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REGRESSION ANALYSIS ON GAIT DYNAMIC PARAMETERS, AGE AND SPEED OF PROGRESSION IN YOUNG CHILDREN

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SUMMARY
The current study presents a linear regression analysis on dynamic parameters in young children (under 7 years old) with both age and speed of progression. The evolution of gait parameters with these two factors has already been studied, but to our knowledge, no study until this one considers both of them and interactions on a young population of children.

INTRODUCTION
Two factors largely influence children gait: age [1] and speed of progression [2]. Speed influence on gait parameters was previously identified in children between 7 and 12 years old [3]. To our knowledge, no equivalent data exists in young children. Moreover, interaction between both age and speed of progression on gait has not yet been quantified. Thus, this study proposes a linear regression analysis on dynamic parameters in young children (under 7 years old) considering both age and speed of progression.

METHODS
Gait analysis was performed on 56 healthy children (between 1 and 7 years old). A total of 691 gait trials were collected. Independent walking was acquired between 10 and 17 months of age and medical examination did not reveal any orthopedic or neurological disorder. Parents gave their informed consent for their child to participate in the study which was approved by the local ethics committee.

Thirty-two retro-reflective markers were fixed on classical anatomical landmarks of pelvis and lower limbs. Children walked at self-selected speed. Fifteen to twenty gait trials were measured for each subject using a Motion Analysis® system with 8 Eagle® cameras (Santa Rosa, USA) and 3 Bertec® force platforms (Colombus, USA), synchronized to a sampling frequency of 100 Hz.
After signal processing (fourth-order butterworth filter, 6Hz cutoff frequency), all markers' trajectories were obtained in an Inertial Coordinate System (ICS) via Cortex® software allowing the construction of each Segment Coordinate System. The hip joint center coordinates were calculated using regression equations of Harrington et al [4], considering only the healthy children's data. The inertial parameters were estimated from scaling equations [5]. The joint forces and moments were computed in the ICS by bottom-up inverse dynamics and the joint angular velocity was computed using the quaternion algebra [6]. The 3D joint power was calculated as the dot product of joint moment and angular velocity. The parameters were normalized following the recommendations of Hof [7].

Specified peaks values of each gait parameter were identified and linear regression analyses were performed on these data. To quantify the interaction between gait parameters, age and speed of progression, the model used was:

$$\text{Parameter} = a * \text{Age} + b * \text{Speed} + c * \text{Age} * \text{Speed} + d$$

with a,b,c,d : constants

Determination coefficients (r²), standard errors and p-values were also calculated to evaluate the goodness of fit.

RESULTS AND DISCUSSION
The 691 trials provided wide ranges of age and speed of progression: [1.1-7 years old] and [0.1-0.7 $m.s^{-1}$/sqrt(g*leg length)] respectively.

Regression analyses coefficients, r² and standard errors are presented in Table 1. All the regressions were significant (p-value <0.05), except for the knee rotation moment at 0-30% of gait cycle. Most of the r² values were greater than 0.1, corresponding to results presented for older children [3]. Especially, knee (Figure 1) and hip 3D powers at 50-100% of gait cycle presented best regressions (r^2>0.5). Ankle, knee and hip sagittal moments also presented relative good correlations (r²>0.25).

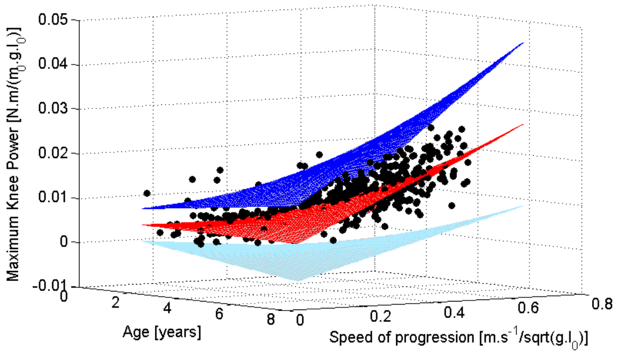

Figure 1: Knee maximum generated power at 70-90% of gait cycle [$N.m/(m_0.g.l_0)$] according to age and speed of progression. (m_0: mass; l_0: leg length g: acceleration of gravity).
Dark points represent all the values for all the trials. Red surf represents values estimated with regression coefficients. Light blue and dark blue surfs represent the confidence interval of 95%, respectively inferior and superior limit.

Many studies dealt with the influence of speed of progression on gait parameters and recommended considering this influence on results interpretation [2,3,8]. The present results demonstrate that both age and speed of progression should be considered in young children. Besides, a previous study regarding gait parameters evolution with speed of progression was performed on older children, and the authors "do not recommend that the data be used to extrapolate the regression data to wider speed ranges" [3].

A previous study on children older than 7 years revealed that speed of progression predominantly characterized gait [9] and not age, in contrast with the current results. This difference was probably due to the youthfulness of the present population. Consequently, speed of progression but also age variation should be considered in young children.
These regression coefficients can be used to approximate gait dynamic parameters from age and speed of progression in healthy young children (with caution, regarding to r^2 value).

CONCLUSIONS

This study proposed linear regression analysis on dynamic gait parameters in young children with both age and speed of progression. Taking into account these two factors provides a good approximation of gait parameters, with regression linear approach, especially for the knee and hip 3D powers, as well as moments in sagittal plane.

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Table 1: Results of regression analysis on typical peaks. Regression coefficients (a,b,c,d), determination coefficient r² (in bold if superior to 0.2) and Standard Error (SE). □: p-value > 0.05

Regression Model : Parameter = a * Age + b * Normalised Speed + c * Age * Normalised Speed + d							
		a	b	c	d	r²	SE
Moments							
Sagittal plane joint moments							
Ankle	max plantarflexion 0-100 %	-0,011	-0,202	0,022	-0,098	0,137	0,002
Knee	max extension 0-30 %	0,010	0,184	-0,004	-0,045	**0,264**	0,002
	max flexion 30-55 %	0,006	-0,134	-0,003	-0,017	0,194	0,001
	max extension 50-100 %	-0,002	0,033	0,011	0,013	**0,266**	0,000
Hip	max flexion 0-25 %	0,021	-0,109	-0,020	-0,144	**0,216**	0,002
	max extension 45-75 %	-0,001	0,017	0,005	0,002	**0,271**	0,000
	max flexion 70-100 %	0,000	0,013	-0,002	-0,004	0,110	0,000
Frontal plane joint moments							
Ankle	max adduction 0-30 %	0,002	0,024	0,000	-0,012	0,039	0,001
	max abduction 30-100 %	0,005	-0,077	-0,002	-0,024	0,091	0,001
Knee	max abduction 0-30 %	0,011	0,042	-0,019	-0,071	0,019	0,001
	max abduction 30-70 %	0,014	0,079	-0,022	-0,088	0,073	0,001
Hip	max abduction 0-30 %	0,010	-0,076	-0,004	-0,128	0,095	0,002
	max abduction 30-60 %	0,005	0,010	0,003	-0,143	0,062	0,002
Transverse plane joint moments							
Ankle	max internal rotation 0-100%	0,006	0,029	-0,008	-0,041	0,024	0,001
Knee	max internal rotation 5-30%	-0,002	0,074	-0,004	0,018	0,065	0,001
	min internal rotation 30-60%	-0,001	-0,008	0,000	-0,004	0,006 □	0,000
Hip	max internal rotation 0-30 %	0,003	-0,023	0,002	-0,046	0,024	0,001
	max internal rotation 35-50 %	0,003	0,035	-0,001	-0,052	0,034	0,001
3D Powers							
Ankle	min 0-20 %	0,004	-0,041	-0,003	-0,017	0,109	0,000
	min 30-50 %	-0,003	0,038	0,004	-0,036	0,059	0,000
	max 40-100 %	0,000	0,093	0,012	0,014	**0,295**	0,001
Knee	min 0-20 %	-0,002	-0,062	0,002	0,012	0,156	0,000
	max 15-30 %	-0,004	0,001	0,012	0,008	0,139	0,000
	min 20-45 %	0,004	-0,054	-0,006	0,003	**0,231**	0,000
	max 40-55 %	-0,002	0,067	-0,001	-0,001	0,118	0,000
	min 50-75 %	0,006	-0,065	-0,024	-0,005	**0,506**	0,000
	max 70-90 %	-0,001	-0,007	0,007	0,005	**0,664**	0,000
	min 80-100 %	0,001	0,002	-0,013	-0,003	**0,649**	0,000
Hip	max 0-30 %	-0,002	0,150	-0,006	0,007	**0,264**	0,001
	min 35-60 %	0,003	0,049	-0,010	-0,007	0,060	0,000
	max 55-75 %	-0,008	0,025	0,027	0,016	**0,566**	0,000
	min 70-100 %	0,003	-0,020	-0,008	0,001	**0,654**	0,000