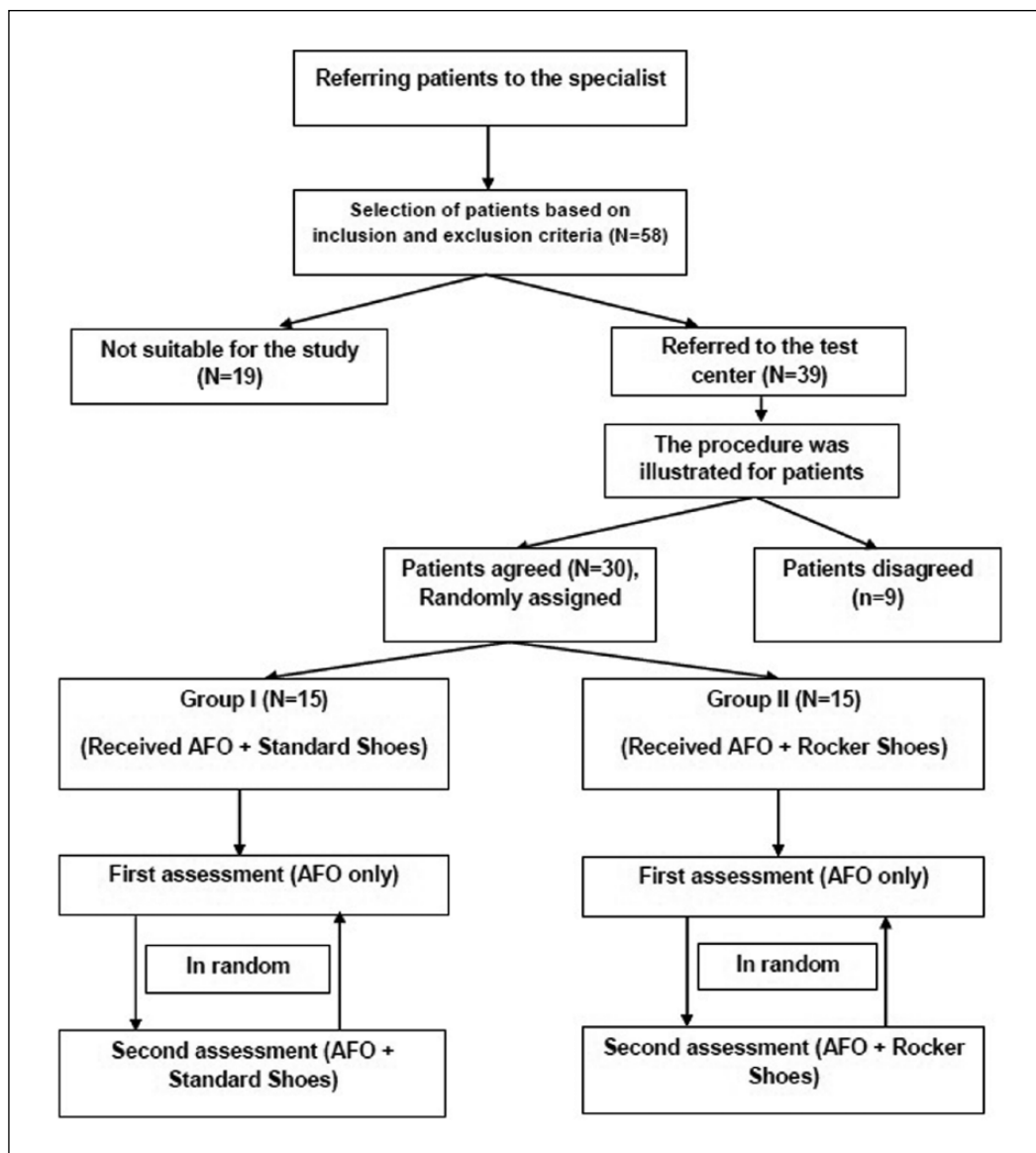
*Oxygen cost.* Oxygen uptake (mL/kg/m) was measured in order to examine the effect of standard and RS on energy expenditure in post-stroke hemiplegic patients. The participants walked on a motorized treadmill at their self-selected speed,<sup>8,29</sup> which had been determined and set before each test, and simultaneously, their oxygen cost was recorded by a breath-by-breath gas analyzer system (Cosmed Quark b2; Cosmed, Rome, Italy). It consisted of a facemask that covered mouth and nose that was tightened to the head. Participants were asked to walk for 5 min while the data of the last 3 min were recorded to be analyzed. The data of O<sub>2</sub> consumption were measured when it reached to a stabilized (steady-state) condition. Five-minute rest in a sitting position was considered appropriate for each patient between the first and second measurements.

With regard to functional tests, at least three trials were performed for each patient, and the overall average of obtained data was used for final evaluation. Prior to each condition (AFO only, AFO+RS, and AFO+SS conditions), patients were given 5–10 min practice time to be acclimatized. Furthermore, in order to become familiar with the test procedures, all participants were asked to perform the tests at least one time before the measurements were taken.

The means and standard deviations were calculated for the performed tests. The study was approved by the local medical ethics committee at the University of Social Welfare and Rehabilitation Sciences, Tehran, Iran and all participants signed a consent form before their participation in the study.

### Data analyses

Kolmogorov–Smirnov test was used to assess the normality of the data. A paired t-test and an independent t-test were used to compare changes between wearing and not wearing SS and RS while using an AFO within each group and between two groups, respectively. The level of  $p < 0.05$  was considered statistically significant. SPSS statistical software version 16.0 (SPSS Inc., Chicago, IL, USA) was utilized for data analysis.



**Figure 2.** Flow chart of the study.

## Results

Table 2 gives information regarding functional mobility tests and oxygen cost recorded from participants of groups I and II while using AFO. In group I, although PWS, TUG, and oxygen cost demonstrated some improvements, no statistically significant changes were found in all outcome measures while patients wore SS ( $p > 0.05$  in all instances). In group II, wearing RS led to significant reduction in the time of performing TUG ( $p < 0.05$ ). PWS was also significantly increased after wearing RS ( $p < 0.05$ ). Accordingly, oxygen cost significantly decreased when patients wore RS along with their AFO ( $p < 0.05$ ). However, as for TUS and TDS, no significant differences were seen following wearing RS while utilizing AFO ( $p > 0.05$ ).

Table 3 provides data analysis on between-group changes. There was no significant difference in outcome measures between the two groups while using AFO only ( $p > 0.05$ ). However, with RS, patients demonstrated significantly more PWS, less time of doing TUG, and less oxygen cost compared with wearing SS ( $p < 0.05$  in all instances). No significant changes were seen regarding stairs tests ( $p > 0.05$ ).

## Discussion

AFOs are commonly used by hemiplegic patients.<sup>30</sup> It is generally believed that AFOs improve functional mobility and increase walking velocity in patients with hemiplegia.<sup>16,17</sup> AFOs are routinely utilized with shoes.<sup>18</sup> Nevertheless,

**Table 2.** Functional mobility and energy expenditure parameters of the participants in group I and group II using AFO (mean  $\pm$  SD).

	TUG (s)	PWS (m/s)	TUS (s)	TDS (s)	O <sub>2</sub> cost
Group I					
AFO only	25.35 $\pm$ 12.84	0.62 $\pm$ 0.12	25.10 $\pm$ 8.07	29.75 $\pm$ 9.48	0.53 $\pm$ 0.14
AFO + SS	22.87 $\pm$ 14.18	0.64 $\pm$ 0.14	24.14 $\pm$ 7.90	30.04 $\pm$ 6.56	0.49 $\pm$ 0.19
p-Value	0.085	0.074	0.416	0.594	0.07
Group II					
AFO only	24.41 $\pm$ 14.32	0.60 $\pm$ 0.18	24.6 $\pm$ 9.83	28.3 $\pm$ 12.56	0.51 $\pm$ 0.04
AFO + RS	18.25 $\pm$ 10.76	0.71 $\pm$ 0.32	26.34 $\pm$ 10.28	29.57 $\pm$ 8.27	0.42 $\pm$ 0.16
p-Value	0.032	0.005	0.281	0.475	0.031

SD: standard deviation; AFO: ankle-foot orthosis; TUG: timed up and go test; PWS: preferred walking speed; TUS: timed up stairs; TDS: timed down stairs; O<sub>2</sub> cost: oxygen cost (mL/kg/m); SS: standard shoes; RS: rocker shoes.

**Table 3.** Comparison of the functional mobility and energy expenditure participants of the two groups (mean  $\pm$  SD).

	TUG (s)	PWS (m/s)	TUS (s)	TDS (s)	O <sub>2</sub> cost
Group I (AFO only)	25.35 $\pm$ 12.84	0.62 $\pm$ 0.12	25.10 $\pm$ 8.07	29.75 $\pm$ 9.48	0.53 $\pm$ 0.14
Group II (AFO only)	24.41 $\pm$ 14.32	0.60 $\pm$ 0.18	24.6 $\pm$ 9.83	28.3 $\pm$ 12.56	0.51 $\pm$ 0.04
p-Value	0.593	0.241	0.364	0.439	0.084
Group I (AFO + SS)	22.87 $\pm$ 14.18	0.64 $\pm$ 0.14	24.14 $\pm$ 7.90	30.04 $\pm$ 6.56	0.49 $\pm$ 0.19
Group II (AFO + RS)	18.25 $\pm$ 10.76	0.71 $\pm$ 0.32	26.34 $\pm$ 10.28	29.57 $\pm$ 8.27	0.42 $\pm$ 0.16
p-Value	0.043	0.021	0.164	0.463	0.039

SD: standard deviation; TUG: timed up and go; PWS: preferred walking speed; TUS: timed up stairs; TDS: timed down stairs; O<sub>2</sub> cost: oxygen cost (mL/kg/m); SS: standard shoes; RS: rocker shoes; AFO: ankle-foot orthosis.

limited data exist regarding the efficacy of different shoes on hemiplegic patients' function while using AFO. Therefore, this study was designed to evaluate the effect of SS and RS on functional mobility and energy expenditure of the post-stroke hemiplegic patients.

According to the obtained data, SS with flat footwear resulted in no significant changes in functional mobility and energy cost in participants of group I. In a study conducted by Churchill et al.,<sup>31</sup> it was concluded that shoes may improve some gait parameters in hemiplegic patients including stride-length, although other parameters such as gait velocity and cadence demonstrated no significant changes. The differences between the results of this study and those reported by Churchill et al. may be attributed to the interventions and group studied. Churchill et al. compared "shoes-only" condition with "shoes+AFO condition," while in this study "AFO-only" condition was compared to "AFO+shoes" condition.

On the other hand, the findings of this study demonstrated a significant increase in PWS while patients wore RS. The results also indicated that the time of performing TUG was considerably reduced and oxygen cost was decreased while patients wore RS along with their AFO. It seems that these improvements may be attributed to the effect of rocker bars which were designed at the sole of the shoes. Many studies have been conducted on the effect of rocker soles on various gait characteristics.<sup>20,21,32-34</sup>

Generally, it was reported that rocker bars in addition to removing weight from special areas like metatarsal heads affect knee-ankle-foot function and, consequently, improve weight transferring and enhance anterior progressive forces during stance phase of gait.<sup>20,21,35</sup> Arazpour et al. investigated the effect of rocker bar on gait characteristics in patients suffering from spinal cord injury. They modified the sole of the foot part of standard advanced reciprocating gait orthosis with cushion heels and forefoot rocker bars. They demonstrated that rocker bars have a positive effect on gait patterns including walking speed.<sup>35</sup> Accordingly, reduction in oxygen cost has most likely been due to improved gait pattern and the better and faster weight transferring from heel strike to toe off during stance phase of gait.

Various studies have demonstrated that any improvement in impaired gait pattern secondary to stroke may lead to diminished energy expenditure.<sup>8,29,36</sup> The results of this study were consistent with previous research which reported that RS improves walking ability in healthy and neurologically disabled subjects.<sup>20,21,35</sup>

Moreover, the results of this study indicated that RS had no significant effect on the time of doing TUS and TDS. As the main effect of forefoot rocker bar is on push off and toe clearance at the late stance phase of the gait cycle, it seems that RS was not able to efficiently affect the time of going up and down stairs.

Between-group changes of this study showed that RS had significantly more positive effect on functional mobility outcome measures (except for stairs tests) and oxygen cost in hemiplegic patients in favor of RS compared with SS. These findings gave support to the previous research in which rocker bars contributed to faster weight progression and as a result better gait pattern.

One of the limitations of this study was that only the immediate effect of the interventions was assessed. Evaluation of the short-term and long-term efficacy of SS and RS in further studies is strongly suggested. Lack of kinetic and kinematic data was another limitation of this study. It is suggested that these outcome measures be included in future studies. Also, examining different kinds of RS along with using AFOs is recommended for further research.

## Conclusion

This study revealed that if RS is utilized along with AFOs in post-stroke hemiplegic patients, further improvement in gait velocity and, consequently, performing TUG task as well as reduction in energy expenditure may be achieved. Finally, findings of this study can potentially provide hemiplegic patients who use AFO to walk and their caregivers with valuable information regarding the effect of standard and RS on functional mobility and energy expenditure.

## Author contribution

All authors contributed equally in the preparation of this manuscript.

## Declaration of conflicting interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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## References

- Strong K, Mathers C and Bonita R. Preventing stroke: saving lives around the world. *Lancet Neurol* 2007; 6: 182–187.
- Feigin VL, Lawes CM, Bennett DA, et al. Worldwide stroke incidence and early case fatality reported in 56 population-based studies: a systematic review. *Lancet Neurol* 2009; 8: 355–369.
- Bonita R and Beaglehole R. Stroke prevention in poor countries: time for action. *Stroke* 2007; 38: 2871–2872.
- Nolan KJ and Yarossi M. Weight transfer analysis in adults with hemiplegia using ankle foot orthosis. *Prosthet Orthot Int* 2011; 35: 45–53.
- Balaban B and Tok F. Gait disturbances in patients with stroke. *PM R* 2014; 6: 635–642.
- Goldie PA, Matyas TA and Evans OM. Gait after stroke: initial deficit and changes in temporal patterns for each gait phase. *Arch Phys Med Rehabil* 2001; 82: 1057–1065.
- Franceschini M, Massucci M, Ferrari L, et al. Effects of an ankle-foot orthosis on spatiotemporal parameters and energy cost of hemiparetic gait. *Clin Rehabil* 2003; 17: 368–372.
- Danielsson A and Sunnerhagen KS. Energy expenditure in stroke subjects walking with a carbon composite ankle foot orthosis. *J Rehabil Med* 2004; 36: 165–168.
- Fatone S and Hansen AH. Effect of ankle-foot orthosis on roll-over shape in adults with hemiplegia. *J Rehabil Res Dev* 2007; 44: 11–20.
- Nolan KJ and Yarossi M. Preservation of the first rocker is related to increases in gait speed in individuals with hemiplegia and AFO. *Clin Biomech* 2011; 26: 655–660.
- De Wit DC, Buurke JH, Nijlant JM, et al. The effect of an ankle-foot orthosis on walking ability in chronic stroke patients: a randomized controlled trial. *Clin Rehabil* 2004; 18: 550–557.
- Wang RY, Lin PY, Lee CC, et al. Gait and balance performance improvements attributable to ankle-foot orthosis in subjects with hemiparesis. *Am J Phys Med Rehabil* 2007; 86: 556–562.
- Pohl M and Mehrholz J. Immediate effects of an individually designed functional ankle-foot orthosis on stance and gait in hemiparetic patients. *Clin Rehabil* 2006; 20: 324–330.
- Erel S, Uygur F, Engin Simsek I, et al. The effects of dynamic ankle-foot orthoses in chronic stroke patients at three-month follow-up: a randomized controlled trial. *Clin Rehabil* 2011; 25: 515–523.
- Tyson SF and Thornton HA. The effect of a hinged ankle foot orthosis on hemiplegic gait: objective measures and users' opinions. *Clin Rehabil* 2001; 15: 53–58.
- Tyson SF, Sadeghi-Demneh E and Nester CJ. A systematic review and meta-analysis of the effect of an ankle-foot orthosis on gait biomechanics after stroke. *Clin Rehabil* 2013; 27: 879–891.
- Tyson SF and Kent RM. Effects of an ankle-foot orthosis on balance and walking after stroke: a systematic review and pooled meta-analysis. *Arch Phys Med Rehabil* 2013; 94: 1377–1385.
- Desloovere K, Molenaers G, Van Gestel L, et al. How can push-off be preserved during use of an ankle foot orthosis in children with hemiplegia? A prospective controlled study. *Gait Posture* 2006; 24: 142–151.
- Perry J and Burnfield JM. *Gait analysis: normal and pathological function*. 2nd ed. Thorofare, NJ: SLACK Incorporated, 2010.
- Wu WL, Rosenbaum D and Su FC. The effects of rocker sole and SACH heel on kinematics in gait. *Med Eng Phys* 2004; 26: 639–646.
- Forghany S, Nester CJ and Richards B. The effect of rollover footwear on the rollover function of walking. *J Foot Ankle Res* 2013; 6: 24.
- Nolan KJ, Savalia KK, Lequerica AH, et al. Objective assessment of functional ambulation in adults with hemiplegia using ankle foot orthotics after stroke. *PM R* 2009; 1: 524–529.

23. Zaino CA, Marchese VG and Westcott SL. Timed up and down stairs test: preliminary reliability and validity of a new measure of functional mobility. *Pediatr Phys Ther* 2004; 16: 90–98.
24. Deathe AB and Miller WC. The L test of functional mobility: measurement properties of a modified version of the timed “up & go” test designed for people with lower-limb amputations. *Phys Ther* 2005; 85: 626–635.
25. Flansbjer UB, Holmback AM, Downham D, et al. Reliability of gait performance tests in men and women with hemiparesis after stroke. *J Rehabil Med* 2005; 37: 75–82.
26. Amatachaya S, Naewla S, Srisim K, et al. Concurrent validity of the 10-meter walk test as compared with the 6-minute walk test in patients with spinal cord injury at various levels of ability. *Spinal Cord* 2014; 52: 333–336.
27. Verschuren O, Zwinkels M, Ketelaar M, et al. Reproducibility and validity of the 10-meter shuttle ride test in wheelchair-using children and adolescents with cerebral palsy. *Phys Ther* 2013; 93: 967–974.
28. Peters DM, Fritz SL and Krotish DE. Assessing the reliability and validity of a shorter walk test compared with the 10-Meter Walk Test for measurements of gait speed in healthy, older adults. *J Geriatr Phys Ther* 2013; 36: 24–30.
29. Thijssen DH, Paulus R, van Uden CJ, et al. Decreased energy cost and improved gait pattern using a new orthosis in persons with long-term stroke. *Arch Phys Med Rehabil* 2007; 88: 181–186.
30. Wang YT and Abi-Sarkis G. Effect of an ankle stabilizing orthosis on selected ankle kinematics during walking. *Res Sports Med* 2007; 15: 297–308.
31. Churchill AJ, Halligan PW and Wade DT. Relative contribution of footwear to the efficacy of ankle-foot orthoses. *Clin Rehabil* 2003; 17: 553–557.
32. Sobhani S, Hijmans J, van den Heuvel E, et al. Biomechanics of slow running and walking with a rocker shoe. *Gait Posture* 2013; 38: 998–1004.
33. Sobhani S, Bredeweg S, Dekker R, et al. Rocker shoe, minimalist shoe, and standard running shoe: a comparison of running economy. *J Sci Med Sport* 2014; 17: 312–316.
34. Forghany S, Nester CJ, Richards B, et al. Rollover footwear affects lower limb biomechanics during walking. *Gait Posture* 2014; 39: 205–212.
35. Arazpour M, Hutchins SW, Ahmadi Bani M, et al. The influence of a rocker sole adaptation on gait parameters in spinal cord injury patients ambulating with the advanced reciprocating gait orthosis—a pilot study. *Disabil Rehabil Assist Technol* 2015; 10: 89–92.
36. Bleyenheuft C, Caty G, Lejeune T, et al. Assessment of the Chignon dynamic ankle-foot orthosis using instrumented gait analysis in hemiparetic adults. *Ann Readapt Med Phys* 2008; 51: 154–160.