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Children Display Adult-Like Kinetic Pattern in the Time Domain but not in the Frequency Domain While Walking with Ankle Load

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Introduction

While external load is added during locomotion, humans increase the activation of extensors during stance and suppress the initiation of flexors during swing [1]. External load at the ankles, rather than on the waist or thigh, elicits higher activities from ankle extensors, and increases stride length and decreases cadence in adults [2].

Spatiotemporal and kinematic patterns become adult-like in children aged 5-8 years. However, little is known if children show adult-like kinetic patterns while walking with external load. This study aimed to investigate differences in kinetic patterns between children and adults while walking with external ankle load using both time- and frequency-domain analyses..

Method

Participants: Twenty two children and 20 adults participated in this study. The children group was 11M/11F, 9.2 ± 1.3 years in age, 1.33 ± 0.09 m in height, and 28.8 ± 5.5 kg in body mass. The adult group was 10M/10F, 23.7 ± 2.4 years in age, 1.69 ± 0.11 m in height, and 68.9 ± 12.9 kg in body mass.

Experimental design: Each subject walked three times across the 10-m walkway at their self-selected speed and the average speed was used for treadmill walking. Treadmill speed was normalized to the subject's leg length: $\hat{v} = v/\sqrt{gl_0}$, where g is gravitational acceleration and l_0 is leg length.

Three bilateral ankle loads were manipulated: no load, low load (2% of body mass on each side), and high load (4% of body mass on each side). A Zebris FDM-T instrumented treadmill was used to register vertical GRF. Two 60-second trials were collected for each load condition.

Data analysis: Vertical GRF data were normalized to the subject's body weight (BW). Customized Matlab programs determined gait events (heel contact and toe off), and the timing and magnitude of the first peak force F_{Z1} after heel contact and the second peak force F_{Z2} before toe off.

A Fourier transform mathematically transforms vertical GRF into harmonics and each harmonic represents the contribution of certain anatomical components [3]. A discrete periodic signal F(t) can be presented as below:

$$F(t) = A_0 + \sum_{n=1}^{N/2} [A_n \cdot \cos(n\omega_0 t) + B_n \cdot \sin(n\omega_0 t)]$$

where N is the total number of data points, A_0 is the mean value of the signal, n is harmonic number, An and Bn are harmonic coefficients, and ω_0 is fundamental frequency which is equal to 2π divided by the period of the signal. Stance time was used to define the periodicity of vertical GRF.

Statistical analysis: Normalized speed was 0.54±0.04 m/s in children and 0.45±0.04 in adults. GRF variables show linear correlations with $\hat{v}$. Two-way ANCOVAs (2 group x 3 load) with repeated measures and a covariate of $\hat{v}$ were conducted on GRF variables. Post-hoc comparisons with Bonferroni adjustments were conducted. Statistical significance was $p<0.05$.

References

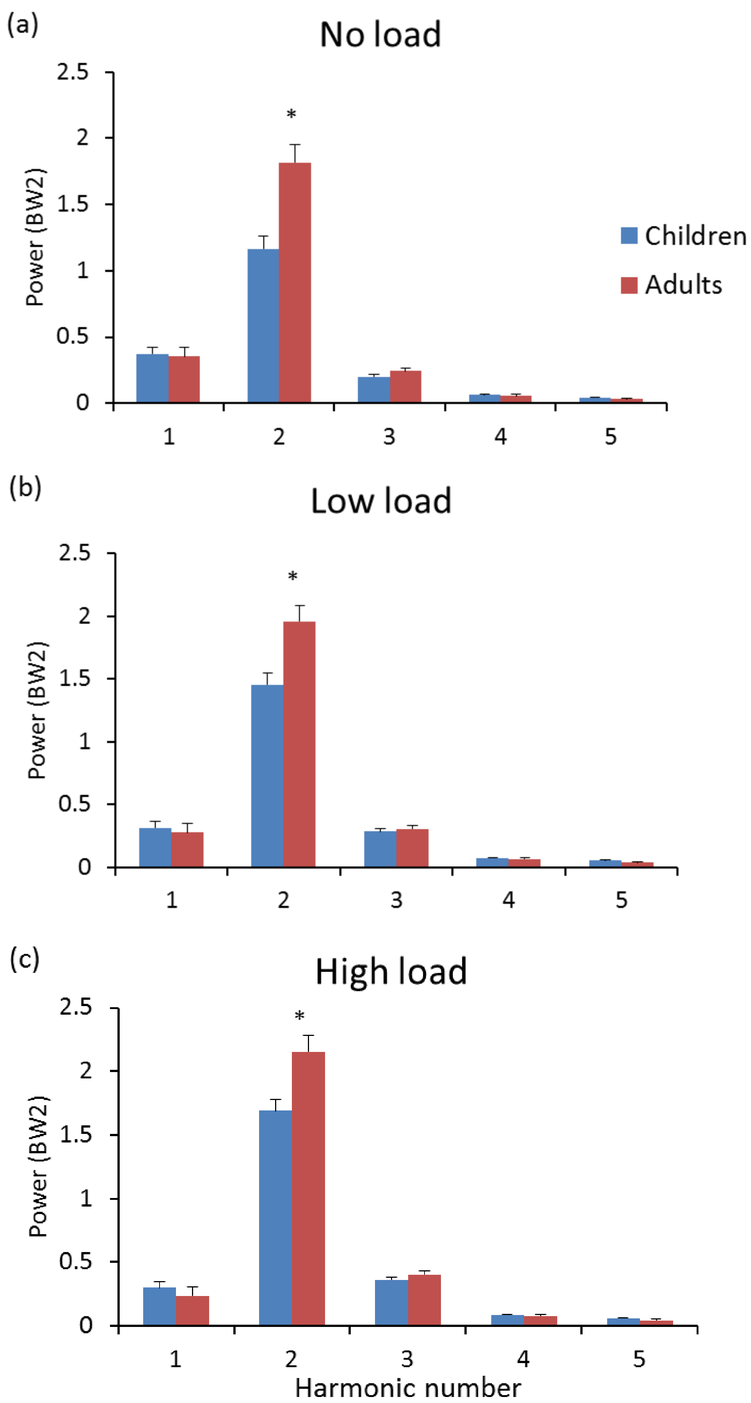
1. Duysens J et al. Physiol Rev 80, 83-133, 2000.
2. Browning RC et al. Med Sci Sports Exerc 39, 515-525, 2007.
3. Schneider E, Chao EY. J Biomech 16, 591-601, 1983.

Results and Discussion

Table 1: Mean (SEM) of adjusted GRF variables

	Children			Adults		
	No load	Low load	High load	No load	Low load	High load
F_{Z1} timing (% stance)	21.5 (0.6)	20.5 (0.6)	20.1 (0.6)	21.6 (0.9)	20.1 (0.9)	19.2 (0.9)
F_{Z2} timing (% stance)	76.2 (0.5)	77.1 (0.5)	77.3 (0.5)	76. 7 (0.6)	77.2 (0.6)	77.1 (0.6)
F_{Z1} magnitude (BW)	1.10 (0.02)	1.16 (0.02)	1.21 (0.02)	1.15 (0.03)	1.18 (0.03)	1.26 (0.03)
F_{Z2} magnitude (BW)	0.99 (0.02)	1.10 (0.02)	1.17 (0.02)	1.03 (0.03)	1.11 (0.03)	1.17 (0.03)

Children produced a similar timing and magnitude of peak vertical GRFs as adults after adjusting for $\hat{v}$ (Table 1). There was a group by load interaction on F_{Z1} timing (p=.005), a load effect on F_{Z2} timing (p<.001), a load effect on F_{Z1} magnitude (p<.001), and a group by load interaction on F_{Z2} magnitude (p<.001).



Children produced a lower power from the 2nd harmonic than adults in each condition after adjusting for $\hat{v}$ (Fig. a-c).

Both groups had the highest power from the 2nd harmonic and increased this power with ankle load.

There was a group by load interaction on the 2nd harmonic power (p = .004), where children increased the power to a greater extent than adults from no load to both load conditions.

There was a load effect on the first five harmonics (all p<.001).

Both groups increased the 2nd to 5th harmonic power, but decreased the 1st harmonic power with the load.

Conclusions

Children aged 7-10 years display adult-like kinetic pattern in the time domain but not in the frequency domain. A frequency analysis helps reveal kinetic differences between children and adults. Neuro-muscular development continues into adolescence.

Acknowledgement

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