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A Functional Approach to Learning to Walk

Preliminary Results

Lucile Dupuy[1] Blandine Bril[1] Gilles Dietrich[2, 1] Daniela Corbetta[3]
(1)Ecole des Hautes Etudes en Sciences Sociales, Groupe de recherche Apprentissage et Contexte, Paris, France
(2)Université Paris Descartes, Paris, France
(3)The University of Tennesse, Knoxville, USA
luciledupuy@yahoo.fr, blandine.bril@ehess, frgilles.dietrich@parisdescartes.fr, dcorbett@utk.edu

Abstract

Learning to walk is viewed here from a functional point of view. To move forward it is necessary to produce propulsive forces that necessitate creating and tuning a distance between the center of mass (CoM) and the center of pressure (CoP) along the antero-posterior axis .We hypothesize that learning to walk consists in learning to produce these propulsive forces. We present here a longitudinal study showing that the distance between the centre of mass and the centre of pressure along the antero-posterior axis increases during the first months of learning to walk, and that this increase is correlated with velocity

1. Introduction

Walking behaviour is the first bipedal form of locomotion a human child acquires, long before running or hopping. It may be expressed as the displacement of the erected body forward through a succession of cycles comprised of a double-support followed by a single-support phase, and a double-support again followed by a single-support of the controlateral foot. Yet, to move the body forward, propulsive forces must be generated through this alternate sequence of leg movements. Hence, the process of learning to walk may be viewed as the gradual acquisition of the capacity to produce –and modulate– these critical propulsive forces. Based on a longitudinal study, this paper considers a functional approach to walking acquisition in toddlers, arguing that what the child has to develop and master in order to learn to walk is the control of these propulsive forces.

It has been shown that the translation of forces applied to the body during gait depend on the relative position of the center of mass (CoM) and the center of pressure (that is the barycentre of the ground reaction forces, CoP) as defined in equation 1 [1]

$$kX''_G = (X_G - X_P)m \Rightarrow F_X = (X_G - X_P)m^2/k \quad \text{eq. 1}$$

were X''_G is the antero-posterior acceleration, X_G is the projection of the CoM on the anteroposterior axis, X_P is the position of the CoP on the antero-posterior axis, m is the mass of the body, k is a constant [1]. During a step, the CoP is first directed backward from the CoM, a quick shift appear with the foot contact when the CoP moves ahead of the CoM producing a break in the phase.

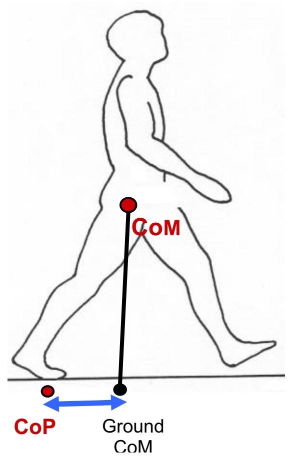

Figure 1. Position of the center of mass (CoM) and the center of pressure (CoP) just prior foot contact. The blue arrow gives the distance between the CoM and CoP along the antero-posterior axis

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We hypothesise that learning to walk entails learning this dynamic process: producing and tuning the distance between the centre of pressure and the centre of mass. This represents a real challenge for a young toddler as she has to face two contradictory constrains: producing disequilibrium and at the same time avoiding to be distabilized.

We present here a longitudinal study showing that the increase in the distance between the centre of mass and the centre of pressure along the antero-posterior axis parallels an increase in walking speed.

2. Material and methods

Participants

Six infants (3 girls, 3 boys) participated in the experiment. Infant gait was recorded every week for the first 8 weeks after the onset of walking, and then every other week until they had 14 to 16 weeks of walking experience.

The study took place at the Department of Health and Kinesiology at Purdue University, USA, while the first author was on Sabbatical leave. The study was approved by the Institutional Review Board of the University.

Apparatus

Walking movements were recorded using two devices. Movement kinematics were recorded using two Northen Digital OPTOTRAK sensors (sampling rate 60 Hz). The sensors were both placed on each side of the walking path at a distance of 4 meters providing a lateral view of each side of the infant walking.
The OPTOTRAK was synchronized with an AMTI force plate which dimensions were 40cm by 60 cm.

Procedure

When the infants arrived at the laboratory their clothing was removed and the sixteen IRED were placed bilaterally onto the fifth metatarsal, lateral malleolus, knee joint, greater trochanter, wrist, elbow and shoulder joints. To record head movement, two IRED were also attached to an infant headband that was placed on the infant head. However infant did not always accepted to wear this headband. When it was not possible only 14 IRED were used.

At each session the infant had to perform about 10 sequences of steps starting behind or on the force plate. After two to three steps on the force plate the child walked approximately ten to twelve steps toward the parent.

Data analysis

The first level of the analysis has been to merge the two files (from the OPTOTRAK and from the forceplate). Missing data were interpolated up to 10 % of actual recorded data with a fourth order Butterworth filter.When too many kinematic data were missing the sequence of steps was eliminated.

The position of the CoM was computed with the classic “method of segmentation” which considers the body as a rigid body of homogeneous and solid cones.

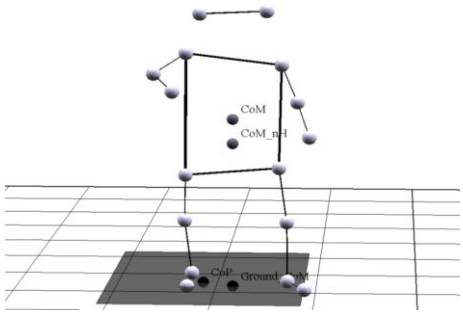

Figure 2. The sixteen ired positions, the center of mass (CoM) (with or without taking the head into account), its ground projection and the center of pressure (CoP) position.

For each step a few parameters were computed: step length, velocity, and distance between the CoP and CoM along the antero-posterior at foot contact. This was considered the time of maximum disequilibrium during a step (see figure 1).

3. Results

Data from one typical child show the significant increase in step length and velocity (figure 3), and a significant decrease in step width described in the literature [2, 4].

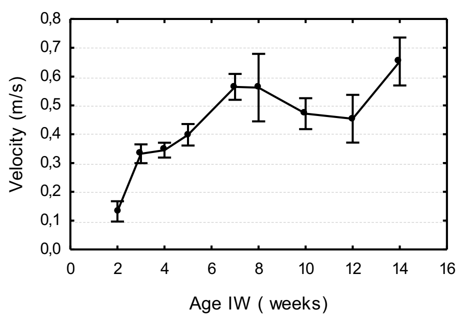

Figure 3. Development of the velocity curve during the first 15 weeks of independent walking for one child demonstrating a typical progression.

The values of the distance between the position of the CoP and the projection of the CoM at foot contact shows as well a significant increase (figure 4).

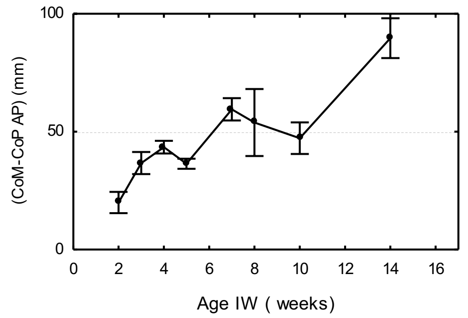

Figure 4. Development of the distance between the CoP and the CoM at foot contact, during the first 15 weeks of independent walking for the same child as in figure 3.

4. Discussion

The preliminary results of this longitudinal study revealed a significant increase of the distance in the antero-posterio axis (CoM-CoP) in one child. This increase parallels the walking velocity commonly described in the literature [2, 4].

The very small values of (CoM-CoP) observed at onset of independent walking, coupled with a very small velocity are interpreted as the consequence of the solution adopted by the child to satisfy a compromise between the necessity to produce propulsive forces that requires a distance between the CoP and CoM and consequently a situation of disequilibrium that directly results from creating such distance. Indeed, such distance could threaten balance and result in a fall.

The discovery process entails an exploratory phase: the child has to explore how to move her body and develops coordination strategies that indeed vary from one child to another as long as these motor strategies satisfy the functional constrains of the task, *i.e.* producing and tuning a distance between CoM and CoP [3].

We argue that learning to walk is a discovery process of the functional properties of the task (mastering the propulsive forces during walking), and that the gait behavior produced by a toddler in her first months of walking development (small steps, wide steps, important double-support duration) reflects this search process.

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