PEDIATRIC WALKING vs. TRAINING ON PROTOTYPE MOTOR-ASSISTED ELLIPTICAL: KINEMATIC AND EMG COMPARISONS AT SELF-SELECTED FAST SPEEDS

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Introduction

Motor-assisted elliptical machines are used to address walking and fitness deficits in adults[1] but the elliptical's motor-assisted adjustable stride length is too long for children. To overcome this limitation, a modified crank system was developed to shorten step length and height to more closely emulate younger children's movement patterns.[2]

Purpose

To compare children's lower extremity joint kinematics and muscle activation patterns while walking at their self-selected fast pace (SSF) and while training at their SSF speed on the modified motor-assisted elliptical with and without motor assistance.

Hypotheses

•While training at a fast speed on the device sagittal plane joint kinematics at the hip, knee and ankle would emulate those occurring during fast gait.

•The device's motor-assistance would decrease muscle demands compared to fast gait, but muscle demands could be increased by having the participant override the motor.

Methods

Subjects:

- Twenty children (ages 3-12) without disabilities

Instrumentation

- Motor-assisted elliptical (Madonna ICARE by Sports Art E872MA-modified)
- Dominant lower extremity 3D kinematics (Qualisys 12-camera; 120 Hz)
- Surface EMG (Delsys, Bagnoli-16;1,200Hz)
- Footswitch (B&L Engineering;1,200 Hz)

Figure 1: Example of unmodified motor-assisted elliptical used in testing.

Methods (Cont.)

Procedures

- Participants walked at their SSF speed and trained on the motor-assisted elliptical with two levels of motor assistance.

1) Motor provided active assistance to maintain self-selected fast speed (AAF) and
2) Participants overrode the motor's assistance to maintain self-selected fast speed (AAF+)

Data Analysis:

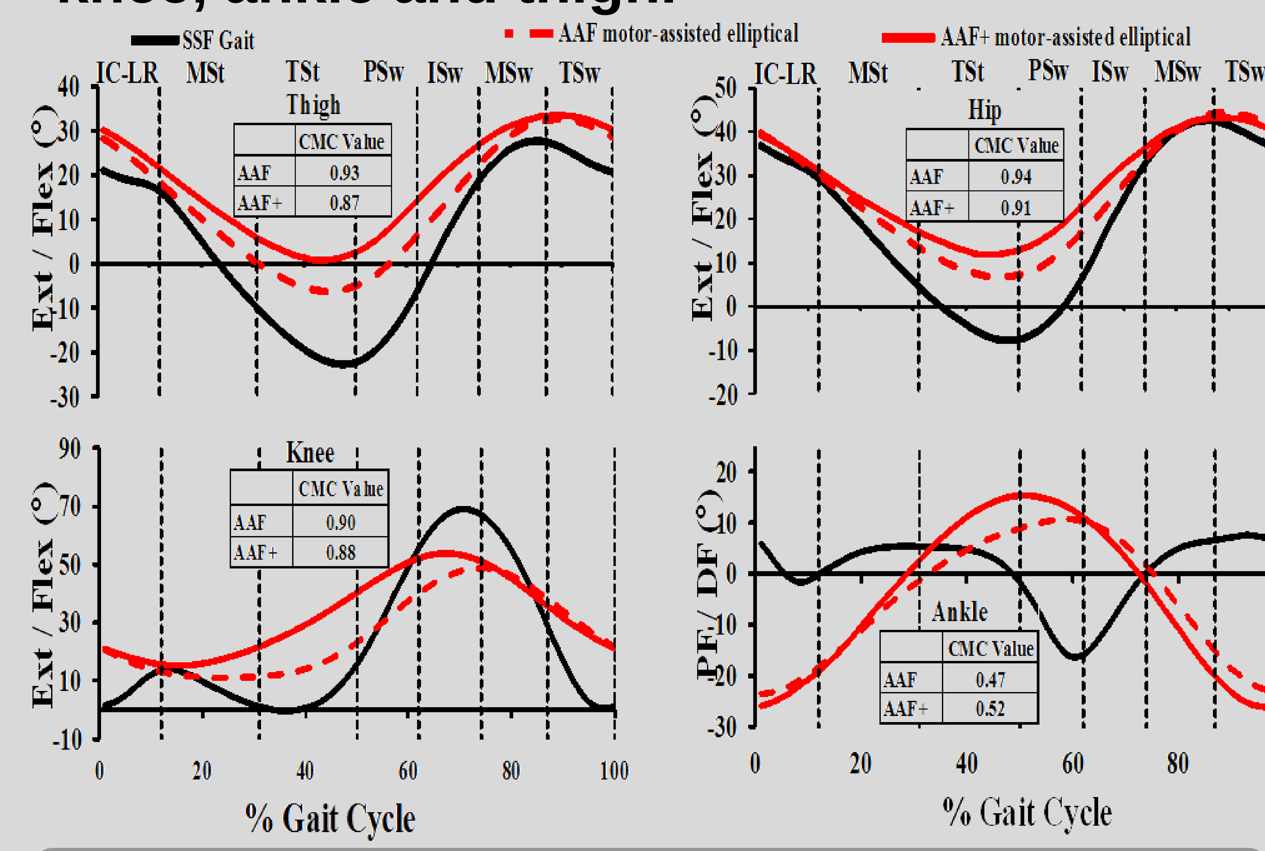
- Footswitches (SSF) and foot pedal (AAF, AAF+) data defined cycle phasing
- A minimum of 10 cycles were analyzed for each participant and condition
- Sagittal plane joint angles calculated for thigh, hip (thigh relative to pelvis), knee, and ankle
- EMG data filtered, rectified and integrated
- Peak and mean activity normalized to maximum recorded and expressed as % MVC
- Duration expressed as percentage of gait cycle (% Movement Cycle [MC])

Statistical Analysis

- Coefficient of multiple correlations (CMCs) evaluated similarities in motion profiles between SSF gait and AAF and AAF+ for hip, thigh, knee, and ankle.
- Separate 3 X 1 analyses of variance with repeated measures identified differences between SSF, AAF and AAF+ for each muscle's activity

Results

Figure 2. CMC comparison between hip, knee, ankle and thigh.



Conclusions

Children's thigh, hip, and knee motion patterns during AAF and AAF+ speed did emulate SSF. However, the ankle differed notably, suggesting a need for additional refinements to the prototype pediatric device. Reduced muscle demands during AAF and AAF+ compared to SSF suggest the device could be used to help children with muscle weakness and control challenges repetitively practice fast gait-like movements.

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Table 1. Electromyography recorded during SSF, AAF and AAF+

Muscle	EMG Variable	SSF	AAF+	AAF	Main Effect (p < 0.001)
Gluteus Maximus	Peak (% MVC)	47 (20)	34 (9)	14 (7)	SSF > AAF+ > AAF
	Mean (% MVC)	23 (9)	16 (4)	9 (2)	SSF > AAF+ > AAF
	Duration (% MC)	51 (17)	43 (8)	19 (8)	SSF > AAF+ > AAF
Vastus Lateralis	Peak (% MVC)	58 (20)	41 (8)	26 (9)	SSF > AAF+ > AAF
	Mean (% MVC)	25 (8)	19 (3)	13 (4)	SSF > AAF+ > AAF
	Duration (% MC)	67 (17)	66 (20)	63 (22)	N.S.
Medial Gastrocnemius	Peak (% MVC)	72 (8)	21 (10)	19 (9)	SSF > AAF+ > AAF
	Mean (% MVC)	34 (6)	13 (3)	12 (4)	SSF > AAF+ > AAF
	Duration (% MC)	51 (15)	24 (22)	19 (11)	SSF > AAF+ > AAF
Tibialis Anterior	Peak (% MVC)	72 (18)	41 (11)	19 (8)	SSF > AAF+ > AAF
	Mean (% MVC)	34 (10)	20 (6)	12 (4)	SSF > AAF+ > AAF
	Duration (% MC)	80 (17)	53 (17)	25 (11)	SSF > AAF+ > AAF

References

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2. Nelson CA, Stolle CJ, Burnfield JM, Buster TW (2015). Modification of the Intelligently Controlled Assistive Rehabilitation Elliptical (ICARE) system for pediatric therapy. Published online, *ASME Journal of Medical Devices.* DOI: 10.1115/1.4030276.

Disclosure Statement

JM Burnfield, TW Buster and CA Nelson are the inventors of the patented motor-assisted elliptical technology. The technology has been licensed and the inventors receive royalties.