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Developmental changes of static standing balance in children

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Abstract

The purpose of the present experiment was to investigate the time course by which children aged 6-, 8- and 10-year-old adapt and maintain their static balance. Participants ($N = 30$) were required to stand on a force platform with their eyes closed. Ten adult subjects served as a reference group. We analyzed moment-to-moment modifications of quiet stance equilibrium by measuring the range and speed of the center of foot pressure (COP) displacements over time (i.e., periods of 2 s). Results showed that: (1) with age, the range of the COP decreased non-monotonically, with a maximum at 8 years of age, whereas the speed of the COP decreased linearly from 6 to 10 years of age, and (2) over time, both parameters decreased and stabilized, similarly for all age groups, suggesting that the processes underlying the maintenance of an optimal postural stability are mature at least as soon as 6 years of age.

Keywords: Children; Non-linear development; Static balance; Upright stance

The developmental progression to independent bipedal stance, usually accomplished during the first year of life, is one of the major milestones of motor development. There are, however, many changes that continue to occur in the control of posture through ontogeny [1]. The postural control has been investigated using various experimental designs. Several authors examined the control of dynamic balance such as locomotion (e.g., [2]) whereas others investigated the control of static balance defined as the ability to maintain an upright posture and to keep the centre of gravity within the limits of the base of support (e.g., [3,9,17]).

The development of balance control in humans during the life span has generated significant interest [1,9,11,16]. More specifically, the period of age from 6 to 10 years provided several observations. Children until 10 years old are less efficient than adults in the control of either static or dynamic balance. However, improvement of postural control during childhood is characterized by a decreasing magnitude [6,8,12], and frequency [3,8] of postural sway. Moreover, several studies reported a non-linear rate of improvement of static balance control characterized by changes in the postural control strategy occurring around 7–8 years of age [4]. Indeed, it is around the age of 7–8 that adult-like balance control strategies begin to appear [9], characterized by a head–trunk coordination [1]. This non-monotonic improvement has been explained by two main developmental changes: a refinement of both the localization and level of muscle activity [17]; and a change in the strategy or mode of control (i.e. improvement of the feedback-based control of balance) (visual input [6,14], somatosensory input [5], and vestibular input [13]). The use of visual information, considered as the most important source of feedback for postural regulations, improves during childhood as a progress from a ballistic strategy (open-loop control) with large and fast corrections to an integrated open-loop and closed-loop mode of control leading to shorter and more frequent excursions of COP [15]. The integration of both modes of control appears in the 7- to 8-year-olds who predominantly use a closed-loop mode of control. Moreover, in a closed eyes condition, the magnitude (e.g., maximum displacement of the center of mass [6]) and the frequency (e.g., mean velocity of the COP [15]) of postural sway were higher than in an opened eyes condition. Nevertheless, the question of how children integrate sources of information to stabilize their body and control their posture has been extensively answered whereas, to our knowledge, no evidences concerning

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how children control and maintain their posture over time have been provided.

The present study investigated the dynamic changes in static balance in children aged 6–10 years. We sought to determine the time course by which children adapt and maintain their static balance when vision is not available. Specifically, we analyzed moment-to-moment modifications of quiet stance equilibrium (magnitude and frequency of the postural sway) in order to investigate how the ability in maintaining body balance evolves with age.

Forty participants, divided into four groups according to their age, participated in the experiment. Each group aged 6, 8, 10 and 24 years was composed of 10 participants. The mean age and standard deviation for each group were 6.2 years (±6.8 months), 8 years (±1.6 months), 10.2 years (±5.4 months) and 24.3 years (±2.1 months), respectively. This research was performed in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki.

Participants stood barefoot in a comfortable upright posture with their eyes closed, their arms hanging loosely by sides, and their feet placed slightly apart on marks drawn on a force plateform (AMTI, model OR6-5-1). They were asked to remain as stable as possible for the complete duration of the trial. The displacements of the center of foot pressure (COP) were recorded at a frequency of 100 Hz (12-bit A/D conversion). Participants performed five trials of 10 s. A trial was initiated once the children adopted the proper position and stabilized their stance.

Two measures of sway were used to describe the participants' postural behavior. The range of the COP (i.e., magnitude [12]), indicates the maximal excursion of the COP in any direction. It is a global measure that allows to estimate overall postural performance (i.e., stability). The speed of the COP (i.e., frequency [8]) indicates the mean speed of COP displacements over the sampled period. It is the sum of the displacement scalars (i.e., the cumulated distance over the sampling period divided by the sampling time). This measure has been suggested to represent the amount of activity required to maintain stability [10], providing a more functional approach of posture.

COP displacements were analyzed over four different 2-s periods. The first period from seconds 1 to 3 (labelled T1), the second from seconds 3 to 5 (labelled T2), the third from seconds 5 to 7 (labelled T3), and the fourth period from seconds 7 to 9 (labelled T4). The first and the last second of each trial were cut in order to avoid a possible preparation or release of participants' postural activity. Comparison of these four temporal frames yielded information on the effects of the time on participants' ability in stabilizing and maintaining body balance.

Two separate 4 Age [6, 8, 10 and 24 years] × 4 Temporal frame [T1–T4] analyses of variance (ANOVAs) with repeated measures on the last factor were applied to the range and speed. Planned comparisons were used whenever it was necessary. The level of significance was fixed at $P < .05$. Fig. 1a and b illustrate the range of COP (mm) and the speed of COP (mm/s), respectively (i.e., the left graphic illustrates the Age results and the right graphic illustrates the Temporal frame ones, for each dependent variable).

For the range, the ANOVA showed main effects of Age ($F(3, 36) = 30.704$, $P < 0.001$) and Temporal frame ($F(3,108) = 3.797$, $P < 0.05$). As illustrated in Fig. 1a, the range increased between 6 ($M = 13.43$, S.D. = 0.7) and 8 years ($M = 16.62$ mm, S.D. = 1.6), and then, decreased between 8 and 10 years ($M = 11.65$ mm, S.D. = 0.9). The adult level was not attained at 10 years of age, as illustrated by a decrease of the range between 10 and 24 years ($M = 4.02$ mm, S.D. = 0.3). No difference was found between ages 6 and 10. In addition, the range showed a decrease from T1 ($M = 12.41$ mm, S.D. = 6.5) to T3 (T2: $M = 11.5$ mm,

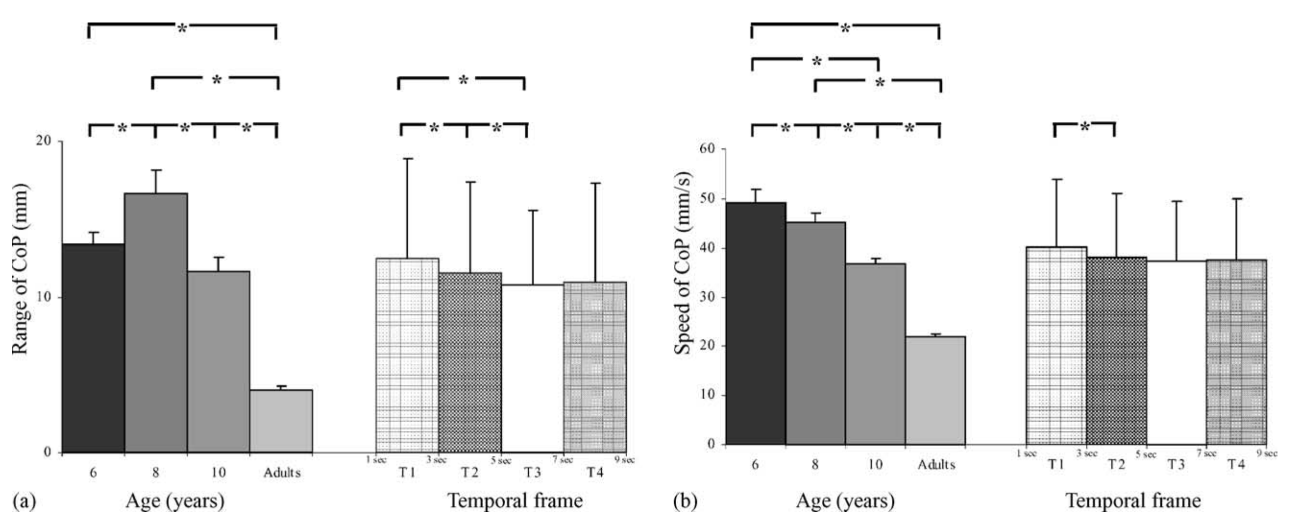

Fig. 1. (a) Mean and standard deviation for the range of COP (mm) (left graphic as a function of Age (6, 8, 10 years and adults) and right graphic as a function of Temporal frames (T1–T4)). (b) Mean and standard deviation for the speed of COP (mm/s) (left graphic as a function of Age (6, 8, 10 years and adults) and right graphic as a function of Temporal frames (T1–T4)).