EVALUATION OF ANKLE AND KNEE MOVEMENT PATTERN DURING MATURATION OF NORMAL GAIT

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ABSTRACT

Objective: The purpose of this study was to evaluate the movement pattern of knee and ankle during stance phase in order to analyze the behavior of these parameters during gait maturation process. Methods: Subjects without neuro-muscular diseases and with complete documentation at gait laboratory were included. Kinematics data were collected during self-selected speed in the children group (n =34) with mean age of 9.7 $\pm$ 2.7 years and in the adult group (n =17) with mean age 25 $\pm$ 3.8 years. The variables analyzed were 1) Knee flexion at initial contact 2) First peak knee flexion in stance 3) Minimum knee flexion in stance and 4) Peak of ankle dorsiflexion in stance. Results: The results were compared and underwent statistical analysis. The children group showed higher knee flexion in stance than the adult group; however, dorsiflexion peak in stance did not present statically significant differences between groups. Conclusion: In the studied group, knee flexion during stance phase was different between children (mean age 9.7 years) and adults (mean age 25 years), which suggests that gait maturation process can last until the second decade of life.

Keywords: Gait. Child. Biomechanics.

Citation: *Morais Filho MC, Reis RA, Kawamura CM. Evaluation of ankle and knee movement pattern during maturation of normal gait. Acta Ortop Bras. [online]. 2010; 18(1):23-5. Available from URL: http://www.scielo.br/aob*

INTRODUCTION

The human gait is a form of biped locomotion with cyclic movements, which calls for interaction among the neuromotor, sensory and musculoskeletal systems, and requires minimum metabolic energy consumption.[1]

The gait cycle is characterized by two consecutive initial contacts performed by the same lower limb, and divided into two different phases (stance and swing). At the habitual gait speed of 80m/min, these phases represent respectively 62% and 38% of the gait cycle.

The stance phase is the period where the foot remains in contact with the ground and it can be divided into first double stance (contact) (0% to 12%), single stance (mid-stance) (12% to 50%), and second double stance (propulsion or toe-off) (50% to 62%). The swing phase is the period when the limb is in progression movement and not in contact with the ground. It can be divided into initial swing (62% to 75%), mid-swing (75% to 85%) and terminal swing (85% to 100%).[2]

Kinematics is defined as the study of movements without taking into consideration the forces that produce them.

The knees flex twice during each gait cycle. Flexion rises to between 8º and 9º after initial contact, soon followed by their extension during stance up to about 40% of the cycle. In the initial third of the swing phase the knee flexes once again and reaches its flexion peak (60º) with the objective of adequately releasing the ipsilateral foot.[3]

The ankles also present two periods of plantar flexion followed by progressive dorsiflexion during most of the stance phase. After the toe-off, the ankles once again describe a dorsiflexion movement that lasts until initial contact.[4]

The current development of gait analysis and its growing application to the study of pathological patterns, have created the need for knowledge of normality data. This is more evident in the study of children. Gait pattern in children differs substantially from the gait pattern of adults, which leads us to believe that measures during the various age brackets are necessary for critical comparisons, yet there is very little literature on this topic.[5]

Many factors complicate the distinction between normal and pathological gait in children. They are: musculoskeletal growth,

All the authors declare that there is no potential conflict of interest referring to this article.

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Article received on 10/4/08 and approved on 6/9/09

maturation of the central nervous system, learning capacity and variations associated with changes in speed.[2]

Five essential determinants for gait maturity are: increase of single stance duration, increase of gait speed, increase of stride length, increase of the proportion between pelvis width and the distance between the ankles, and cadence reduction,[2] yet gait maturity acquisition age is a controversial subject in literature, ranging from 3.5 up to 11 years, according to the analysis method used.[3,5-10]

Accordingly, the aim of this study was to describe the knee and ankle movement pattern in the stance phase in different age groups, with the proposal of identifying how these parameters behave during normal gait maturation.

METHODS

Participants

This study involved the gathering of data on 51 normal individuals that were divided into two groups:

1 – Group of children (n=34) with mean age 9.7 + 2.7 years (15 boys and 19 girls);

2 – Group of adults (n=17) with mean age 25 + 3.8 years (6 men and 11 women).

The individuals were all volunteers and filled out the informed consent form for use of data gathered during the gait examination, which consists of a non-invasive and painless procedure. Before participation, all the procedures were explained to each individual and responsible caretaker.

All the data was gathered during gait with free speed on a 8-meter track. The individuals wore swimsuits to allow the placement of markers directly on the skin and went barefoot during the exam.

The inclusion criteria for the study were that the individuals had to be sound, without previously known presence of osteo-muscular or neurological pathologies and without previous orthopedic surgery on the lower limbs.

Place

This is a retrospective study, where the gathering of normal gait data was performed in the Gait Laboratory of Associação de Assistência à Criança Deficiente (AACD; Association for Assistance to Handicapped Children) in São Paulo, Brazil.

Instrumentation

The kinematics data was gathered by means of the three-dimensional gait analysis system Vicon 370 (Oxford Metrics Limited; UK) composed of 6 infrared cameras with a frequency of 60fps (Hertz) and passive markers with a diameter of 25mm – the dynamic calibration system Dynacal 2, from the same company, was used to gather all the data.

The capturing programs employed were versions 2.7 and, subsequently, 4.5 of Vicon DataStation, and the post-processing of the data was generated in full by the Vicon Clinical Manager (MCV), version 1.37. The latter has as biomechanical models the Helen Hayes marker system,[11] the equations of Davis, Ounpuu, Tyburski and Gage for the estimate of the articular centers of the lower limbs.[12]

Six cycles were collected for each individual, selecting 1 representative cycle from each side.

Part of the kinematics of the movement or the spatial orientation of the segments at each instant is expressed in Euler angles by the CGS, having as rotation sequence: flexion, abduction and rotation. The three Euler angles of the pelvis and the foot progression angle (a) are relative to a system of coordinates associated with the laboratory (global system) and it is defined by the calibration method of the Vicon 370 system. The other segments are oriented having as a reference the proximal adjacent segment (local system), where a system of coordinates is generated with the help of anatomical points and previous anthropometric measurements.[12]

The following parameters of kinematics were analyzed for the study: 1) Knee flexion at initial contact, 2) First peak knee flexion in stance, 3) Minimum knee flexion in stance, 4) Peak of ankle dorsiflexion in stance.

Statistical Analysis

The statistical analysis was conducted through the application of the Student's t-test, with $p \leq 0.05$ or 5% considered significant.

RESULTS

The degree of knee flexion at initial contact was higher in the group of children 7.18º than in the group of adults 3.17º ($p < 0.001$).

The first peak knee flexion in stance was higher in the group of children 21.51º than in the group of adults 13.44º ($p < 0.001$).

The minimum knee flexion in stance was also higher in the group of children 6.19º than in the group of adults -0.24º ($p < 0.001$) (Figures 1 and 2).

However, the peak of dorsiflexion in stance did not demonstrate a significant statistical difference between the group of children 13.58º and the group of adults 12.64º ($p = 0.170$) (Table 01).

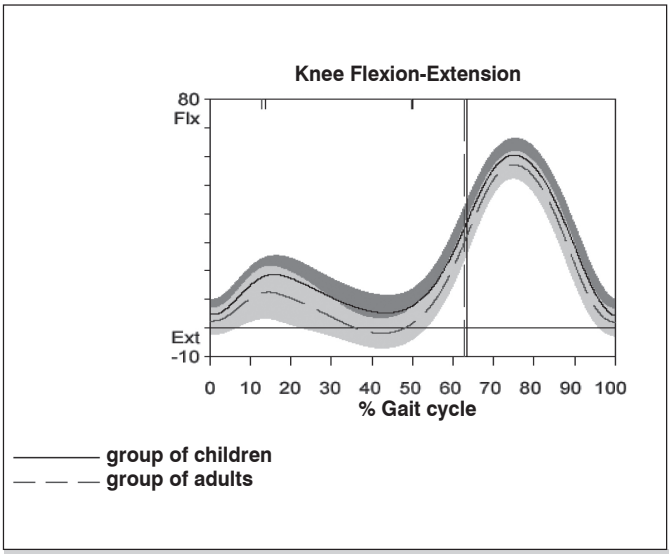

Figure 1 – *Comparison of the articular angles of the knees between the groups of children and adults.*

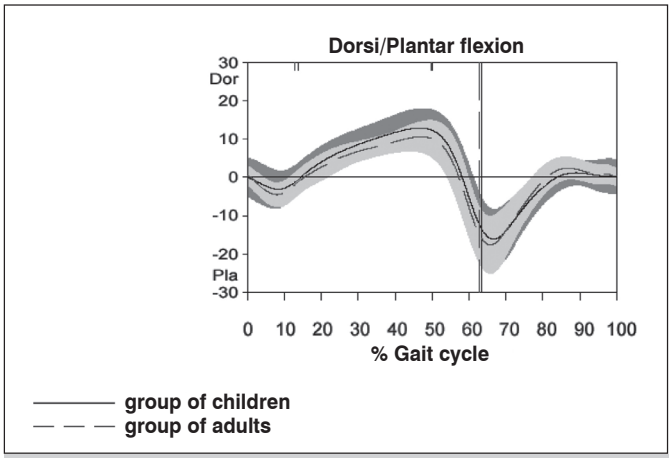

Figure 2 – *Comparison of the articular angles of the ankles between the groups of children and adults.*

Table 1 – *Differences between the groups of children and adults.*

	children's group		adults' group		P value
	Mean value	SD	Mean value	SD	
Knee flexion at initial contact	7.18	5.71	3.17	4.86	< 0.001
First peak knee flexion in stance	21.51	6.57	13.44	7.50	< 0.001
Minimum knee flexion in stance	6.19	4.76	–0.24	4.50 < 0.001	
Peak of ankle dorsiflexion in stance	13.58	4.06	12.64	3.95	= 0.170

Subtitle: Values in degrees. SD (standard deviation).

DISCUSSION

There is a clear need for objective measures instead of subjective judgments in gait evaluation. Gait analysis quantifies the walk and contributes to the evaluation of changes before therapeutic interventions. Furthermore, the collection of some normal gait parameters is necessary for pathological gait interpretation and quantification.

Through the data gathered in this study we observed that the adults exhibited a lower degree of knee flexion at initial contact, in the first flexion wave in stance, and in minimum flexion in stance when compared with the children. A possible explanation for these findings, is that through knee flexion in the stance phase, children obtain an approximation of the center of mass to the ground, providing greater gait stability.

The dorsiflexion peak in stance did not exhibit a significant difference between the groups of adults and children.

Sutherland et al.[3] observed an increase of about 10º in knee flexion after initial contact in children aged 2 and 7 years, followed by a decrease in flexion, whereas at around 35 to 40% of the cycle the flexion angle was equivalent to that measured during initial contact. In the group of two year olds, the knees presented more flexion and returned more gradually to the initial contact position than in the seven year olds. The two year olds also presented a higher degree of dorsiflexion during stance phase.

In the study by Ganley and Powers[7], no differences were observed in the joint kinematics of hip, knee and ankle between seven year olds and adults.

The growth process involves neuromuscular development together with an increase in stature, and both aspects of this process can influence gait pattern development in normal children. Kyriaris[8] reported slight differences in the gait of children above the age of 10 years when compared with adult gait, and declared that the determinant factor was lower limb length.

Ounpuu et al.[5] observed evidence through the gathering of data on normal gait that children establish a mature kinematic and kinetic pattern before the age of 5.

However, in the sample studied the group formed by children with mean age of 9.7 years presented greater knee flexion in the stance phase when compared with the adult group. This data suggests that the gait maturation process persists after this age, which points to the performance of future studies for better definition of the normal gait maturation process.

CONCLUSION

This study shows that the knee movement pattern in the stance phase differs between the groups of children and adults. The children presented a higher degree of knee flexion at initial contact, in the 1st wave of flexion in stance, and in minimum flexion in stance. However, the ankle movement pattern in the stance phase did not present a statistically significant difference between the groups.

ACKNOWLEDGMENTS

To the entire team from the Gait Laboratory of AACD that contributed toward the performance of this study.

REFERENCES

1. Rose J, Gamble JG. Marcha humana. 2a ed. São Paulo: Editorial Premier; 1998.
2. Sutherland DH, Olshen RA, Biden EN, Wyatt MP. The development of mature walking. Oxford: Mac Keith Press; 1988.
3. Sutherland DH, Olshen RA, Cooper L, Woo SL. The development of mature gait. J Bone Join Surg Am.1980;62:336-53.
4. Beck RJ, Andriacchi TP, Kuo KN, Fermier RW, Galante JO. Changes in the gait patterns of growing children. J Bone Joint Surg Am. 1981;1452-6.
5. Ounpuu S, Gage JR, Davis RB. Three-dimensional lower extremity joint kinetics in normal pediatric gait. J Pediatr Orthop. 1991;11:341-9.
6. Cupp T, Oeffinger D, Tylkowski C, Augsburger S. Age-related kinetic changes in normal pediatrics. J Pediatr Orthop. 1999;19:475-8.
7. Ganley KJ, Powers CM. Gait kinematics and kinetics of 7-year-old children: a comparison to adults using age-specific anthropometric data. Gait Posture. 2005;21:141-5.
8. Kyriazis V. Temporal gait analysis of children aged 9-10 years. J Orthop Traumatol. 2002;3:31-4.
9. Katoh M, Mochizuki T, Moriyama A. Changes of sagittal-plane ankle motion and ground reaction force (fore-aft shear) in normal children aged four to 10 years. Dev Med Child Neurol. 1993;35:417-23.
10. Stansfield BW, Hillman SJ, Hazlewood ME, Lawson AA, Mann AM, Loudon IR, et al. Sagital joint kinematics, moments, and powers are predominantly characterized by speed of progression, not age in normal children. J Pediatr Orthop. 2001;21:403-11.
11. Kadaba MP, Ramakrishnan HK, Wootten ME. Measurement of lower extremity kinematics during level walking. J Orthop Res. 1990;8:383-92.
12. Davis RB, Ounpuu S, Tyburski D, Gage JR. A gait analysis data collection and reduction technique. Human Mov Sci.1991;10:575–87.