Adjusting spring force of ankle foot orthoses according to gait type helps improving joint kinematics and time-distance parameters in patients with hemiplegia following stroke

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Stroke

impairment of locomotion programmes

malfunction of executing extremities

false biomechanical situation

compensatory mechanisms

pathological gait

accompaning spasticity

ankle-foot orthoses (AFOs)

Gait classification in stroke

CLASSIFICATION OF GAIT TYPES ACCORDING TO PERRY				
Class	Description	Velocity	Knee (MSt)	Ankle (MSw)
Class I	FAST Walker	Fast (55%)	Normal	Neutral position
Class II	MODERATE Walker	Moderate (32%)	Flexed	Neutral position
Class III	SLOW EXTENDED Walker	Slow (17%)	Hyperextended	Plantar flexion
Class IV	SLOW FLEXED Walker	Slow (9%)	Flexed	Plantar flexion

[Perry et al. 2014]

[Sabbagh et al. 2014]

Introduction > Methods > Results > Discussion
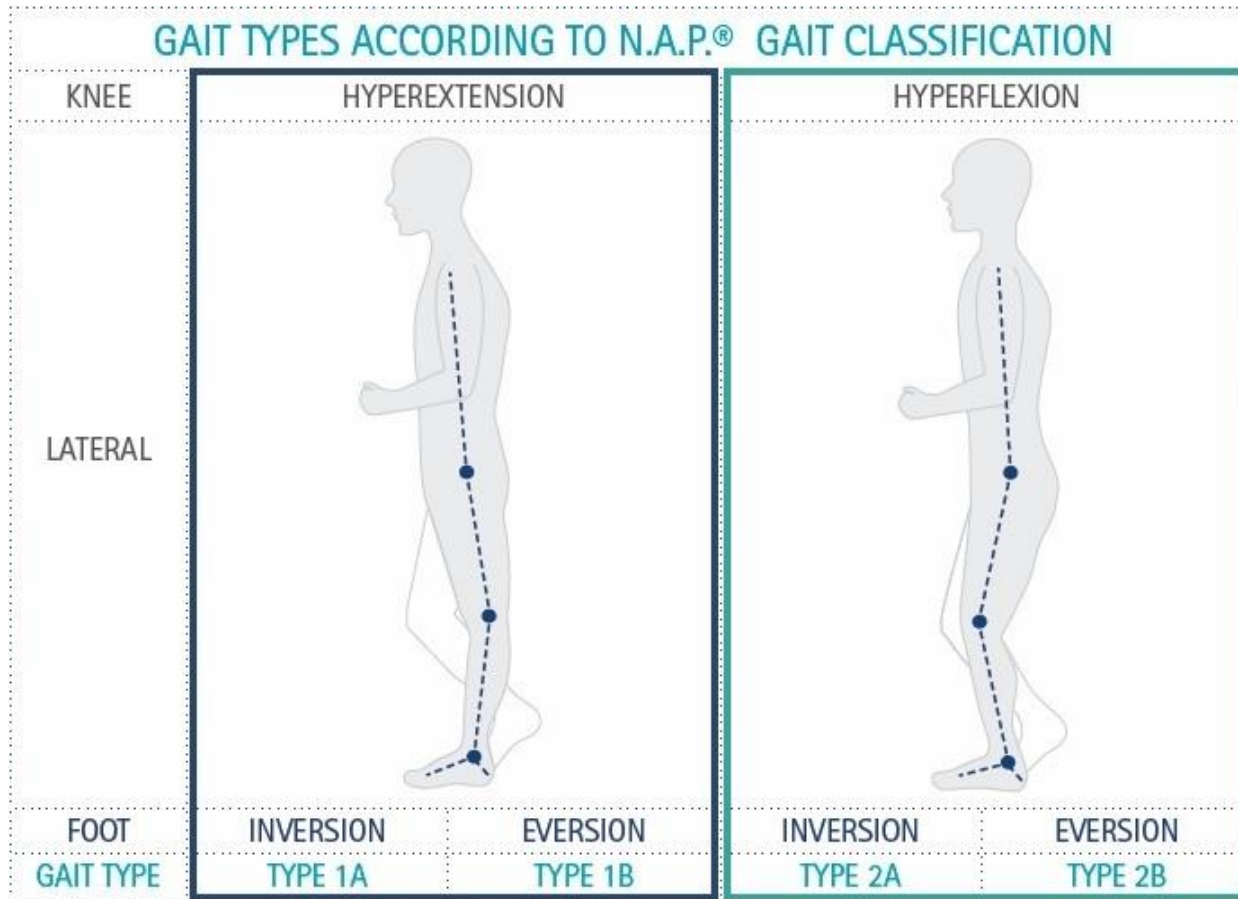
Orthotic management in stroke rehabilitation

AFOs play an important role in stroke management [Fatone 2009]

different AFO designs [Sabbagh et al. 2013]

different outcome parameters

several studies on orthotic intervention in stroke [Bowers et al. 2004, Condie et al. 2008]
- positive effects of AFOs – but not throughout
- mostly no differentiation of gait types
- poor methodology (e. g. different AFO designs)

positive results of changing AFOs spring force [Kobayashi et al. 2012, Kerkum et al. 2015]

Central Question: Can gait be improved by setting the AFOs stiffness according to the gait type?

Patients

n=8 (ø age 52.4, ø weigth 82 kg, ø heigth 177 cm)

ischemic insult (Middle Cerebral Artery Stroke)

hemiplegia

gait type 1a+b (n=5), gait type 2a+b (n=3)

Inclusion criteria

6 Minute Walking Test, TUG Test

Exclusion criteria

pain

walking aids

Gait analysis

2-dimensional video analysis

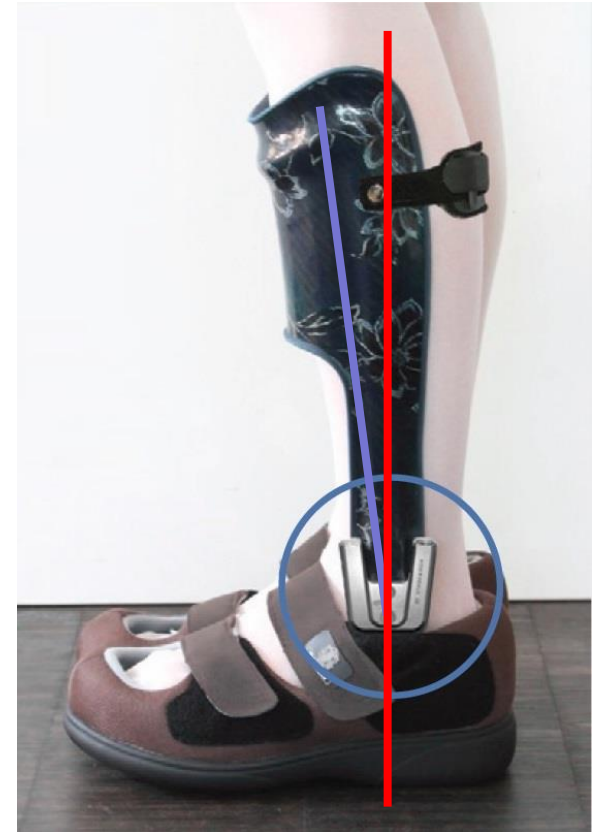2 conditions: a) Standardised footwear + DA-AFO, b) shoes only
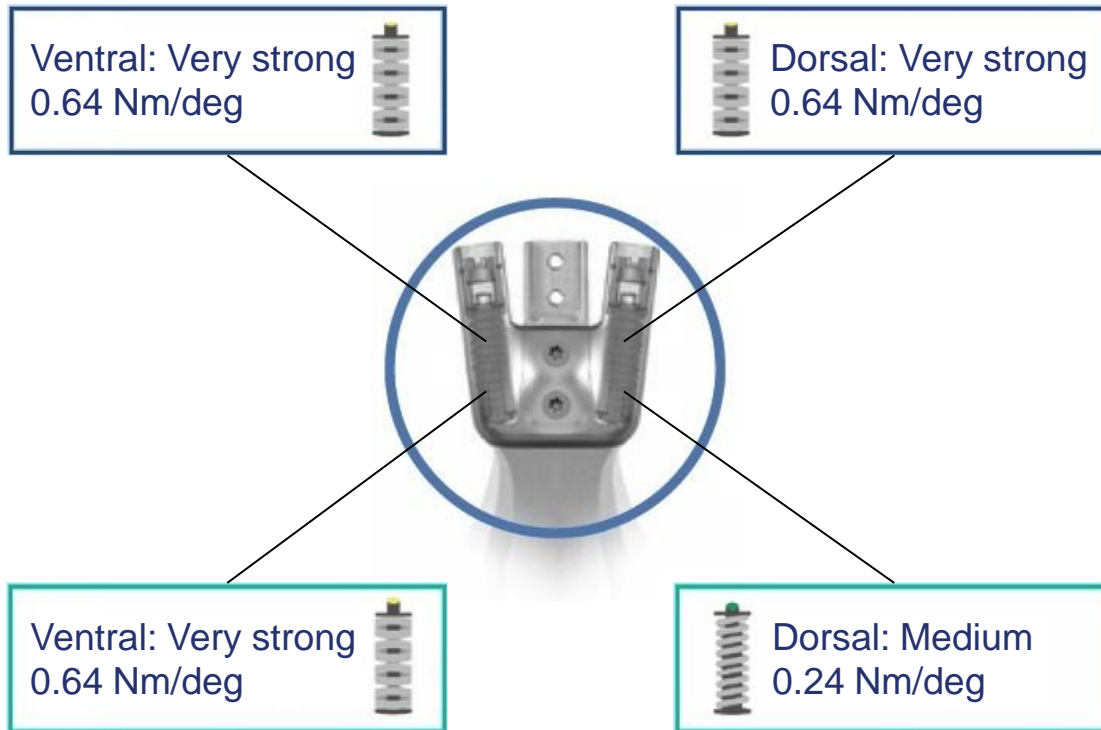
3 full gait cycles

- time-distance parameters
- lateral kinematics: hip, knee, ankle
- maximum joint positions in stance (0-65% of gait cycle)

Wilcoxon rank-sum test (* $p<0.05$, ** $p<0.01$)
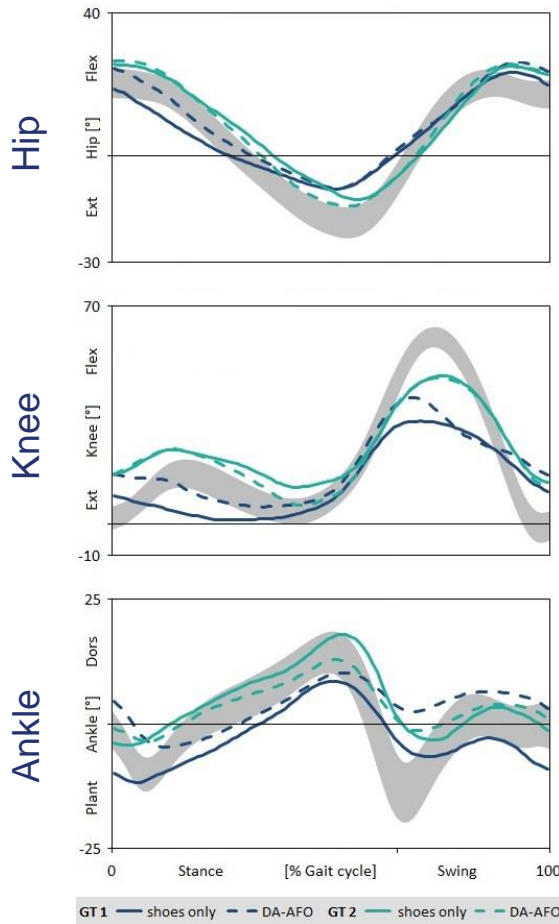
DA-AFO

Gait type 1 (knee hyperextension)

Ventral: Very strong 0.64 Nm/deg	Dorsal: Very strong 0.64 Nm/deg

Ventral: Very strong 0.64 Nm/deg	Dorsal: Medium 0.24 Nm/deg

Gait type 2 (knee hyperflexion)

Kinematics

Gait type 1 (n=5)	Gait type 2 (n=3)

Hip

Stance: Flexion +

2nd half of stance: Flexion -

Knee

Stance: Flexion +

2nd half of stance: Flexion -

**Ankle**

1st rocker improved
Stance: DF +
Swing: DF +

1st rocker improved
2nd half of stance: DF -
Terminal stance: Peak DF -

Time-Distance Parameters

			Gait type 1 (n=5)			Gait type 2 (n=3)			Reference (n=26)
			Shoes only	DA-AFO	W RST	Shoes only	DA-AFO	W RST	Shoes only
Hip	max. ext	[°]	-10.2 (±6.1)	-9.9 (±3.6)	-	-13.1 (±0.9)	-15.2 (±1.7)	-	-19.0 (±4.5)
Knee	max. ext	[°]	0.8 (±4.0)	5.2 (±3.2)	*	11.4 (±3.3)	6.4 (±1.2)	*	3.8 (±4.1)
Ankle	at IC	[°]	-9.9 (±5.0)	4.6 (±2.1)	**	-5.1 ±11.4	1.2 (±4.6)	-	-1.2 (±3.8)
	max. DF	[°]	10.7 (±3.1)	11.7 (±2,8)	-	18.1 (±1.9)	13.9 (±1.3)	*	14.7 (±4.3)
Stride length		[m]	0.9 (±0.3)	1.0 (±0.2)	*	0.8 (±0.3)	0.9 (±0.3)	*	1.6 (±0.1)
Velocity		[m/s]	0.5 (±0.3)	0.7 (±0.2)	**	0.5 (±0.2)	0.5 (±0.2)	*	1.4 (±0.2)
Cadence		[Steps/min]	65.6 ±15.1)	73.7 (±8.7)	*	72.6 (±4.3)	74.7 (±8.7)	-	104.4 (±9.0)
Stance		[% GC]	67.5 (±8.5)	66.0 (±7.1)	-	70.6 (±5.4)	64.6 (±4.0)	*	65.3 (±2.0)
Swing		[% GC]	32.5 (±8.5)	34.0 (±7.1)	-	29.4 (±5.4)	35.5 (±4.0)	*	34.7 (±2.0)

Wilcoxon rank-sum test (W RST): * indicates $p < 0.05$, ** indicates $p < 0.01$
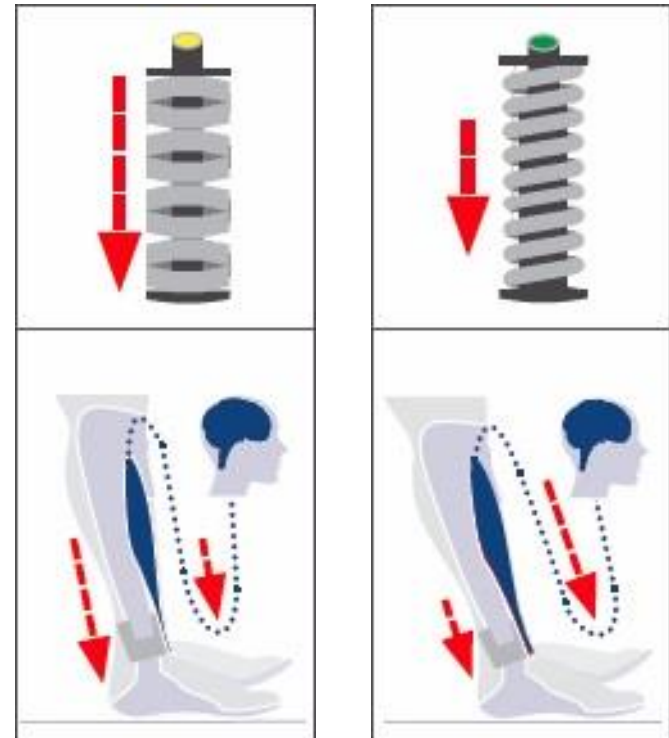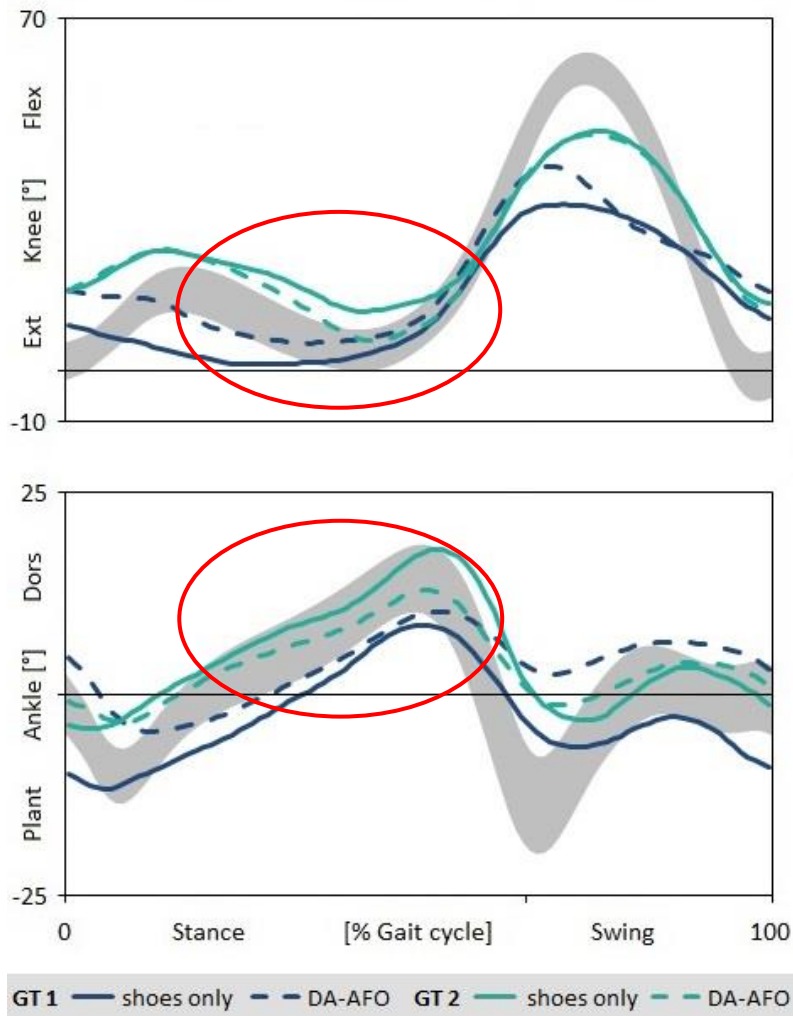
Heel Rocker
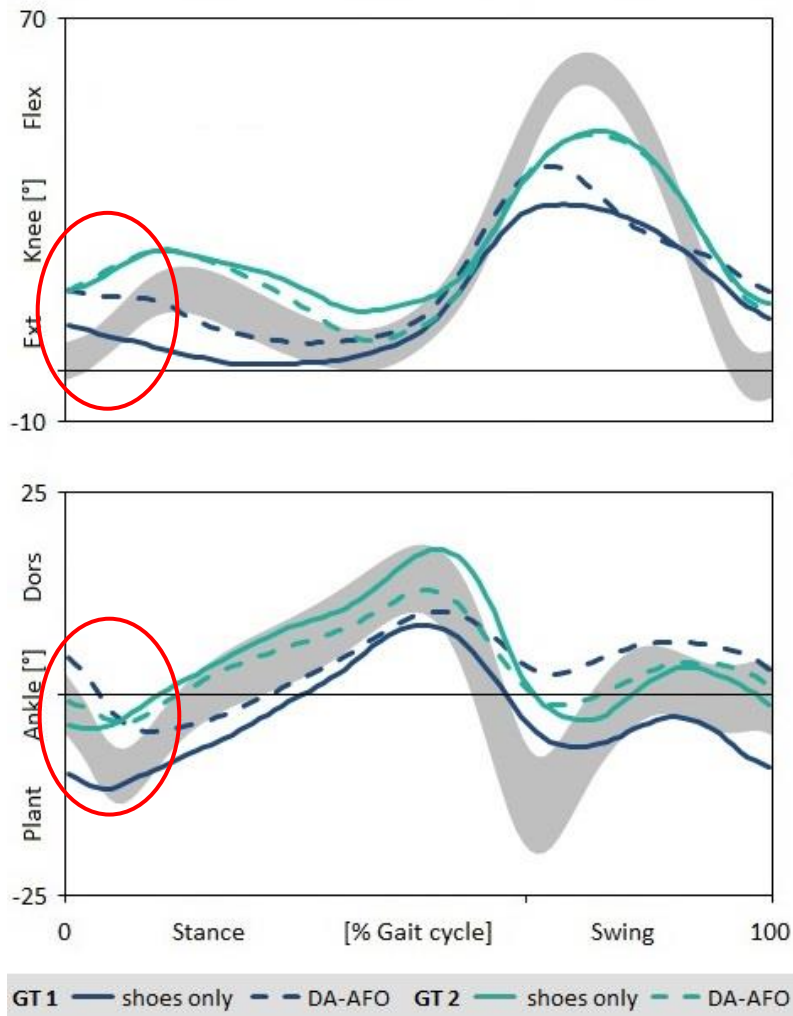
Dorsal spring

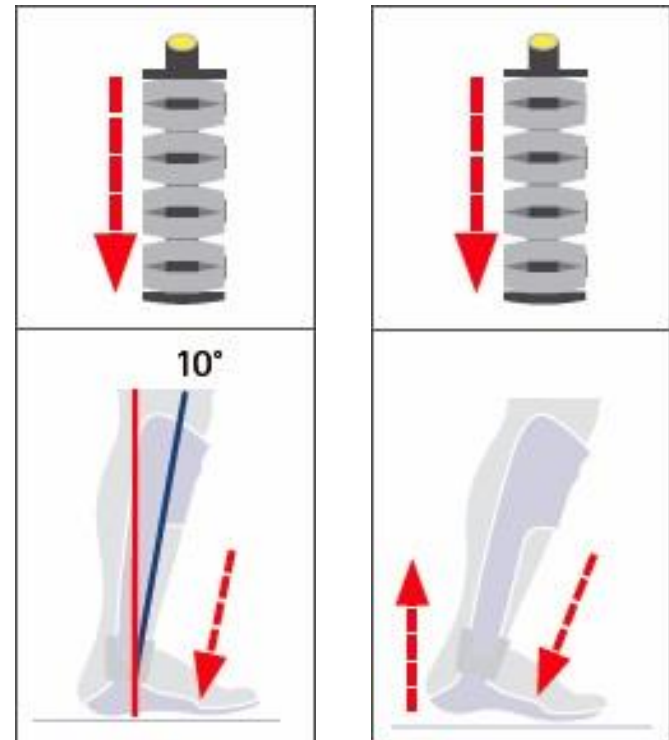Gait type 1   Gait type 2

Dorsiflexion resistance

Ventral spring

Gait type 1   Gait type 2

Conclusions

improvements in both gait types

time-distance parameters follow kinematic improvements

diffenerent spring forces different effects individual biomechanical situations

setting spring force according to gait type leads to gait improvements [Kerkum et al. 2015]

individual setting and alignment of AFO is necessary

**Thank you
for your
attention!**

Patient #	Gait type	Spring unit					
		ventral			dorsal		
		Code	Spring force	Nm/deg	Code	Spring force	Nm/deg
1	1	yellow	very strong	0.64	yellow	very strong	0.64
2	1	yellow	very strong	0.64	yellow	very strong	0.64
3	2	yellow	very strong	0.64	green	medium	0.24
4	2	white	strong	0.52	green	medium	0.24
5	1	red	extra strong	1.71	green	medium	0.24
6	1	white	strong	0.52	green	medium	0.24
7	2	red	extra strong	1.71	green	medium	0.24
8	1	yellow	very strong	0.64	yellow	very strong	0.64