Comparison of 2 Orthotic Approaches in Children With Cerebral Palsy

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Purpose: To compare dynamic ankle-foot orthoses (DAFOs) and adjustable dynamic response (ADR) ankle-foot orthoses (AFOs) in children with cerebral palsy. **Methods:** A total of 10 children with cerebral palsy (4-12 years; 6 at Gross Motor Function Classification System level I, 4 at Gross Motor Function Classification System level III) and crouch and/or equinus gait wore DAFOs and ADR-AFOs, each for 4 weeks, in randomized order. Laboratory-based gait analysis, walking activity monitor, and parent-reported questionnaire outcomes were compared among braces and barefoot conditions. **Results:** Children demonstrated better stride length (11-12 cm), hip extension (2°-4°), and swing-phase dorsiflexion (9°-17°) in both braces versus barefoot. Push-off power (0.3 W/kg) and knee extension (5°) were better in ADR-AFOs than in DAFOs. Parent satisfaction and walking activity (742 steps per day, 43 minutes per day) were higher for DAFOs. **Conclusions:** ADR-AFOs produce better knee extension and push-off power; DAFOs produce more normal ankle motion, greater parent satisfaction, and walking activity. Both braces provide improvements over barefoot. **(Pediatr Phys Ther 2015;27:218–226)** *Key words: ankle joint/physiopathology, articular, cerebral palsy/physiopathology, cerebral palsy/rehabilitation, child, foot, gait, hip joint/physiopathology, humans, knee joint/physiopathology, locomotor activity, muscle spasticity, orthotic devices, patient satisfaction, preschool, range of motion, walking*

INTRODUCTION AND PURPOSE

Ankle-foot orthoses (AFOs) are commonly prescribed to improve gait in children with cerebral palsy (CP). Ankle-foot orthoses can improve gait kinematics and temporal-spatial parameters,[1-5] activity levels,[6] and metabolic costs.[7,8] However, many different types of AFOs are available and little evidence exists to guide orthosis selection for individual patients. Consequently, improvements in gait with AFOs are highly variable and often unsatisfactory.[9] Limitations of AFO design and inappropriate prescription for an individual's gait pattern can hinder the effectiveness of AFOs.[10]

Traditional AFOs are usually molded from plastic. Common styles include solid AFOs and hinged AFOs with dorsiflexion or plantar-flexion stops. Unfortunately, many traditional AFOs have detrimental effects such as reducing push-off power because of the AFO restricting plantar flexion.[4,10,11] This is problematic because ankle plantar flexor power generation in preswing is 1 of the 3 primary mechanisms used to increase walking speed.[12,13] Some orthosis companies provide additional or alternate designs, for example, dynamic AFOs (DAFOs) and adjustable dynamic response (ADR) AFOs. Posterior leaf spring AFOs (DAFO 3.5) are offered by Cascade DAFO, Inc (Ferndale, WA), with a trimmed posterior strut to allow greater

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flexibility than solid AFOs, in addition to more traditional solid (DAFO 3) and hinged (DAFO 2) orthoses and other designs. Ultraflex Systems, Inc (Pottstown, PA), promotes ADR-AFOs featuring joints with an elastomer component that produces variable resistance to dorsiflexion and plantar flexion. Dorsiflexion and plantar-flexion stiffness can be adjusted separately by an orthotist or physical therapist to "tune" the brace for the individual patient. The purpose of this study was to compare the Cascade DAFO and Ultraflex ADR-AFO approaches to orthotic prescription in children with CP and crouch and/or equinus gait.

METHODS

Participants wore braces prescribed using the DAFO and ADR-AFO approaches during a randomized crossover design. The participants wore each brace for 4 weeks in randomized order. They were assessed barefoot before they started wearing the first brace (baseline), barefoot and braced after wearing the first brace for 4 weeks, and barefoot and braced after wearing the second brace for 4 weeks. The braces were worn consecutively, with no "washout" period between the 2 brace wear periods. Differences in gait while wearing braces or while barefoot were examined. Walking activity and parent-reported outcomes were compared between the 2 bracing methods.

Participants

The study participants were 10 children with CP (age 4-12 years); 6 were classified at Gross Motor Function Classification System (GMFCS) level I, and 4 were at GMFCS level III. All had crouch and/or equinus gait. Crouch was defined as excessive knee flexion throughout stance phase and equinus as excessive static or dynamic plantar flexion throughout stance phase on the basis of the physical therapists' visual observation of the child's gait.[14] Five participants had bilateral involvement, and 5 had unilateral involvement (3 right, 2 left; Table 1). All participants and/or parents provided written assent and consent after approval of the study by our hospital's Institutional Review Board.

Orthoses Fabrication and Fitting

A single certified and experienced pediatric orthotist molded and fit each child for both DAFO and ADR-AFOs (5 unilateral and 5 bilateral) (Figure 1). The manufacturers of the orthoses determined the specifications of the orthoses provided to each participant (including the type of DAFO) on the basis of a physical examination performed by the motion analysis laboratory physical therapist before molding, specifically range of motion, muscle tone, and a videotape of the participant walking barefoot. The same shoes designed for use with AFOs (Apis Answer2 Shoes, Apis Footwear Company, South El Monte, CA) were worn with both orthoses. These were sized to accommodate the ADR-AFO brace, which tends to be bulkier than the DAFO;

TABLE 1
Participant Characteristics

ID	Sex	Age, y	GMFCS Level	Braced Side	Equinus	Crouch	Assistive Device for Testing	ADR-AFO Wedging, cm	DAFO Type	DAFO PF	DAFO DF
1	Male	4.3	III	B	B	B	Handheld	1.25	Turbo	Block	Block
2	Male	7.6	III	B	B	B	Handheld	0.5	DAFO 3.5	Resist	Resist
3	Male	12.2	I	L	None	L	None	0.25	Tami 2	Block	Resist
4	Female	7.4	I	R	None	B	None	1.0	DAFO 3.5	Resist	Resist
5	Female	5.5	I	L	L	None	None	0.75	DAFO 3	Block	Free
6	Female	6.5	III	B	B	B	Walker/handheld[a]	1.5	Tami 2	Block	Free
7	Female	8.2	I	R	None	B	None	0.75	DAFO 3.5	Resist	Resist
8	Female	9.9	III	B	None	R	Crutches/handheld[a]	0.75	DAFO 3.5	Resist	Resist
9	Male	7.8	I	B	B	L	None	0.75 L, 1.5 R	DAFO 2	Block	Free
10	Female	5.6	I	R	None	B	None	0	DAFO 3.5	Resist	Resist

Abbreviations: ADR-AFO, adjustable dynamic response ankle-foot orthosis; B, bilateral; DAFO, dynamic ankle-foot orthosis; DF, dorsiflexion; GMFCS, Gross Motor Function Classification System; L, left; PF, plantar flexion; R, right.
[a]Assistance varied between test sessions.

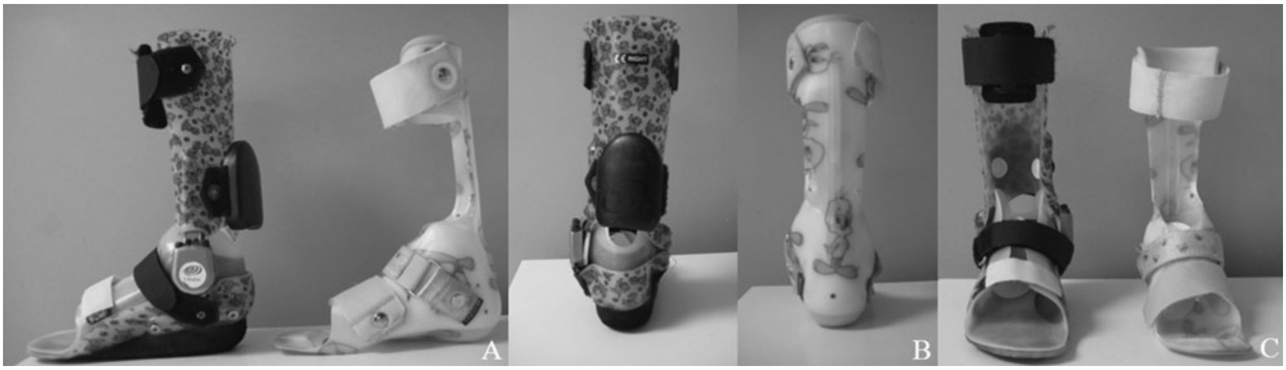

Fig. 1. Lateral (A), posterior (B), and anterior (C) view of an Ultraflex adjustable dynamic response (ADR) ankle-foot orthosis (AFO) (on the left side of figure) and Cascade dynamic ankle-foot orthosis (DAFO) DAFO 3.5. The ADR-AFO is seen on the left side of each part of the figure, and the DAFO is seen on the right side of each part of the figure. Note: Not all DAFO braces used in this study were included in this figure.

shims were provided to ensure good fit when the DAFOs were worn in the shoes. All participants were prior orthosis users and were instructed not to use their previous AFOs during the course of the study. No gait training specific to use of the new orthoses was provided, but participants continued with their regular physical therapy programs.

Final fitting of both orthoses and tuning of the ADR-AFO braces was done by the orthotist investigator. The concept underlying the ADR-AFO approach is that dorsiflexion and plantar-flexion stiffness of the brace can be separately adjusted (after the brace has been made) by using an Allen wrench to compress anterior and posterior elastomer channels on joints built into the brace. The orthotist's objective was to optimize knee and ankle position during loading response, terminal stance, and preswing. Heel wedges placing the foot in a more plantar flexed position in the shoe were used to enable initial contact with the heel and to promote the first rocker. The height of the heel wedge was selected by the manufacturer to allow loading of the heel with the tibia vertical in a weight-bearing position (creating a 90° angle between the tibia and sole of the shoe); the heel wedge height was measured with the child in the supine position, knee fully extended. The DAFOs follow a more conventional approach with the brace having a fixed stiffness and optional dorsi-/plantar-flexion stops. The level of support was adjusted by selecting the appropriate DAFO style, which was done by the manufacturer in this study.

Walking Activity Measures

Walking activity while wearing the braces was measured during each wear period using a StepWatch activity monitor (Orthocare Innovations, Mountlake Terrace, WA) that was mounted on the brace to ensure compliance with the monitoring (Figure 1A and B). The StepWatch was individually calibrated for each participant at each visit and set to record for up to 30 days; the first and last days were not included in the analysis because they were partial days. Days where the StepWatch recorded less than 5% of the participant's average daily step count were also excluded from the analysis under the assumption that the brace was not worn that day. Compliance with brace wear was assessed by the percentage of days the brace was worn (number of days with step count ≥5% of average daily step count/number of full days in recording period). The number of hours the brace was worn was estimated as the time between the first recorded activity (step) and the last recorded activity (step) in a day, and active time was calculated as the total number of minutes in which at least 1 step was recorded.

Instrumented Gait Analysis

Gait analysis using a Vicon 612 motion capture system (Vicon Motion Systems Ltd, Oxford, UK) with 4 in-floor triaxial force plates (Advanced Mechanical Technology, Inc, Watertown, MA) was performed using the conventional gait model[15] at baseline and at the end of each 4-week brace wear period. The testing was completed barefoot at baseline and barefoot and braced (using the brace worn for the previous 4 weeks) after each bracing period. Testing was performed without assistive devices for all children at GMFCS level I. Children in GMFCS level III were tested either with the assistive device they used in everyday life or with hands held if data could not be collected with the assistive device because of marker obstruction. Two children had different assistance between tests because they forgot to bring their assistive device to 1 of the test sessions (Table 1). Data from 4 to 10 strides were averaged to calculate kinematic, kinetic, and temporal-spatial parameters. Asymmetry of gait was assessed by examining the magnitude of difference in step length, step time, and single-limb stance time between the left and right sides for each participant. For subjects who could stand independently, standing balance was assessed at the same time points by analyzing motion of the center or pressure (COP) while the participant stood on a force plate on both feet with eyes open for 30 seconds. Twenty seconds of data from the middle of the trial were analyzed to determine the range and standard deviation of anterior-posterior and medial-lateral motion, as well as the average speed of COP motion (ie, path length/time).

Parent Satisfaction Measures

Parent-reported outcomes were assessed at the end of each wear period using the Orthotics and Prosthetics Users' Survey (OPUS)[16] and the Pediatric Outcomes Data Collection Instrument (PODCI) questionnaires.[17] The OPUS is a validated set of questionnaires assessing functional status, quality of life, and satisfaction with orthotic and prosthetic devices and services.[16] The PODCI is a validated instrument commonly used to assess function and quality of life in pediatric orthopedics.[18] The questionnaires were completed by a parent and were scored following the instructions for each instrument. Raw scores are reported for the OPUS, and standardized scores (0-100) are reported for the PODCI.

Statistical Analyses

Outcomes were compared between braces and between braced and barefoot conditions using paired *t* tests. The pairing was within the same session for braced versus barefoot and between sessions for DAFO versus ADR-AFO. Because different styles of DAFOs were used, analysis was also performed subdividing the DAFOs according to the type of stance-phase dorsiflexion (free vs block/resist) and plantar-flexion (block vs resist) control they provided. All statistical analysis was performed using Stata (version 12.1, StataCorp LP, College Station, TX).

RESULTS

In terms of overall gait, children took longer strides (11-12 cm difference; $P < .0001$) at a reduced cadence (8-11 steps/min difference; $P \leq .005$) when wearing both types of orthoses compared with walking barefoot (Tables 2-3). Velocity increased significantly when walking in DAFOs ($P = .006$), and a trend toward increased velocity in the ADR-AFOs did not reach statistical significance. The differences in temporal-spatial parameters were smaller for DAFOs that blocked plantar flexion and allowed free dorsiflexion. Temporal-spatial parameters did not differ significantly between the 2 orthotic approaches (Table 3). No significant effects of bracing or type of brace were observed on gait asymmetry ($P > .3$) or standing balance ($P > .51$) (Tables 4 and 5).

Both orthotic approaches improved dorsiflexion (restricted plantar flexion) in swing compared with barefoot (9°-17° difference vs barefoot; $P \leq .01$). Dorsiflexion also increased significantly in stance for the DAFOs (13° difference from barefoot; $P = .003$) and showed a trend toward increasing in the ADR-AFOs, but did not reach statistical significance (6° difference from barefoot; $P = .08$). Dorsiflexion in stance and swing was greater in the DAFOs than in the ADR-AFOs (9°-10° difference; $P \leq .003$) because of wedging of the ADR-AFOs and greater plantar-flexion stiffness of the DAFOs. Knee extension in stance was better in the ADR-AFOs than in the DAFOs (5° difference; $P = .006$), but neither brace differed significantly from barefoot. Hip extension in stance was improved in both types of braces compared with barefoot (2°-4° difference;

TABLE 2
Descriptive Comparison of Gait Parameters by Bracing Condition

	Barefoot[a] Mean ± SD	DAFO Mean ± SD	ADR-AFO Mean ± SD	Reference[b] Mean ± SD
Temporal-spatial (n = 15)				
Velocity, m/s	0.72 ± 0.34	0.78 ± 0.34	0.84 ± 0.29	1.28 ± 0.07
Cadence, steps/min	117.8 ± 29.2	111.8 ± 24.7	116.2 ± 18.6	138.0 ±6.1
Stride length, m	0.69 ± 0.21	0.79 ± 0.23	0.85 ± 0.20	1.13 ± 0.05
Double-limb stance time, % GC	37.9 ± 7.7	35.1 ± 6.6	35.4 ± 4.3	22.1 ± 2.7
Kinematic (n = 15)				
Dorsiflexion mean in stance, °	−4.3 ± 11.4	8.9 ± 4.4	−0.4 ± 8.5	3.0 ± 2.2
Dorsiflexion mean in swing, °	−11.4 ± 11.5	5.5 ± 4.9	−4.2 ± 7.2	−4.3 ± 2.0
Knee flexion peak in loading response, °	31.9 ± 9.9	35.5 ± 13.5	32.7 ± 13.9	21.0 ± 4.9
Knee extension peak in stance, °	10.9 ± 9.7	12.5 ± 12.1	7.1 ± 13.7	1.3 ± 3.3
Hip extension peak in stance, °	7.6 ± 10.4	5.0 ± 9.9	3.8 ± 11.0	−10.0 ± 5.1
Pelvic tilt mean in stance, °	20.2 ± 5.3	19.9 ± 4.8	19.8 ± 4.8	11.5 ± 4.4
Kinetic (n = 7)				
Dorsiflexion moment peak in loading response,[c] Nm/kg	0.19 ± 0.12	−0.04 ± 0.17	0.02 ± 0.21	−0.11 ± 0.06
Plantar-flexion moment peak in late stance,[d] Nm/kg	0.75 ± 0.17	0.98 ± 0.21	0.94 ± 0.21	1.10 ± 0.26
Plantar-flexion power peak in push-off, W/kg	1.36 ± 0.74	0.74 ± 0.36	1.06 ± 0.50	3.00 ± 0.93
Knee extension moment peak in loading response, Nm/kg	−0.11 ± 0.09	−0.1 ± 0.3	−0.1 ± 0.2	−0.32 ± 0.09
Knee flexion moment peak in mid-late stance,[e] Nm/kg	−0.20 ± 0.15	−0.32 ± 0.27	−0.34 ± 0.19	−0.35 ± 0.09
Hip flexion moment peak in mid-late stance, Nm/kg	−0.39 ± 0.15	−0.50 ± 0.22	−0.36 ± 0..43	−0.61 ± 0.15

Abbreviations: ADR-AFO, adjustable dynamic response ankle-foot orthosis; DAFO, dynamic ankle-foot orthosis; GC, gait cycle; SD, standard deviation.
[a]Barefoot data were averaged over the 3 visits for each subject. Barefoot temporal-spatial and kinematic data were missing for 2 sides from 1 subject.
[b]Reference data are from 15 children who were healthy and without disability in the same age range tested in our laboratory.
[c]Loading response = 2% to 12% GC.
[d]Late stance = 30% to 50% GC.
[e] Mid-late stance = 12% to 50% GC;

TABLE 3

Difference in Gait Parameters Between Bracing Conditions

	DAFO—Barefoot		ADR-AFO—Barefoot[a]		DAFO—ADR-AFO	
	Difference Mean (CI)	*P* Value	Difference Mean (CI)	*P* Value	Difference Mean (CI)	*P* Value
Temporal-spatial (n = 15)						
Velocity, m/s	0.06 (0.02 to 0.10)	.006	0.03 (−0.03, 0.09)	.23	0.02 (−0.03 to 0.07)	.49
Cadence, steps/min	− 8.1 (−12.2 to −3.9)	.001	− 10.5 (−17.1 to −3.9)	.005	4.2 (−0.3 to 8.7)	.06
Stride length, m	0.11 (0.07 to 0.15)	<.0001	0.12 (0.09 to 0.14)	<.0001	− 0.02 (−0.06 to 0.02)	.26
Double-limb stance time (% GC)	− 2.2 (−5.2 to 0.7)	.12	− 1.7 (−4.5,1.2)	.23	− 1.8 (−4.0 to 0.5)	.12
Kinematic (n = 15)						
Dorsiflexion mean in stance,°	13.2 (5.3 to 21.0)	.003	5.6 (−0.8 to 12.0)	.08	9.2 (3.7 to 14.8)	.003
Dorsiflexion mean in swing,°	17.0 (10.3 to 23.8)	.0001	8.9 (2.4 to 15.4)	.01	9.7 (4.7 to 14.7)	.0009
Knee flexion peak in loading response,°	1.6 (−2.4 to 5.5)	.41	1.6 (−2.4 to 5.6)	.40	2.8 (−0.7 to 6.2)	.11
Knee extension peak in stance,°	− 2.1 (−5.7 to 1.5)	.23	− 1.4 (−4.8 to 2.0)	.39	5.4 (1.8 to 8.9)	.006
Hip extension peak in stance,°	− 4.2 (−5.5 to −2.9)	<.001	− 2.4 (−3.8 to −1.0)	.002	1.2 (−2.8 to 5.2)	.54
Pelvic tilt mean in stance,°	− 0.3 (−1.7 to 1.1)	.62	0.0 (−1.3 to 1.4)	.94	0.1 (−1.8 to 2.1)	.88
Kinetic (n = 7)						
Dorsiflexion moment peak in loading response,[b] Nm/kg	− 0.24 (−0.44 to −0.04)	.02	− 0.19 (−0.51 to 0.13)	.20	− 0.06 (−0.21 to 0.09)	.37
Plantar-flexion moment peak in late stance,[c] Nm/kg	0.19 (0.03 to 0.34)	.03	0.17 (−0.08 to 0.42)	.15	0.04 (−0.25 to 0.33)	.76
Plantar-flexion power peak in push-off, W/kg	− 0.57 (−0.94 to −0.18)	.01	− 0.44 (−0.81 to −0.07)	.03	− 0.32 (−0.61 to −0.03)	.04
Knee extension moment peak in loading response,[b] Nm/kg	− 0.05 (−0.28 to 0.39)	.72	0.04 (−0.15 to 0.23)	.62	0.01 (−0.15 to 0.17)	.87
Knee flexion moment peak in mid-late[d] stance, Nm/kg	− 0.13 (−0.34 to 0.09)	.19	− 0.11 (−0.29 to .06)	.17	0.02 (−0.28 to 0.32)	.85
Hip flexion moment peak in mid-late stance,[d] Nm/kg	− 0.11 (−0.26 to 0.05)	.14	0.08 (−0.31 to 0.46)	.64	− 0.15 (−0.48 to 0.18)	.30

Abbreviations: ADR-AFO, adjustable dynamic response ankle-foot orthosis; CI, confidence interval; DAFO, dynamic ankle-foot orthosis; GC, gait cycle.

[a]Barefoot temporal-spatial and kinematic data were missing for 2 sides from 1 subject.

[b]Loading response = 2% to 12% GC.

[c]Late stance = 30% to 50% GC.

[d]Mid-late stance = 12% to 50% GC.

$P \leq .002$), but no difference was found between the 2 brace approaches.

Push-off power was significantly reduced in both brace approaches (0.4-0.6 W/kg difference; $P \leq .03$) but was significantly higher in the ADR-AFOs than in the DAFOs (0.3 ± 0.2 W/kg difference; $P = .04$). Peak plantarflexion moment in late stance was higher in both types of braces compared with barefoot (0.17-0.19 Nm/kg), reaching statistical significance for the DAFOs ($P = .03$). During the loading response, a dorsiflexion moment was not seen for any limb barefoot, but was seen in 3 of the 7 limbs in ADR-AFOs and 5 of the 7 limbs in DAFOs, with the difference being significantly different from barefoot for the DAFOs ($P = .02$). We were not able to identify any clear pattern of differences in kinematics or kinetics associated with the style of DAFO used.

TABLE 4

Descriptive Comparison of Gait Asymmetry and Standing Balance by Bracing Condition

	Barefoot[a] Mean ± SD	DAFO Mean ± SD	ADR-AFO Mean ± SD
Gait asymmetry (n = 10)			
Step length asymmetry, m	0.04 ± 0.06	0.04 ± 0.02	0.03 ± 0.02
Step time asymmetry, s	5.1 ± 3.7	5.9 ± 5.0	5.7 ± 3.5
Single-limb stance time asymmetry (% GC)	4.2 ± 3.0	4.7 ± 3.7	3.6 ± 3.3
Standing balance (n = 10)			
COP AP range, mm	29.3 ± 8.0	25.5 ± 11.0	24.2 ± 5.0
COP AP SD, mm	5.9 ± 1.5	5.6 ± 1.9	5.3 ± 1.4
COP ML range, mm	37.7 ± 17.3	30.7 ± 13.6	33.6 ± 6.0
COP ML SD, mm	7.8 ± 4.1	6.6 ± 2.1	7.1 ± 1.1
COP mean speed, mm/s	21.9 ± 7.4	21.2 ± 10.1	19.2 ± 4.8

Abbreviations: ADR-AFO, adjustable dynamic response ankle-foot orthosis; AP, anterior-posterior; COP, center of pressure; DAFO, dynamic ankle-foot orthosis; GC, gait cycle; ML, medial-lateral; SD, standard deviation.

[a]Barefoot data are averaged over the 3 visits for each subject. Barefoot asymmetry data were missing for 1 subject.

Parent-reported patient satisfaction with the orthoses was significantly higher for the DAFO-style orthoses compared with the ADR-AFOs (9.2 ± 6.7 point difference in OPUS device satisfaction; $P = .002$) because of higher satisfaction with fit, weight, comfort/pain, ease of use, and cosmesis ($P \leq .05$) (Table 6). No differences were found between orthotic approaches in terms of function, service, or quality of life as measured by the OPUS and PODCI questionnaires.

Participants spent more time walking (3.9 vs 3.2 hours per day; $P = .02$) and recorded more steps per day in the DAFO-style braces (5952 steps per day) compared with the ADR-AFOs (5224 steps per day) with an average within-participant difference of 729 ± 1119 steps per day ($P = .07$; Table 6). All 10 participants recorded more walking time in the DAFO-style braces than in the ADR-AFOs, and 8 of the 10 participants recorded more steps per day when using DAFOs (Figure 2). No difference was found between orthotic approaches for the percentage of days used, but there was a trend toward a longer time from the first recorded activity to the last in DAFOs compared with ADR-AFOs ($P = .12$, Table 6).

DISCUSSION

Both the DAFO and ADR-AFO approaches improved hip extension in stance and dorsiflexion in swing during gait compared with the barefoot condition. The DAFO braces all blocked or restricted plantar-flexion motion and produced more normal first rocker as evidenced by a more frequent and greater magnitude internal dorsiflexion moment in loading response. They also allowed more normal dorsiflexion motion in stance phase with associated improvement in plantar flexor moment production in stance, indicating a more normal second rocker. By design, the ADR-AFOs were set to provide customized resistance to plantar flexion in stance. This allowed for some preservation of push-off power at preswing, which theoretically should be beneficial for energy-efficient gait;

TABLE 5

Difference in Gait Asymmetry and Standing Balance Between Bracing Conditions

	DAFO—Barefoot		ADR-AFO—Barefoot[a]		DAFO—ADR-AFO	
	Difference Mean (CI)	P Value	Difference Mean (CI)	P Value	Difference Mean (CI)	P Value
Gait asymmetry (n = 10)						
Step length asymmetry, m	− 0.03 (−0.12 to 0.07)	.54	0.00 (−0.02 to 0.01)	.59	0.01 (−0.03 to 0.04)	.73
Step time asymmetry, s	0.7 (−1.7 to 3.1)	.53	0.8 (−1.0 to 2.6)	.35	0.3 (−1.3 to 1.8)	.72
Single-limb stance time asymmetry (% GC)	0.7 (−1.7 to 3.0)	.53	0.3 (−1.1 to 1.6)	.68	1.2 (−1.3 to 3.6)	.32
Standing balance (n = 6)						
COP AP range, mm	− 4.0 (−15.1 to 7.0)	.39	− 3.6 (−18.9 to 11.6)	.57	1.3 (−13.3 to 15.9)	.83
COP AP SD, mm	− 0.1 (−3.2 to 3.0)	.84	− 0.1 (−3.4 to 3.1)	.93	0.3 (−2.8 to 3.5)	.81
COP ML range, mm	− 4.4 (−19.1 to 10.3)	.48	5.4 (−10.0 to 20.9)	.41	− 2.9 (−19.1 to 13.2)	.66
COP ML SD, mm	− 0.2 (−2.3 to 1.9)	.78	1.7 (−1.5 to 4.8)	.23	− 0.5 (−2.5 to 1.4)	.51
COP mean speed, mm/s	− 1.1 (−10.6 to 8.3)	.70	− 0.8 (−5.4 to 3.9)	.69	2.0 (−7.8 to 11.8)	.62

Abbreviations: ADR-AFO, adjustable dynamic response ankle-foot orthosis; AP, anterior-posterior; CI, confidence interval; COP, center of pressure; DAFO, dynamic ankle-foot orthosis; GC, gait cycle; ML, medial-lateral; SD, standard deviation.

[a]Barefoot asymmetry data were missing for 2 sides from 1 subject.

TABLE 6

Comparison of Scores on the Orthotics and Prosthetics Users' Survey and Pediatric Outcomes Data Collection Instrument Questionnaires and StepWatch Activity Monitoring

	DAFO Mean (SD)	ADR-AFO Mean (SD)	Difference (DAFO vs ADR-AFO)	*P* Value
OPUS score				
Function	51.1 ± 23.4	50.0 ± 26.3	1.1 (−5.8 to 8.0)	.73
Quality of life	41.5 ± 13.8	43.3 ± 12.6	− 1.8 (−14.2 to 10.6)	.75
Device satisfaction	44.4 ± 5.1	35.2 ± 9.1	9.2 (4.4 to 14.0)	.002
Service satisfaction	42.8 ± 7.6	40.6 ± 7.2	2.2 (−4.3 to 8.7)	.46
PODCI score				
Upper extremity	63.4 ± 22.3	65.6 ± 17.6	− 2.1 (−9.4 to 5.2)	.53
Transfers and basic mobility	64.6 ± 33.1	62.9 ± 34.5	1.7 (−3.6 to 7.0)	.49
Sports and physical functioning	44.0 ± 22.0	41.8 ± 19.9	2.2 (−4.4 to 8.8)	.47
Pain and comfort	76.1 ± 23.9	72.7 ± 17.0	3.4 (−13.0 to 19.8)	.65
Happiness	80.0 ± 21.5	68.3 ± 29.3	11.7 (−3.0 to 26.3)	.10
Global functioning	62.9 ± 19.8	62.4 ± 16.9	0.4 (−5.1 to 5.9)	.87
SAM				
Steps per day	5952 ± 4100	5224 ± 3657	729 (−72 to 1530)	.07
Days used, %	67.8 ± 18.1	64.0 ± 21.3	3.8 (−10.7 to 18.3)	.57
Total time per day, h	9.2 ± 1.8	8.3 ± 1.4	0.90 (−0.27 to 2.1)	.12
Active time per day, h	3.9 ± 1.8	3.2 ± 1.7	0.7 (0.1 to 1.3)	.02

Abbreviations: ADR-AFO, adjustable dynamic response ankle-foot orthosis; CI, confidence interval; DAFO, dynamic ankle-foot orthosis; OPUS, Orthotics and Prosthetics Users' Survey; PODCI, Pediatric Outcomes Data Collection Instrument; SAM, StepWatch activity monitoring; SD, standard deviation.

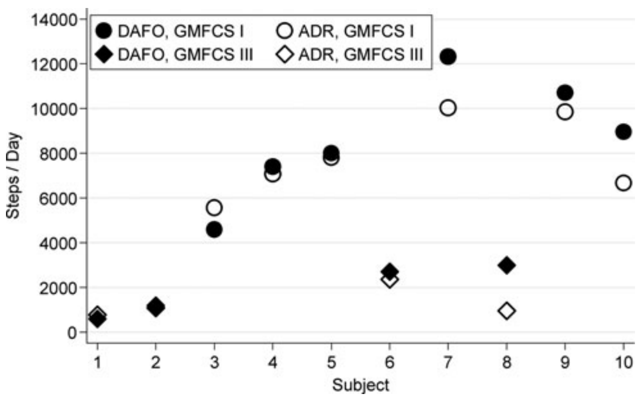

Fig. 2. Comparison of StepWatch activity monitor results between braces for each participant.

though this was not reflected in our outcomes for gait speed, number of steps taken per day, or parent-reported patient satisfaction. Follow-up studies measuring oxygen consumption could provide a more direct measure of energy efficiency. Although knee extension in stance was not significantly changed from the barefoot condition with either orthotic approach, knee extension in stance phase was better in the ADR-AFOs compared with the DAFOs, possibly as a result of more plantar flexion at the ankle. Because all but 1 of the participants had crouch gait with or without equinus, improved knee extension in stance is an important goal of bracing in addition to the control of ankle position. The small number of subjects precluded comparisons of subjects with equinus versus crouched gait.

The ADR-AFO braces positioned the ankle in a plantar flexed position for most participants in the current study, which could raise concerns about worsening plantar flexor spasticity or contracture over time for these participants. During the month-long period of ADR-AFO use in the current study, no participants experienced a clinically significant change in values for the gastrocnemius or soleus of either the angle of catch after fast velocity stretch (R1) or the angle of full passive range of motion (R2),[19] indicating no effect of plantar flexed walking on spasticity or range of motion. The DAFO-style orthoses tended to promote a more flexed posture (more dorsiflexion and knee flexion during stance). Because crouch gait tends to worsen over time in patients with CP,[14,20] allowing children with equinus and crouch to walk in more relative plantar flexion to promote a more upright posture may be appropriate and safe. Additional research with more subjects and longer follow-up is needed to further investigate this issue.

We noted that the children used the DAFO-style orthoses more than the ADR-AFOs and recorded more steps per day when wearing the DAFOs, and they expressed a preference for the DAFO on the OPUS questionnaire. Five children maintained similar walking times regardless of the brace approach. However, the other 5 were more active in the DAFO-style braces, averaging 1 hour and 23 minutes more active time in the DAFOs than in the ADR-AFOs. Although 5 children took about the same number of steps in both brace types, 3 walked at least 2000 steps per day more in the DAFOs, 1 walked 855 steps per day more in the DAFOs, and only 1 walked significantly more (974 steps per day) in the ADR-AFOs. These may be clinically significant differences because children at GMFCS level I normally average approximately 11 000 steps per day whereas children at GMFCS level III average approximately 3000 steps per day.[21] Because the step monitor was mounted on the AFO, however, whether the higher recorded active time and number of steps was due to the children walking more during the DAFO period or better compliance with brace wear when using the DAFOs cannot be determined. Both compliance with brace wear and walking activity are clinically important. Patients must wear their braces to receive any benefit in function from their AFOs. It is an added benefit if bracing can also increase activity, participation, and quality of life. Although we did not observe any patterns suggesting an accommodation period for either brace approach, these benefits may require a longer time to occur for the ADR-AFO braces because most of the children wore either traditional AFOs or DAFOs before the study. A longer wear period may be needed to adapt to the ADR-AFO braces, which represent a bigger change from the children's previous braces.

Limitations

This study has several limitations. First, only 10 children with CP with a mix of crouch and/or equinus gait participated. Because of the small sample size and heterogeneity of the participants, power of the statistical tests was generally low; additional differences between braces may exist but not have been detected in the current analysis (type 2 error). Only children in GMFCS levels I and III are represented although the inclusion criteria allowed for the participation of children in GMFCS level II. The study results should therefore be considered preliminary until they can be confirmed and refined by larger follow-up studies. Also, 2 children had different forms of assistance during tests because they forgot to bring their assistive devices to 1 of the test sessions. Ideally, assistive devices would have remained consistent across all test sessions because the change in assistance may have affected the gait parameters measured. All but 1 of the ADR-AFO braces had a heel wedge attached, whereas none of the DAFOs were wedged. The wedging rather than other aspects of brace design possibly caused some of the differences seen between the 2 brace types. Although the use of shoes without braces can alter gait, a "shoes alone" condition was not tested because the shoes used in the study do not fit well without orthoses. In addition, because of the age of the participants, this study assessed parent-reported satisfaction and functional ability; views on functionality and cosmesis may differ between the parent and the child.

Finally, because each child has a different clinical presentation, bracing was individualized rather than standardized. Bracing must be customized to the individual to be effective, and we believe this provides the fairest representation of how bracing is applied in actual clinical practice. Both manufacturers were given the information they requested to be able to provide the braces they deemed most appropriate for each child. Future research should focus on identifying the brace characteristics most appropriate for individuals with different gait patterns and clinical presentations.

CONCLUSIONS

Both Cascade DAFO and Ultraflex ADR-AFO orthotic approaches improve stride length, hip extension in stance, and dorsiflexion in swing compared with barefoot walking. The DAFO approach produces more normal ankle kinematics and kinetics through late stance, but the ADR-AFO method allows more normal push-off power at preswing, which may improve the energy efficiency of gait. Stance-phase knee extension is better in the ADR-AFO compared with the DAFO orthoses. Parent-reported patient satisfaction and walking activity are higher for the DAFOs because of lower weight and better comfort, fit, cosmesis, and ease of use.

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CLINICAL BOTTOM LINE

Commentary on: "Comparison of 2 Orthotic Approaches in Children With Cerebral Palsy"

"How could I apply this information?"

Physical therapists are often asked "what brace should my child wear?" and "will this brace make my child walk better?" Orthotic prescription is complex. Often more than 1 orthotic might be effective and appropriate. Although orthotics might improve some aspects of gait, they may limit movements that are required to walk efficiently. Therapists determine the goal of the orthotic and consider what movements are being compromised to attain the goal. The results of this study support use of the Ultraflex Adjustable Dynamic Response ankle-foot orthosis when the primary goal of bracing is to improve knee extension in stance or push-off in terminal stance. Alternately, the Dynamic AFO (DAFO) may be more appropriate when the goal of bracing is to improve dorsiflexion in stance, foot clearance in swing, or to increase walking velocity. Families and children preferred DAFO orthotics over the Ultraflex, resulting in improved compliance and increased walking with DAFO use.

"What should I be mindful about when applying this information?"

The limited follow-up precluded assessment of the effect of bracing on passive range of motion over longer periods. Although the authors report no change in the gastrocnemius or soleus muscle over the 4-week study period, the possibility exists for a negative effect on the length tension relationship, resulting in less muscle force, or a decrease in passive muscle length of the gastrocsoleus over periods longer than the 4 weeks. The muscle may become overlengthened, and closed-chain restraint of tibial progression can be diminished facilitating crouch posture or contracture of the gastrocsoleus leading to development of toe walking. As a result, consideration of the natural history of the condition and progression of the individual patient is important when applying these results.

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