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ANKLE-FOOT ORTHOSIS HAS LIMITED EFFECT ON WALKING TEST PARAMETERS AMONG PATIENTS WITH PERIPHERAL ANKLE DORSIFLEXOR PARESIS

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The aim of this study was to determine the relationship between ankle dorsiflexor strength and performances on several walking tests and to determine the effect of ankle-foot orthosis (AFO) use on walking tests. The following tests were used: 10-metre walking test (with and without three stairs), a complex walking task (6-minute walk with cognitive loading) and a subjective evaluation (SIP68 mobility scale and questionnaire). Isometric strength of the ankle dorsiflexors was measured. All walking tests were performed with and without AFO in random order. When relating torque values to walking performances, the highest correlation was found with the "10 metre" and "10 metre with stairs" test ($r = -0.51$, i.e. an inverse relationship). No threshold in the degree of paresis was found below which walking disability suddenly increased. No significant improvement could be demonstrated from AFO use on the 10-metre tests. Improvement on the 6-minute test was nearly significant ($p = 0.06$), the questionnaire revealed a positive opinion on AFO use related to overall walking function and effort. Thus, we have to conclude that these walking tests do not aid the clinician in estimating the severity of (progression of) the paresis nor to detect differences in degree of paresis between subjects.

Key words: paresis, orthosis, AFO, walking test.

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INTRODUCTION

The ICIDH (1) (International Classification of Impairments, Disabilities and Handicaps) suggests a relationship between an impairment, i.e. loss of a physical function, and a disability, loss of a capacity to perform. Two models, as extremes of a continuum, are suggested in the literature to describe this relationship. These are a sliding scale and a threshold model, as illustrated in Fig. 1.

In a sliding scale, a linear relationship exists between the degree of impairment and the subsequent disability. A threshold model allows for a certain amount of impairment, i.e. loss of strength before walking disabilities become evident (2). The same is true for example for loss of vision or cardiac output, before driving or sporting becomes impaired.

Study A tried to identify the nature of this relation for ankle dorsiflexor strength and walking. Walking ability was assessed by the 10-metre walking test, with and without 3 stairs, the 6-minute test with a cognitive task, which was used to mimic a walking situation related to daily function, i.e. walking while focusing attention elsewhere, and the SIP68 mobility scale (3). This scale consists of 12 statements to which a subject can agree or disagree concerning walking in varying circumstances, such as "I walk shorter distances or stop to rest often".

The following questions were posed in this study:

1. Which relationship does exist between ankle dorsiflexor strength and the outcome on 4 walking tests?
2. Which walking test is the most sensitive to strength loss of the dorsiflexors?

Patients with an ankle dorsiflexor paresis often use an ankle-foot orthosis (AFO) to facilitate walking. Of course, the foot drop is corrected by the orthosis, but it also hinders ankle mobility, adds weight to the leg and is sometimes difficult to accept (4). Study B was focused on the question whether and in which circumstances the use of an AFO does improve performances on the aforementioned walking tests in paretic patients. All tests were performed with and without AFO in random order. Finally, those patients who used an AFO over 6 weeks filled in a questionnaire in which they could indicate whether, in their perception, certain activities had improved by wearing an AFO.

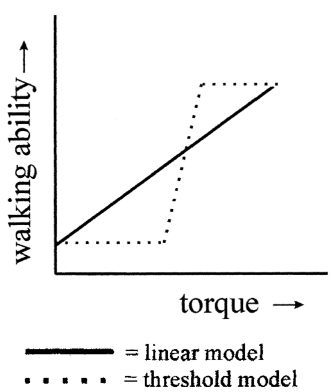

Fig. 1. Difference between threshold model and sliding scale model in the relation between torque and function (i.e. walking ability).

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Table I. *Subjects participating in Study A and B*

	Test	M:F	Mean age (years)	Duration paresis (weeks)
Study A				
$n = 36$	10-metre test 10-metre test with stairs SIP	27:9	52 (SD = 16)	101 (SD = 183)
$n = 13$	6-minute test	12:1	54 (SD = 16)	241 (SD = 14)
Study B				
$n = 27$	10-metre test 10-metre test with stairs	20:7	54 (SD = 17)	130 (SD = 15)
$n = 13$	6-minute test	12:1	54 (SD = 16)	241 (SD = 14)
$n = 16$	questionnaire	11:5	57 (SD = 17)	19 (SD = 15)

M:F = ratio male:female subjects; SD = standard deviation of the mean; SIP = sickness impact profile.

The following questions were posed:

1. To what extent do the scores on the 10-metre walking test, with and without stairs, and the 6-minute walking test, immediately improve when an AFO is used?
2. Is there a perceived amelioration of function after 6 weeks of AFO use?

METHODS

In different sessions, the relationship between the degree of paresis and walking performances, and the effect of AFO use on walking tests were studied.

Subjects

Study A: relationship between paresis and walking performances. Thirty-six patients, 27 men and 9 women, participated in this study meeting the following inclusion criteria: age 18 years or older, foot drop MRC 1–4 (5) (Medical Research Council strength gradation; 0 = paralysis, 1 = muscle contraction, 2 = movement without overcoming gravity, 3 = against gravity, 4 = against slight resistance, 5 = against resistance), caused by a lesion of the peroneal nerve or a L5 radiculopathy, no AFO use and no additional pain, orthopaedic, rheumatologic or neurologic pathology that could interfere with their walking ability. All subjects signed an informed consent. The study was approved by the SRL/iRv Medical Ethical Committee. Patients were recruited from the outpatient clinic from the departments of neurology and rehabilitation from a regional hospital. Measurements took place at a rehabilitation research centre.

Study B: effect of AFO use on walking performances. Twenty-seven patients from study A later on agreed to participate in study B. These patients performed both 10-metre tests with and without AFO. A random 13 of these patients also walked the 6-minute test with and without AFO.

A random 16 of the 36 patients of study A (allocated randomly alternately in the order in which subjects were included) started AFO use after the first measurements. They completed a questionnaire with a subjective evaluation after 6 weeks.

Table I describes the subjects participating in the experiments. Figure 2 relates the MRC values of the participating subjects to their strength values.

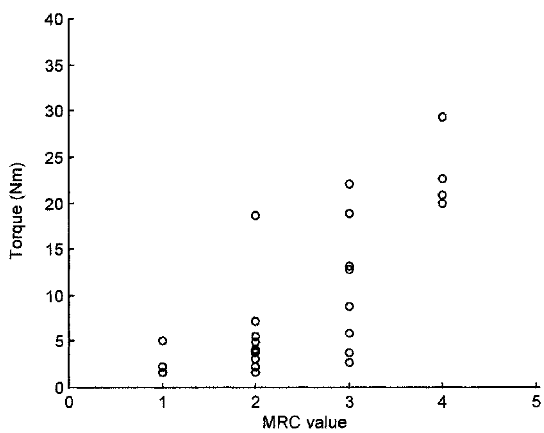
Measurements

All subjects started with the isometric ankle dorsiflexion torque measurements. Both sides were measured consecutively while the patient was in a supine position with the hips slightly flexed and knees in extension. The foot was positioned against a small horizontally placed bar at the level of the first metatarso-phalangeal joint. A load cell (Tedea-Huntleigh model 601 Europe Ltd, Cardiff, UK) was used to measure force. Data acquisition was performed using a 12-bit DT2824 PGL A/D converter board (Data Translation Inc., Marlboro, MA) and MUCAPS software (Multi Channel Acquisition and Processing System, iRv, Hoensbroek, Netherlands) with a sample frequency of 500 Hz and a sample time of 10 seconds. Torque was calculated using force and force lever data, i.e. the distance between the contact area of the dynamometer with MTP1 and the line connecting the apices of the lateral and medial malleolus, representing the position of the ankle flexion axis (6). The centre of the beam was in alignment with the centre of the load cell through the use of an U-shaped rigid light-weight hook, as illustrated in Fig. 3.

Calibration of the dynamometer was performed under static conditions with a known weight after each complete session. Body weight, height and foot size were also measured. Measurements took place in 30 plantar flexion of the ankle. Subjects repeated the contraction 5 times with a 1-minute interval to prevent fatigue. All patients were given standardized verbal instruction to pull the foot against the beam with a maximum effort during 5 seconds. No verbal encouragement was given. An analogue gauge positioned next to the patient gave visual feedback on the relative strength of the contraction. Reproducibility of this measurement protocol was tested in an earlier study and resulted in a coefficient of variation (CV) of 4.2% (SD = 3.6) (7).

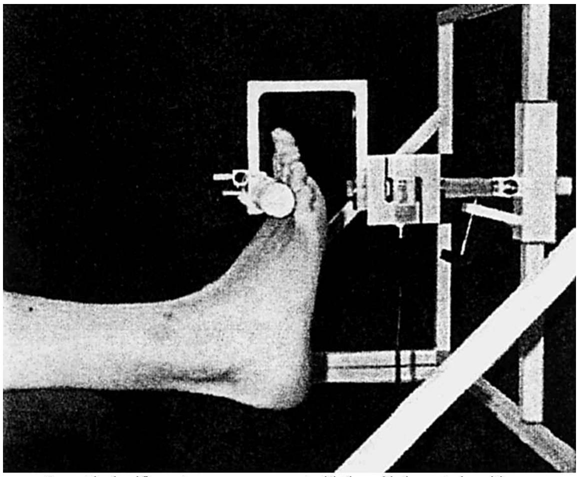
Three walking tests were performed and a questionnaire was filled out afterwards.

First, walking ability was measured by asking the patient to walk 10 metres at maximum safe walking speed while time was recorded by a stopwatch. Patients started from a standing position. Use of a walking aid



MRC = strength gradation system 0 = paralysis; 1 = slight contraction; 2 = movement; 3 = movement against gravity; 4 = against minimal resistance; 5 = against substantial resistance.

Fig. 2. Relationship between MRC value and torque (Nm) of the ankle dorsiflexors.



Isometric dorsiflexor torque measurement with the ankle in neutral position (0°). The plastic beam at the level of the metatarsalphalangeal joints is connected by a U-shaped hook to a load cell.

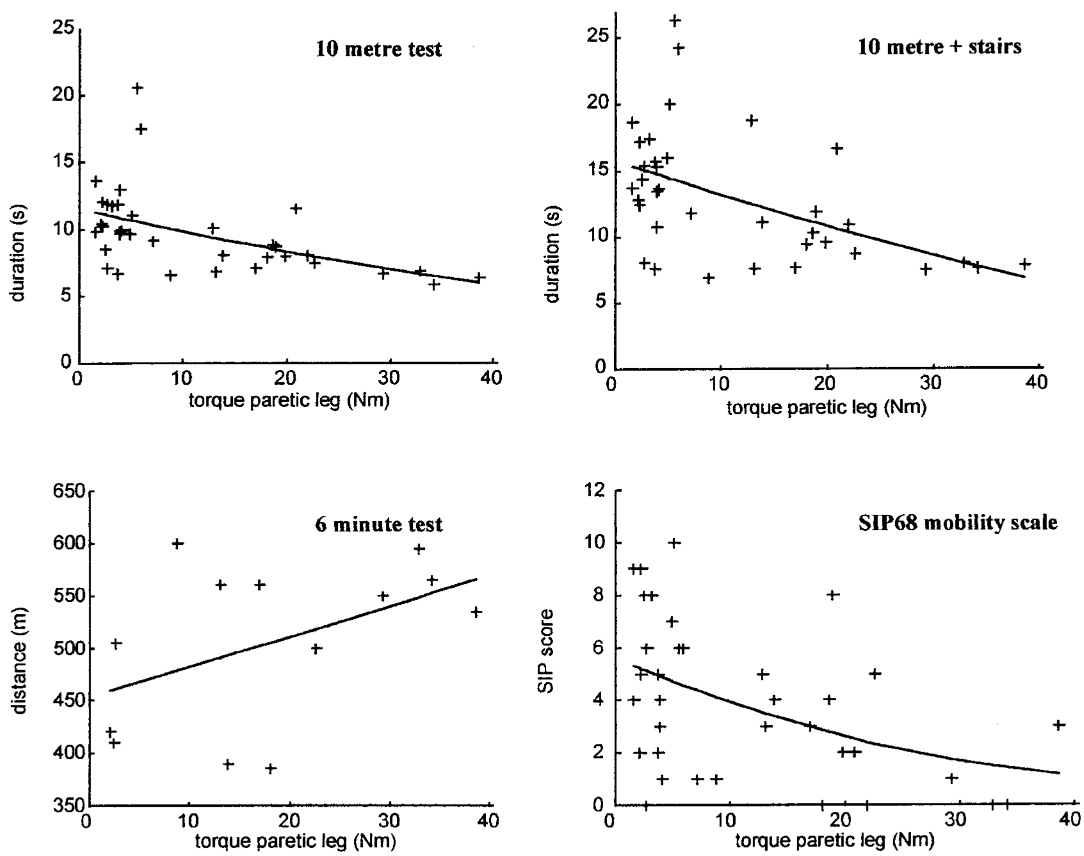
Fig. 3. Torque measurement of the ankle dorsiflexors.

was allowed during the test, but only 2 people used a crane or crutch. The test was performed with and without an AFO, in random order. A standard AFO was used. Secondly, the 10-metre walking test was modified by adding a three-step stair in the middle of the track. The protocol was identical to the first 10-metre test. After a break of 10 minutes, patients were asked to walk for 6 minutes at maximum walking speed while subtracting 7 from 1000 without verbal encouragement. The cognitive task was added to mimic a functional situation in which walking is often combined with performing tasks or talking. The calculation task hinders possible cognitive compensation mechanisms involved in safe walking with a dorsiflexor paresis. The walking distance was registered at 5 metre intervals, every 2 minutes and could be read from signs which where placed at the wall every 5 metres along an indoor, flat surface track. The test was performed twice, i.e. at random with and without an AFO. Both tests were interspaced by a resting period of 15 minutes. In this time patients filled out the mobility scale of the SIP68.

Sixteen patients started AFO use after this measurement session and completed a questionnaire with subjective evaluation of AFO use after 6 weeks.

Data analysis

Strength data were analysed off-line using the MATLAB software



A second order curve is fitted:

10 m test:	$F(x)=0.0009\,x^2 - 0.1799\,x + 11.5718$
10 m test stairs:	$F(x)=0.001\,x^2 - 0.2691\,x + 15.7762$
6 min test:	$F(x)=0.0029\,x^2 + 2.668\,x + 454.2175$
SIP68:	$F(x)=0.0019\,x^2 - 0.1873\,x + 5.6247$

Fig. 4. Relationship between torque of the ankle dorsiflexors and walking test performances.

package (The Math Works Inc., Natick, MA). A 1-second sustained maximum force effort was calculated from the load cell signal for each trial for each subject using a windowing technique. In order to determine the net muscle strength it is necessary to correct for the effect of the weight of the foot (8), which is estimated at 1.4% of the total body weight (9). The three highest torque values were selected and the average of these three values was used as the maximum value for the subject, a procedure also used by Heinonen et al. (10). This process resulted in one mean torque value, corrected for gravity, for each subject. Outcome of the 10-metre walking test and the 10-metre walking test with stairs was given in seconds. Results of the 6-minute walking test were expressed in metres walking distance.

The relation between the strength values and walking tests outcome was expressed by the Pearson correlation coefficient. The percentage of variance in walking test results that could be explained by the strength parameter was also given. An iterative process involving a linear fitting of the data using incremental numbers of data points of the total data set was done, in search of a clear cut off point below which a sharp decline in function occurred.

The Wilcoxon's signed rank test was used to determine the amount of change in walking test performances induced by AFO use. All statistical analyses were done with SPSS (SPSS Inc., Chicago, IL).

RESULTS

Study A: relation between degree of paresis and walking performances

The relationship between torque and the performances on the walking tests are given in Fig. 4. A second order curve is fitted through the data.

No threshold, i.e. a sharp distinct transition between the slopes of the consecutive lines during the incremental linear fitting, could be identified for either of the four tests. The Pearson correlation coefficient, indicating the degree to which there is a linear relation between the variables, varied between 0.46 and −0.51. The subsequent amount of variance explained by the degree of the paresis ranged from 21 to 26% (Table II).

Study B: effect of AFO use on walking performances

There was no significant improvement on either test on AFO use, with p-values of 0.88 and 0.37 respectively for the 10-metre test and the 10-metre with stairs test. The 6-minute test had a p-value of 0.06 with only 13 subjects, indicating a tendency to an improved performance with AFO use.

The subjective evaluation of 16 patients after 6 weeks of AFO use, indicated a positive result on walking performance and walking effort in 75% of all cases. No subjective improvement was reported on walking stairs or walking speed. Squatting with an AFO was difficult.

Table II. *Correlation between torque and scores on the walking tests*

	10-metre	10-metre + stairs	6-minute	SIP68
Pearson's r	−0.51	−0.51	0.46	−0.45
Variance explained	26%	26%	22%	21%

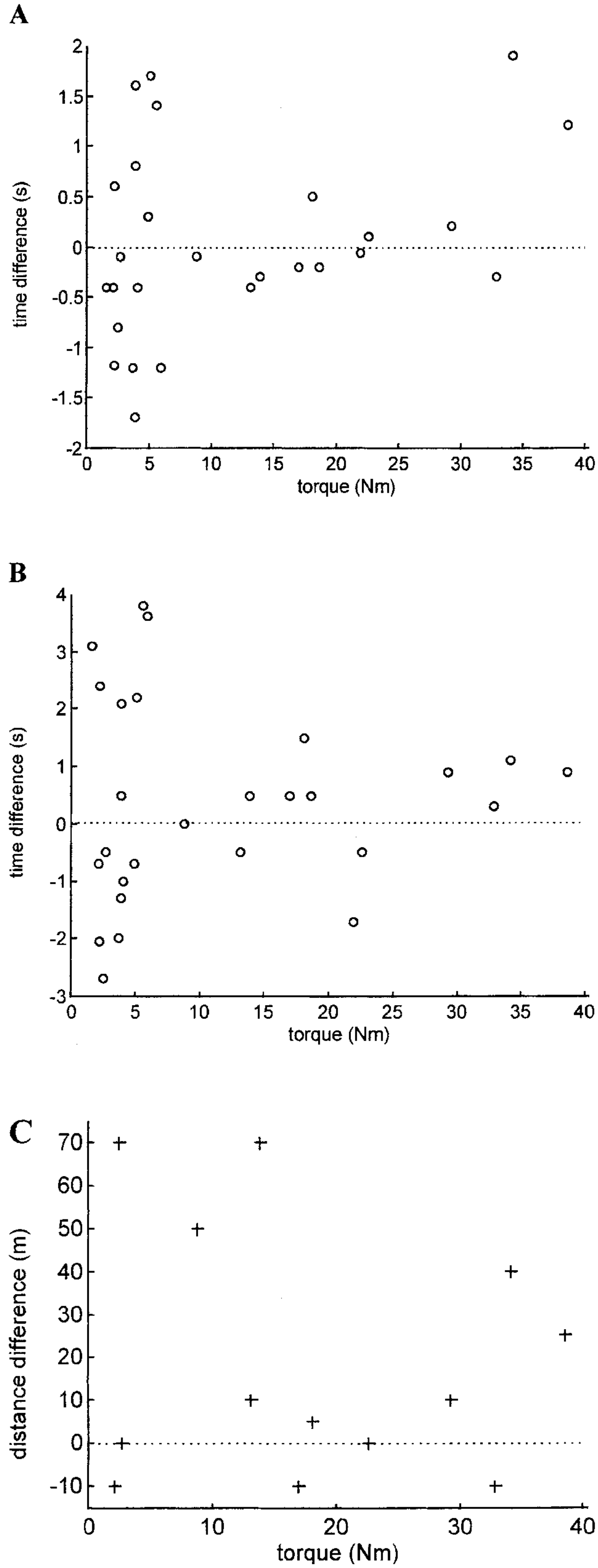


Fig. 5. Differences in walking scores between ankle-foot orthosis (AFO) and no-AFO use (score on test with AFO minus score on test without AFO) for A: 10-metre test, B: 10-metre with stairs, C: 6-minute walk.

DISCUSSION

Relationship between ankle dorsiflexion strength and walking test performances

The results on the walking tests reflect a large inter-individual variety, especially in those subjects with a low strength value. In these subjects, very large differences in test results are seen, some results even comparable with those of normal strength values. The distance walked in the 6-minute walking test (525 metres (SD = 76)) by our paretic subjects was comparable with that of healthy subjects (631 (SD = 93)(11) and 535 metres (12)).

A clear cut-off point in torque value below which walking difficulties occurred could not be demonstrated, neither on the walking tests, nor on the SIP68 mobility scale measuring perceived walking comfort. We could demonstrate neither a linear nor threshold model in our data.

Other researchers in the rehabilitation field however did describe these models. An example of the threshold model is found in Stam & Binkhorst (13) who described this effect in Guillain-Barré patients. All patients had good functional scores with strength levels of 80% or more of their normal strength, and very bad test scores below 20% of their normal strength. Between 20% and 80% of normal strength values, scores on functional tests differed largely, possibly indicating differences in compensation abilities. Rantanen et al. (14) found poor walking ability in older women with a knee extension torque of less than 1.1 Nm/kg, above this strength gradual improvement occurred up to a threshold of 2.3 Nm/kg above which no increase of walking speed was gained by more strength.

A sliding scale is described by Salsich & Mueller (15) for example, who found a strong ($r = 0.69$) correlation between hip extension strength and walking speed in diabetic patients with a transmetatarsal amputation. Rantanen et al. (16) also found a significant ($p < 0.001$) association between knee extension torque and maximum walking speed and climbing stairs in older subjects.

The highest (inverse) correlation ($r = -0.51$) was found with both the 10-metre tests. Adding stairs in the 10-metre distance did not change the test's sensitivity. Torque of the dorsiflexors explained thus only 26% of the variance of the test results. Lankhorst et al. (17) also found that strength of the knee muscles could only explain 25–35% of the variance in walking tests of patients with gonarthrosis.

Clinical implications

It remained unclear, why some patients with a mild paresis reported a lot of problems in daily life, whereas others, with a more severe paresis perceived only few problems. Apparently, other factors play an important role, for example an increase of attention focused on the task, visual control, a slower walking speed, compensation from other muscles, movement skill or overall condition (18). Geurts et al. (19) demonstrated that in patients with a prosthesis after a recent amputation, concentration was highly focused on maintaining balance, especially in the first weeks of rehabilitation. The accumulated effect of these different compensation facilities can probably account for the large inter-individual variety, especially between patients with comparable low torque values. Due to this large inter-individual variety, and the fact that no threshold was found, these tests can not be used for early detection of the development of functional problems, for example in patients with a (progressive) paresis. For this purpose, a decrease in functional test scores should precede an imminent decline in daily functioning as Guralnik et al. (20) demonstrated in the relation between scores on walking tests and subsequent disability after 4 years follow-up in elderly persons.

Thus, we have to conclude that these walking tests do not aid the clinician in estimating (progression of) the severity of the paresis nor to detect differences in degree of paresis between subjects.

Effect of AFO use on walking tests performances

In subjects with a dorsiflexor paresis, an AFO of course assists to correct the foot drop, thus preventing stumbling. No significant improvement on the 10-metre tests was found. The 6-minute test with cognitive task, which was added to mimic a functional situation, tended to show a significant improvement on AFO use, even with the rather low number of 13 subjects. Thus, walking problems induced by fatigue, as is induced in this test, might be helped by AFO use. However, evaluation in a larger group will be necessary to be able to significantly demonstrate this. Subjective evaluation was also positive for walking performance and walking effort.

A comparable result, i.e. a lack of significant improvement on SIP scores or walking speed, was reported by Beckerman et al. (21) in evaluating the influence of tibial nerve block and AFO use on walking ability of stroke patients.

Clinical implications

Walking is a highly automated activity. It is often combined with other tasks on which attention is focused, such as talking, watching or working (22). However, when a failure in the neuromotor system is present, this automatism is impaired. Restoration of walking after central or peripheral neurological damage, is an often encountered task in rehabilitation medicine. A patient, being able to set a few steps in a therapeutic setting, still has a long way to go to regain walking ability as an automated function on which he can rely while performing other tasks. Orthosis are often prescribed during the process of regaining walking ability.

For subjects with a dorsiflexor paresis, we concluded that an AFO does not support walking performances as measured by the 10-metre tests, and might support walking in longer distances (6-minute test). The subjective evaluation by the questionnaire revealed a predominantly positive result on perceived walking effort and walking performance, and most physiatrists and therapists will argue they experience positive results in numerous patients.

Thus, even in this simple diagnosis, i.e. peripheral paresis of the dorsiflexors, it turns out to be difficult to precisely formulate when and in which circumstances a paresis results in walking problems, and which function, associated with walking is best helped by AFO use.

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