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Time-of-day effects on postural control and attentional capacities in children

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HIGHLIGHTS

• Children's postural control is better in the middle morning and the late afternoon.
• The diurnal rhythm of postural control is close to that of body temperature.
• The diurnal rhythm of postural control is close to that of attentional capacities.

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ABSTRACT

The present study aimed to examine the effect of time-of-day on postural control, body temperature, and attentional capacities in 5–6 year old children. Twelve male children (5–6-year-old) were asked to maintain an upright bipedal stance on a force platform with eyes open (EO) and eyes closed (EC) at 07:00, 10:00, 14:00, and 18:00 h. Postural control was evaluated by center of pressure (CoP) surface area (CoP_{Area}), CoP mean velocity (CoP_{Vm}), length of the CoP displacement as a function of the surface (LFS) ratio and Romberg's index (RI). Oral temperature and the simple reaction time were also recorded at the beginning of each test session. The one way ANOVA (4 time-of-day) showed significant time-of-day effects on CoP_{Area} ($p < 0.001$), CoP_{Vm} ($p < 0.01$), LFS ratio ($p < 0.001$) and RI ($p < 0.01$). Children's postural control was lower at 07:00 h and at 14:00 h in comparison with 10:00 h and 18:00 h. Likewise, the reaction time was significantly ($p < 0.001$) better at 10:00 h and 18:00 h in comparison with 07:00 h and 14:00 h. Oral temperature was higher at 14:00 h and 18:00 h than 08:00 h and 10:00 h ($p < 0.001$). In conclusion, the children's postural control fluctuates during the daytime (i.e., better postural control at 10:00 h and at 18:00 h) with a diurnal rhythm close to that of body temperature and attentional capacities. Therefore, the evaluation of changes in postural control of 5–6-year-old children using force plate measures is recommended in the middle morning or the late afternoon to avoid the post-awakening and the post-prandial phases.

1. Introduction

Chronobiology refers to the branch of science concerned with time-keeping functions in biological-systems [1]. A multitude of biological rhythms in the human body can be attributed to (i) a mixture of influences from the external environment (e.g., daylight, temperature, social interactions, and timing of meals) [2], (ii) the individual's sleep–wake cycle and (iii) the internal body clock [1]. The term "circadian rhythms" refers to the systematic fluctuations in physiological functions that recur over a 24-hour period [1]. These rhythms induce fluctuations in physiological functions in the human organism that affect our ability to perform various types of motor tasks [3]. Previous studies concerning circadian rhythms and their desynchronizations had practical applications in the postural control field [4–6]. Postural control results from the integration of visual, somatosensory and vestibular information [4] by the central nervous system [5] to contract muscles adequately in order to maintain balance [6]. Furthermore, it has been shown that postural control requires attentional resources [7]. In fact, this sensory integration needs a high level of vigilance, particularly when one of the sensory inputs is no longer effective [8]. Recently, it has been found that attentional capacities in trained adults are time-of-day dependent, with the best values observed in the afternoon for reaction time [9,10].

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Several studies have reported that postural control is influenced by the time-of-day [6,11–15]. It has been reported that the postural control is low between 05:00 and 08:00 h [11,16] corresponding to the bathyphase of the body temperature rhythm [17] and around 13:00 h [18] corresponding to the post-lunch dip observed in the vigilance level [19]. In this context, it has been established that the postural control of young adults fluctuates according to a rhythm [6] which is close to that of body temperature and/or vigilance [11,18]. However, it has been reported that older adults were less stable in the late afternoon [20]. These authors suggested that this impaired postural control observed during the later parts of the day could be related to sleepiness, fatigue accumulating throughout the day or hormone levels. Thus, previous studies have proposed that the time-of-day influence on postural control may exist in young [6] and old adults [20] and this effect varied depending on the age factor. To the best of our knowledge, this aspect has not been examined in young children. It has been showed that young children exhibit a greater magnitude of postural sway than adults during a quiet standing position [21]. Moreover, the age range between 5- and 6-year olds has been identified as one of the critical stages of postural development [22]. During this age range, children seem to be learning how to integrate sensory information and how to calibrate sensory feedback for use in postural control [23]. In fact, they have been shown to use higher rate of postural corrections [24] indicating the predominance of feedback responses. Indeed, the impaired postural control observed in children at this age may increase the fall risk [24]. Clinicians and scientists were interested in evaluating and developing the balance control in children at this critical age. They seek to protect them from injuries and to develop their ability in completing the required movements [25,26]. Since it has been established that the postural control fluctuates according to time-of-day in young and older adults as mentioned above, we hypothesized that children's postural control could be affected by time-of-day. Moreover, we think that we need to know the diurnal rhythm of children's postural control at this age to take it into account when evaluating children's postural control in order to ovoid disparate findings. To date, despite the broad use of postural force plate analysis in both scientific and clinical settings, a lack of consensus exists on when and how the technique should be used.

Therefore, the aim of the present study was to examine the effect of time-of-day on postural control, on the attentional capacities and on the body temperature in 5–6-year-old children.

2. Methods

2.1. Subjects

Twelve male children (age: 5.6 ± 0.4 years; height: 115.2 ± 2 cm; weight: 20.6 ± 2.3 kg; foot length: 27 ± 2 cm) were recruited from a private pre-school in Sousse (Tunisia), to participate in the present experiment. They have the same criteria in terms of socio-economic status and ethnic origin. Moreover, they are sedentary without previous experience in any type of sport (i.e., they practice only recreational activities irregularly). We have taken into account the level of fitness of the subjects because it could influence the results. In previous studies, it has been reported that physical training may improve the postural control in children [26,27]. In fact, practitioners of specific sports acquired new specific balance and sensory organization abilities compared to sedentary subjects [26,27]. Besides, in the chronobiology field, it has been shown that the amplitude of the diurnal rhythm is higher in trained compared to untrained subjects [28]. The exclusion criteria were the presence of vestibular or visual disorder, musculoskeletal or neurological disease and history of injury in the past 12 months requiring medical attention. The study was conducted in accordance with the Declaration of Helsinki and was approved by the Clinical Research Ethics Committee of the National Centre of Medicine and Science of Sports of Tunis (CNMSS). The procedures were fully explained to the participants and their guardians, and they all gave their written informed consent before testing.

In order to guarantee sample homogeneity, the subjects were selected according to their chronotype with reference to their parents' answers to the Morningness–Eveningness questionnaire (MEQ: version for infants) [29], modified for students [30]. This questionnaire consisted of seven questions: three pertaining to sleep onset, three to sleep offset, and once to the peak timing of activity. Each question allows for choice (scored from 1 to 4) and the M–E score was the sum of the seven answers. Scores ranged from 7 to 28, with lower scores representing evening-types and higher scores representing morning-types. All of the subjects were morning-types.

2.2. Experimental design

Each subject was evaluated during four test sessions. As postural control may develop concomitantly with body temperature and/or vigilance rhythm, it seemed necessary to carry out recordings at the bathyphase and acrophase of these rhythms. Thus, four test sessions had to be set-up in a randomized order: in the early morning (at 07:00 h just after the habitual awakening time of our subjects), in the middle morning (10:00 h), in the early afternoon (14:00 h) and in the late afternoon (18:00 h) (Fig. 1). Subjects perform one test session per day. All test sessions are randomized and separated by a period of rest (more than 36 h) in order to eliminate the learning effect.

In this study, the control of a number of factors recommended for diurnal fluctuation studies was taken into account (i.e., chronotype). Masking effects such as the consumption of stimulant drinks (coffee), meals or even physical activity [31] were also controlled [18]. Throughout the experimental protocol, the mean ambient temperature of the laboratory was kept stable (21.2 ± 1.0 °C). Parents were asked to keep the usual sleeping habits of their children. Children were requested to avoid tiring activities during the 24 h before each test session in order to eliminate the fatigue effect which may affect the postural control. It was easy to control compliance with these instructions, because the subjects had exactly the same daily schedules in the pre-school.

2.3. Temperature measurements

Oral temperature was recorded during the four test sessions with a calibrated digital clinical thermometer (Omron®, Paris, France; accuracy: 0.1 °C) inserted sublingually for at least 3 min with the subjects in a seated resting position for at least 15-min.

2.4. Posturographic assessments

Postural control was evaluated using a force platform (PostureWin©, Techno Concept ®, Cereste, France; 40 Hz frequency, 12-bits A/D conversion) which records the displacements of the center of pressure (CoP) with three strain gauges. The platform was level with the surrounding floor. The subjects were asked to stand as still as possible on a force platform with their arms comfortably placed downward at either side of the body, their bare feet were separated by an angle of 30° and their heels placed 5 cm apart. To maintain the same foot positions for all the measurements, a plastic device provided with the platform was used. The subjects were first requested to maintain balance with the eyes open (EO) and then with the eyes closed (EC). In the EO condition, participants were instructed to look straight ahead at a white cross placed onto the wall 2 m away at eye level. In the EC conditions, they were asked to keep their gaze horizontal in a straight-ahead direction. Following French Posturology Association norms, each trial lasts 25.6 s.

CoP excursions were computed from the ground reaction forces and their associated torques. As subjects oscillate during the upright standing postures with their body relatively rigid, the reaction force applied to the body is relatively constant and so the variations of the