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Kinematic variables assessment during the first three months of independent walking

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SUMMARY
In the first 5-6 months of independent walking important transitions appear in all gait parameters that should be monitored with longitudinal studies. The aim of this study is to assess kinematic variables along a three-month period during the acquisition of walking in toddlers. Nine 13 month old toddlers participated in this study. The toddlers walked freely on a 5 meter walkway. The variables selected were: spatio-temporal parameters and joint bidimensional angles. The Dvideow 5.0 and Matlab softwares were used for data digitalization and processing. No significant differences were found, however toddlers showed speed, cadence improvements and also an increase in the first wave of the knee flexion. The study concluded that gait experience acquired during the first three-months of independent walking was not enough to cause significant changes in the biomechanical variables studied.

INTRODUCTION
The first 4-5 months of independent walking are part of the transition phase when the baby learns how to coordinate the vertical posture and the movement of the body segments during forward progression [1]. During this phase the child's gait pattern is typically instable [2,3] with frequent falls and high variability. Therefore, this study aimed to assess and describe changes that occur during the first months of independent walking in spatiotemporal variables and lower limb angular kinematics in the sagittal plane.

METHODS

Subjects and Procedures
The project was sanctioned by the UFSCar Ethical Committee in Human Research (Nº 013/2010).

Nine healthy children participated in the research, weighing at birth more than 2,5 kg (3,400 ± 386 g). This longitudinal study was conducted during the first months of independent walking and all children were evaluated three times, with a one month gap between assessments. By the time of the first evaluation, all children were 13 months-old. They were all 14 months-old during the second assessment and 15 months-old during the third.

In order to analyze the kinematic pattern of the emergent walk four digital cameras were used (Panasonic, AG-DVC), with a 60 Hz acquisition frequency. Reflexive markers were fixed in specific anatomic points (fifth metatarsal, calcaneus, lateral malleolus, knee joint line, greater trochanter of the femur and acromion) to bild body segments (trunk, thigh, leg and foot) and describe their movement in the sagittal plane.

The markers were tracked using the videogrammetry software Dvideow 5.0 (Digital video for biomechanics for Windows) [4]. Data analysis was conducted using Matlab (Mathworks, Inc, 2009).

Variables Analyzed
The spatiotemporal variables chosen for the analyses were stride length, stride duration, walking speed, cadence, stance period and swing phase duration.
Maximum, minimum and average angular displacements (in degrees) between thigh, leg and foot called respectively thigh, knee and ankle angles were also calculated in the sagittal plane. The discrete points reached by the angular displacements described as maximum ankle dorsiflexion (T1), maximum ankle plantar flexion (T2), maximum knee flexion after foot contact (J1), maximum hip flexion in stance (Q1), maximum hip extension in stance (Q2) and maximum hip flexion in swing (Q3) were selected for analysis.

To verify any significant differences between the three assessments Friedman's ANOVA for repeated measures was used. The STATISTICAL PACKAGE FOR THE SOCIAL SCIENCE (SPSS) – version 17 was used and the significance level defined as $p \leq 0, 05$.

RESULTS AND DISCUSSION

Spatiotemporal parameters
There were no significant differences ($p \leq 0,05$) in any spatiotemporal parameters (Table 1). Qualitatively, stride length, speed and stride frequency increased between evaluations. The opposite occurred with stride duration alng the three months. Support phase percentage decreased in the third assessment, as well as values of support phase

duration, which diminished from the first to the second evaluation and also from the second to the third. Despite not providing significant differences, qualitatively, data corroborated literature (Hallemans et al, 2005).

Joint angles and qualitative angular displacement

No significant differences were found ($p \leq 0,05$) after data analysis of the studied variables (Table 1)

Hip

Hip flexion during swing phase (Q3) registered low values. Children started support with an average 18,9º flexed hip (Q1) in the first assessment, 16,8º during second and 16,2º in the third. They also exhibited negative hyperextension (Q2), averaging -1,6 º and -3,5º along the assessments. The results suggest that leg movement amplitude was not explored fully, that may have resulted in less than optimal propulsion in this age [5].

Knee

Marked increases of the first wave of knee flexion (J1) between evaluations were observed, which conforms to the main changes in the flexion/extension knee curve already described [7].

Ankle

Dorsiflexion (T1) and plantarflexion (T2) values are in line with other assessments recorded in literature [6,7]. Figure 1 shows that children's foot initiates dorsiflexion by the time it touches the soil, not performing plantarflexion until the whole foot is supported on the ground. That indicates the absence of the first rocker, confirming previous results [6].

These behaviors suggest that the gait pattern in this period still shows an incomplete foot-floor contact that may lead to an underdeveloped walking strategy. It is possible that the independent walking experience acts as functional factor to achieve a more mature walking pattern regarding ground reaction forces interactions.

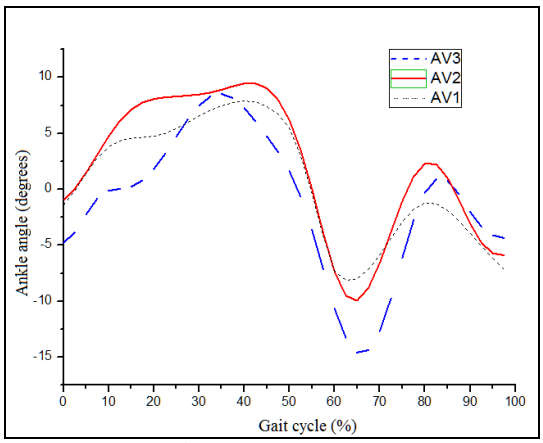

Figure 1: Mean values of the angular displacement all children during stride cycle (% of the cycle) for the first (AV1), second (AV2) and third (AV3) assessments. Positive values indicate ankle dorsiflexion and negative values indicate ankle plantarflexion.

CONCLUSIONS

Along the first three months of independent walking the children of the present study do not develop the first knee flexion peak during the support phase and the neither the plantarflexion at the foot strike.

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Table 1: Mean (standard deviation) of the spatiotemporal parameters and selected variables analysed during all three assesssments

Variables	Assessment 1	Assessment 2	Assessment 3	*p*
Stride length (m)	0,45 (±0,08)	0,48 (±0,09)	0,49 (±0,09)	0,70
Stride duration (s)	0,73 (±0,09)	0,65 (±0,09)	0,64 (±0,10)	0,20
Speed (m/s)	0,59 (±0,17)	0,74 (±0,20)	0,74 (±0,20)	0,33
Cadence (steps/min)	155 (±24)	179 (±36)	180 (±38)	0,07
Stance period (% of the stride cycle)	64,6 (±3,9)	66,3 (±6,6)	63,2 (±3,50)	0,32
Swing phase duration (s)	0,27 (±0,09)	0,22 (±0,02)	0,23 (±0,05)	0,06
Support phase duration (s)	0,50 (±0,10)	0,46 (±0,14)	0,45 (±0,11)	0,32
T1 (º)	15,9 (±7,2)	10,0 (±3,8)	13,2 (±7,0)	0,72
T2 (º)	-12,6 (±6,0)	-18,7 (±7,4)	-19,7 (±11,1)	0,20
J1 (º)	10,8 (±4,7)	11,2 (±3,1)	14,5 (±4,7)	0,49
Q1 (º)	18,9 (±3,7)	16,8 (±4,7)	16,2 (±5,9)	0,40
Q2 (º)	-2,40 (±2,5)	-3,50 (±2,7)	-1,60 (±4,6)	0,15
Q3 (º)	27,2 (±6,5)	30,9 (±9,4)	24,4 (±6,1)	0,09