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Effects of external load on spontaneous kicking by one and two-month-old infants

Efeitos do peso externo nos chutes espontâneos de lactentes nos primeiros dois meses de vida

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Abstract

Objective: To characterize the spontaneous kicking patterns among one and two-month-old infants, and find whether an external load can modify such patterns at this age. **Methods:** Eight infants were filmed at the ages of one and two months, while in the supine position in a baby chair reclined at 0°. There was a mobile above the infants' arms and a board above their legs. The experiment lasted for six minutes and 20 seconds and, during this time, the infants' kicking movements with and without external loads of 1/10 and 1/3 of their leg mass were observed. The external loads were added to the infants' ankles. The analysis of the images collected using digital video recorders were used to verify the frequency of kicking, the frequency of foot contact with the board, the frequency of one or two-foot movements, foot preference and intra-limb coordination pattern. **Results:** The chi-square test showed that the frequency of kicking was significantly increased at the age of two months and under the conditions of 1/10-load and post-load. Foot contact with the board was less under the condition of 1/3-load but increased at the age of two months. One-foot kicking predominated under all the conditions and at all ages, and the infants showed no preference between the legs. In addition, the intra-limb coordination pattern of the kicking was characterized as in-phase at both ages. **Conclusions:** Intrinsic factors such as the infants' age and extrinsic factors such as external loads of 1/10 of their leg mass promoted increased frequency of spontaneous kicking in one and two-month-old infants.
Article registered in the Australian New Zealand Clinical Trials Registry (ANZCTR) under the number ACTRN12607000555459.

Key words: infant; psychomotor performance; spontaneous kicking.

Resumo

Objetivo: Caracterizar o padrão de chutes espontâneos de lactentes nas idades de um e dois meses, bem como verificar se o peso externo modifica o padrão dos chutes nessas idades. **Métodos:** Oito lactentes foram filmados nas idades de um e dois meses, estando em supino em uma cadeira infantil reclinada a 0º, na qual havia um móbile na extremidade superior e um painel na extremidade inferior. O experimento teve a duração de seis minutos e 20 segundos, durante os quais foram observados os movimentos de chutes nas situações sem e com peso de 1/10 e 1/3 da massa do membro inferior do lactente. Os pesos externos foram adicionados nos tornozelos do lactente. Pela análise das imagens coletadas por filmadoras digitais, foram verificados a freqüência de chutes e de contatos dos pés em um painel, os movimentos uni e bipodais, a preferência podal e o padrão de coordenação intramembro. **Resultados:** O teste qui-quadrado revelou aumento significativo da freqüência de chutes nas idades de dois meses e nas situações de peso de 1/10 e pós-peso. Na situação de peso de 1/3 da massa do membro, verificaram-se diminuição do contato dos pés no painel e, na idade de dois meses, aumento da freqüência de contatos. Em todas as situações e idades, houve predomínio por chutes unipodais, não havendo preferência por um dos membros. Além disso, o padrão de coordenação intramembro dos chutes foi caracterizado como em-fase em ambas as idades. **Conclusões:** Fatores intrínsecos como a idade e extrínsecos como o peso externo referente a 1/10 da massa do membro inferior promoveram o aumento da freqüência dos chutes espontâneos em lactentes nas idades de um e dois meses.
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Palavras-chave: lactente; desempenho psicomotor; chutes espontâneos.

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Introduction

Spontaneous kicks are among the earliest forms of motor behavior in infants, occurring even before birth[1]. In the first six months after birth, the pattern of the spontaneous kicks changes considerably[2-8]. In the first month of life, the spontaneous kicks are characterized by mass movements of the lower limbs (total flexion/extension), i.e. the newborns flex or stretch the hips, knees, and ankles simultaneously[2-4]. These are considered in-phase movements between the joints and can occur both in joints of the same limb (intralimb) and between the limbs (interlimb)[9]. For Kelso[10] and Kelso and Schöner[11], these movements are executed at high speed, with a simultaneous and homologous muscular action of the joints involved.

At around two months of age, the infant starts to perform different spontaneous kicks, and there is a dissociation between the knee and the ankle in the intralimb pattern, i.e. while one joint is bent, the other one is stretched[7,12]. In the interlimb coordination pattern, there is the emergence of the unipedal kicks between one and four months[2,7]. The kicks with these dissociation characteristics between the limbs and between the joints of the same limb are considered out-of-phase[5,7]. These movements are executed at low speed, with the muscles acting simultaneously in the joints, but in a non-homologous fashion[10,11]. From five months of age, new kicking patterns begin to take place, and there are alternate unipedal kicking movements. However, in most infants, the interlimb pattern becomes in-phase again[8].

These changes in the early spontaneous kicking characteristics of infants become noticeably more complex each passing month, culminating in a pronounced dissociation of the hip, knee, and ankle joints by the sixth month[7]. All of the changes that occur in the kicking pattern and in the pattern of the other lower limb movements during the first six months of life seem to be necessary for the infant to be able to crawl, walk, and climb[5,7].

In order to understand the mechanisms of development and control of the spontaneous kicking in infants, researchers have been examining how factors intrinsic and extrinsic to the organism might influence these movements. With regard to the intrinsic factors, the studies have been evaluating different age groups or groups of premature, syndromic, or brain-damaged infants[13-17].

The extrinsic factors have been investigated in studies that alter the individual's posture, offering sensorial stimuli as reinforcement or adding braces with weights to body segments[1,18-21]. In these studies, the researchers tested different weight proportions relative to the mass of the body segments; however, they were not able to clearly show in which proportion the external weight would change the spontaneous kicks so that it could be used to facilitate these movements in infants.

Thus, the aims of the present study are to characterize the spontaneous kicking patterns of one and two-month-old infants, and determine whether the external weights of 1/10 and 1/3 the lower limb mass change the kicking pattern acquired at that age. The choice of these weights was based on the literature, which state that 1/3 the lower limb mass of four-month-old infants reduces the frequency of spontaneous kicking. We carried out the tests with one and two-month-old infants but chose a smaller amount of weight, i.e. 1/10, with the intention of offering a proprioceptive stimulus to the lower limbs and not limit the execution of kicks due to the increase in limb mass.

Based on the knowledge that spontaneous kicking patterns change over time, the following hypotheses were tested: (1) at two months of age, the frequency of kicks is greater than at one month; (2) regardless of age, the weight of 1/10 the lower limb mass promotes a greater proprioception in lower limbs, and therefore increase the frequency of kicks; (3) regardless of age, the 1/3 weight hinders lower limb movements, thus reducing the frequency of kicks; and (4) the weights change the coordination pattern of the kicks from in-phase to out-of-phase. Given these results and the fact that the spontaneous kicks may be related to locomotion, external weights can be used to help increase the frequency of kicks and alter the coordination pattern from in-phase to out-of-phase.

Methods

Subjects

Eight healthy infants (five boys and three girls) took part in the study. The infants were born at term (38.75weeks±0.7) with Apgar score equal to or greater than eight in the first minute (8.4±0.5) and nine in the fifth minute (9.4±0.5), and with adequate mass for the gestational age (3348g±411.95). The subjects were selected from the charts of a Basic Health Unit (BHU) of the city of São Carlos in the State of São Paulo.

Materials

To collect the data, we used a digital scale, an anthropometric ruler, a tape measure, a baby chair with a mobile hanging over the top end and a board (0.30x0.10m) above the bottom end, which activated the mobile when raised (Figure 1)[22], a fabric brace and ball-shaped lead weights that could be added to the brace according to the mass of each

infant. Two digital camcorders (JVC® GY DV-300) were also used. They were attached to tripods and connected to a computer for analysis.

Procedures

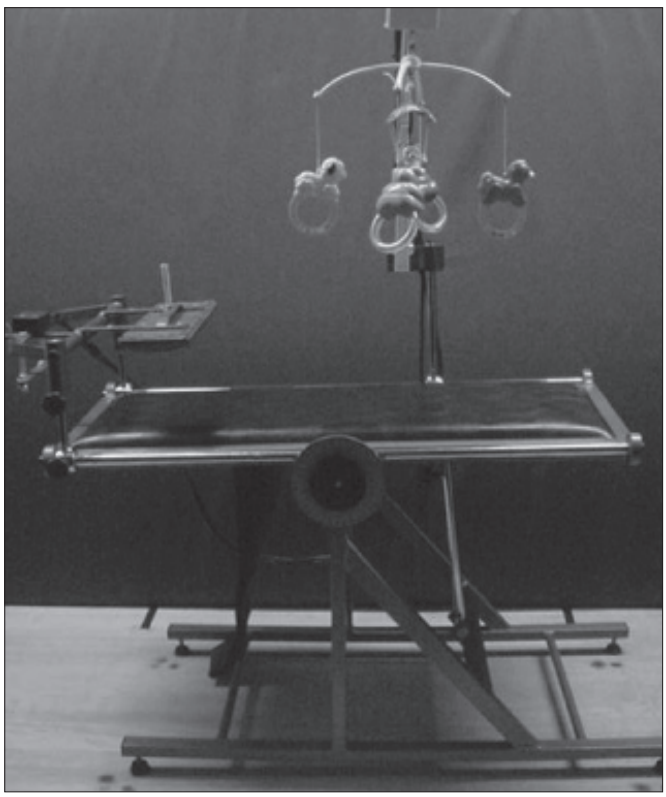
The present study was approved under protocol number 044/2005 by the Human Research Ethics Committee of Universidade Federal de São Carlos (UFSCar), and the infants' parents signed a consent form. The infants were evaluated longitudinally at one and two months of age, with a seven-day interval before or after the day of birth.

Upon arriving at the laboratory, the examiner collected the infants' anthropometric measures, including mass, height, length of lower limbs and limb segments (thighs, legs, and feet), and the circumference of the segments. These data were used to estimate the mass of the infants' lower limbs, according to the method by Schneider and Zernicke[23], and to define the position of the board attached to the chair[1]. The infant had to be in a state of inactive or active alertness during the entire experimental procedure, according to the Prechtl-Beintema behavioral scale[24].

After the anthropometric data collection, the infant was placed in the supine position on the baby chair reclined at 0º[25,26]. The experiment lasted for six minutes and twenty seconds, subdivided into five conditions:

- Training (T): infant in the supine position on the baby chair. The examiner held the infant's ankles and placed the right foot, followed by the left foot, then both feet simultaneously on the footboard to lift it and activate the mobile. At this point, the mobile would spin and play a children's song to stimulate the learned movement. The process was repeated three times;
- Standard Condition (SC): infant in the supine position on the baby chair for one minute. The infant would occasionally lift the board while kicking, thus activating the mobile;
- Load Condition 1 (SC1): identical to the previous condition. A brace containing a weight of 1/10 the lower limb mass was placed around the ankle;
- Load Condition 2 (SC2): identical to the previous condition. This time a weight of 1/3 the lower limb mass was added;
- Post-load Condition (PC): identical to SC.

A 20-second interval was allowed after each condition for preparation. The order of the conditions 3 and 4 was determined by convenience, according to the order of arrival of the infants, i.e. the first infant to participate executed the third condition, followed by the fourth, while the second participant executed the fourth condition, then the third. This variation was repeated with the next infants so as not to interfere with the order in which the weights were placed for each test condition.



Source: adapted from Carvalho, Tudella, Barros[26].
Figure 1. Baby chair.

Data analysis

The images recorded on video were transferred to a computer using an image capture card. The AVI files were then viewed in the Dvideow 6.3 system in order to analyze the kicking[27,28]. The spontaneous kicks executed with the infants' right lower limb were analyzed using the images captured by the camera to their right, and the kicks executed with the left lower limb were analyzed using the images captured by the camera to their left[22].

The kicks were considered spontaneous when the infant extended the hip and the knee of one or both lower limbs towards the footboard, either touching it or not. The number of kicks was counted in each experimental condition to obtain the frequency. Afterwards, they were categorized into: 1) kick with contact, when the infant touched the footboard with the right or left foot, or both feet simultaneously while extending the hip and knee; 2) kick without contact, when the infant did not touch the footboard while kicking.

In addition to these, there was also the bipedal kick, in which the infant extended both lower limbs simultaneously,

and the unipedal kick, in which the infant kicked using only one of the lower limbs, either the right or the left leg, which revealed foot preference.

The pattern of intralimb coordination was also observed, being considered in-phase when the hip, knee, and ankle flexed or extended simultaneously, and out-of-phase when the movement of the joints was uncoordinated.

Statistical analysis

The Chi-Square Test was applied to verify possible differences concerning the experimental conditions (SC, SC1, SC2, and PC) and the age (one and two months), separately. A level of significance of 5% was considered.

Results

A total of 1,332 kicks executed by the eight infants was included in the analysis. Next, we display the analyses for the following variables: frequency of kicks, frequency of footboard contact, unipedal and bipedal kick frequency, as well as foot preference and the intralimb coordination pattern in relation to the experimental conditions and ages.

Frequency of kicks

For the experimental conditions, we observed an increase in the frequency of kicks in the SC1 and PC when compared with SC ($\chi^2(3)=11.934$; p=0.008), as shown in Figure 2A. In the age comparison, there was a significant increase in the frequency of kicks in the second month compared with the first month ($\chi^2(1)=60.553$; p<0.001), as displayed in Figure 2B.

Frequency of footboard contact

There was a significant difference between the experimental conditions ($\chi^2(3)=96.05$; p<0.001), and SC2 promoted a lower footboard contact frequency (Figure 3A). For the ages, there was a higher frequency of footboard contact in the second month ($\chi^2(1)=9.278$; p=0.002), as seen in Figure 3B.

Unipedal and bipedal kicks and foot preference

There were no significant differences between the experimental conditions (Figure 4A) and between the ages (Figure 4B), when comparing the frequency of unipedal and bipedal movements. Regardless of the condition or age, most movements were unipedal ($\chi^2(1)=895.243$; p<0.001). There was no significant difference for the unipedal kicks when comparing the preference for kicking with the right or left lower limb.

Intralimb coordination pattern

There was no significant difference between the experimental conditions (Figure 5A), nor between the ages (Figure 5B). Regardless of the condition or age, the intralimb coordination pattern was in-phase ($\chi^2(1)=4.688$; p=0.03).

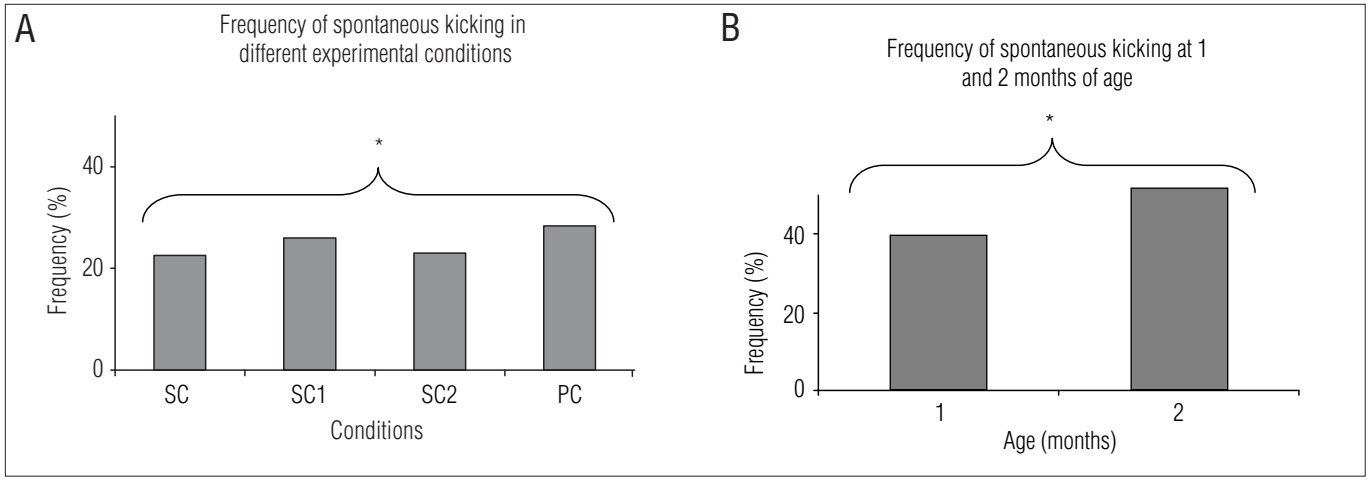


Figure 2. Frequency of spontaneous kicking. A. in different experimental conditions (SC=standard condition; SC1 [load condition 1] corresponds to 1/10 of infant's lower limb mass; SC2 [load condition 2] corresponds to 1/3 of infant's lower limb mass; PC=post-load condition; *significantly higher, $\chi^2[3]=11.934$, p=0.008). B. at one and two months of age (*significantly higher, $\chi^2[1]=60.553$, p<0.001).

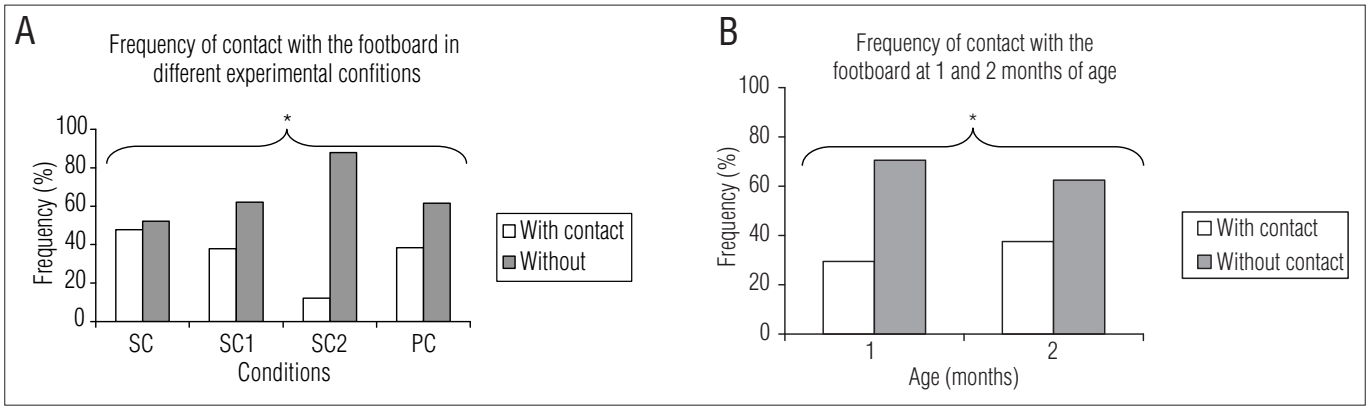


Figure 3. Frequency of contact with the footboard. A. in different experimental conditions (SC=standard condition; SC1 [load condition 1] corresponds to 1/10 of infant's lower limb mass; SC2 [load condition 2] corresponds to 1/3 of infant's lower limb mass; PC=post-load condition; *significantly higher, $\chi^2[3]=96.05$, $p<0.001$). B. at one and two months of age (*significantly higher, $\chi^2[1]=9.278$, $p=0.002$).

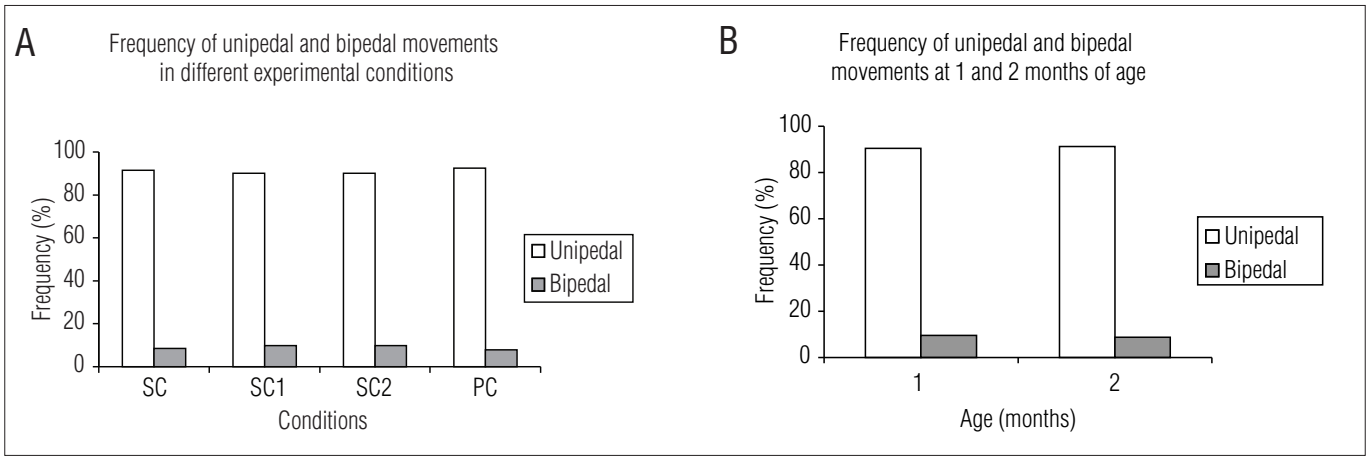


Figure 4. Frequency of unipedal and bipedal movements. A. in different experimental conditions (SC=standard condition; SC1 [load condition 1] corresponds to 1/10 of infant's lower limb mass; SC2 [load condition 2] corresponds to 1/3 of infant's lower limb mass; PC=post-load condition; $\chi^2[3]=1.081$, $p=0.782$). B. at one and two months of age ($\chi^2[1]=0.299$, $p=0.584$).

Discussion

The comparison of the frequency of kicks in different experimental conditions revealed an increase in the SC1 (1/10) frequency and the PC in relation to the SC. In a similar study, Vaal, van Soest and Hopkins[19] showed that an added weight corresponding to 1/3 the lower limb mass of infants aged six to 12 weeks resulted in a decrease in the kicking frequency. It is believed that the 1/10 weight provided a proprioceptive stimulus to the infant, promoting the increase of the kicking frequency. Furthermore, it is possible that the mobile motivated the infant to kick because every successful kick activated the mobile, stimulating the infant's visual and auditory systems. Therefore, the stimuli may influence the kicking movements, changing them from spontaneous to voluntary. We also suppose that there may have been a learning process, given that in the PC there was an increase in the frequency of kicks in comparison to the SC. When the kick was executed successfully, the infants stopped and watched the mobile spinning around. These results show that the infants are capable of learning even at such an early age (one and two months old).

The increase in the frequency of kicks with age may be attributed to factors intrinsic and extrinsic to the organism. In relation to the intrinsic factors, the self-organization of the organism subsystems may have had an influence, because the development of the central nervous system, visual and auditory systems, as well as the learning development promoted the increase in kicking frequency in the second month of life. There were also changes in the musculoskeletal system that allowed the additional 1/10 weight to increase the proprioception of the lower limb and, consequently,

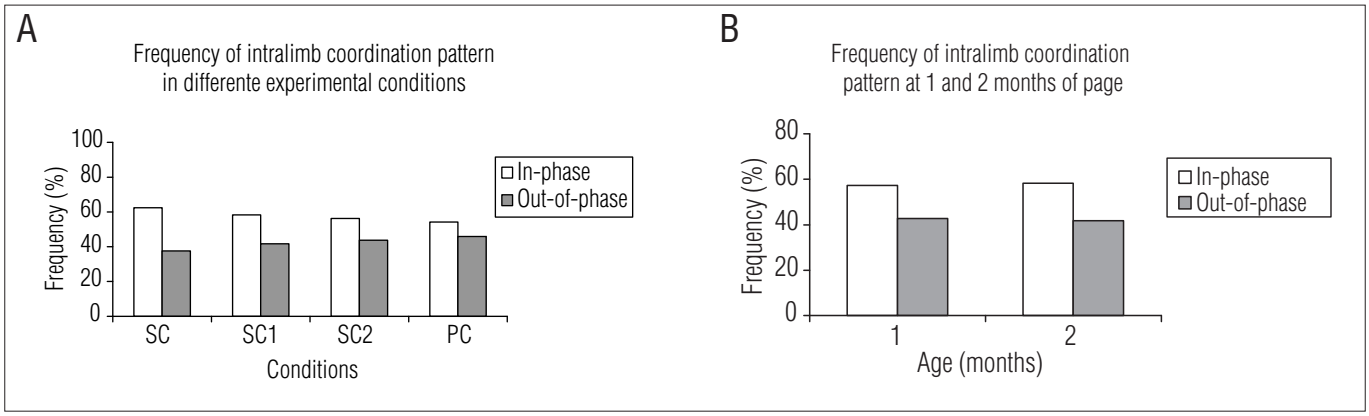


Figure 5. Frequency of intralimb coordination pattern – in-phase and out-of-phase kicks. A. in different experimental conditions (SC=standard condition; SC1 [load condition 1] corresponds to 1/10 of infant's lower limb mass; SC2 [load condition 2] corresponds to 1/3 of infant's lower limb mass; PC=post-load condition; $\chi^2[3]=0.744$, p=0.862). B. at one and two months of age ($\chi^2[1]=0.021$, p=0.884).

elevate the frequency of kicks. At two months of age, however, the infant does not have enough muscle strength to make the proprioception offered by the 1/3 weight increase kick frequency.

The analysis of the contact between the feet and the footboard showed that in the SC2 (1/3) the contact frequency decreased. This result shows that although the 1/3 weight did not change the frequency of kicks, as in the study carried out by Vaal, van Soest and Hopkins[19], it made it more difficult for the infant to elevate the feet to reach the footboard. By observing the infants during the experimental conditions, we found that in SC2 the kicks were executed with greater hip abduction and with the lower limbs closer to the support surface. Therefore, we conclude that the infants' muscle strength at one and two months of age was not sufficient to lift the feet to the level of the footboard with the 1/3 weight. That can be confirmed by the result of the frequency, because in the SC2 there was no reduction in the number of kicks.

When comparing ages, we found that the infants increased the contact between feet and footboard in order to activate the mobile, which reinforces the knowledge that experience and interest in the mobile influenced the increase in the number of contacts. Another factor that was considered was the greater interest in the surroundings during the second month, based on the increase in the number of footboard contacts, probably due to the development of the sensorimotor systems.

In regard to the unipedal and bipedal movements, there was a preference for unipedal kicks regardless of the experimental conditions or age. This is confirmed by Thelen, Bradshaw, Ward[2] and Thelen[7], who verified the emergence of unilateral kicks in infants aged one to four months old.

There was an individual preference for kicking with one of the limbs. According to Droit, Boldrini and Cioni[29], there is evidence that when the infant is in the asymmetrical tonic neck reflex (ATNR) position, more movements are produced by the lower limb of the facial side. Some authors also claim that infants spend most of time in the right ATNR position[29,30]. However, in this study we did not determine whether there was an influence of the ATNR in the laterality of the infants' kicks. Thelen, Bradshaw and Ward[2] did not observe a dominant laterality, although there was evidence that the infants favor one of the limbs when kicking. Thus, the observation of the head position and the association of individual and group analyses must be taken into account for future studies as it may reveal the extent of the influence of ATNR on the results.

In the results for intralimb coordination, Piek and Gasson[5] and Thelen[7] attest that around the second month, there is an emergence of the out-of-phase patterns. Nevertheless, our results revealed that at this age the infants still display the in-phase coordination pattern. This discrepancy between results may be explained by the fact that the in-phase pattern had to be used to lift the footboard.

According to our findings, the first hypothesis of the study was accepted because we observed that the frequency of spontaneous kicks increased with age. The second hypothesis was also accepted because the external weight corresponding to 1/10 of the infant's lower limb mass increased the frequency of kicks. The third hypothesis was rejected as there was no reduction in the number of kicks in the 1/3 weight condition. Nonetheless, the reduction in the number of contacts between the feet and the footboard cannot be discarded. The fourth hypothesis was equally rejected as there were no changes in the

coordination pattern of the kicks when the 1/10 and 1/3 weights were added.

Thus, we conclude that, as the months elapsed, the spontaneous kicks underwent changes. These changes result from factors that are intrinsic to the organism, such as the increase in muscle mass and strength, the infants' behavioral state and the development of the central nervous system. Changes also come from extrinsic factors, namely the interest in kicking to obtain the reward of the mobile, and the experiences concerning the interaction with the surroundings. Furthermore, the infants' spontaneous kicks at one and two months of age are influenced by the increase in proprioception; in that sense, 1/10 of the limb mass may facilitate the spontaneous kicks of healthy infants at those ages. We suggest that new studies be carried out in order to determine how interest and experience may influence spontaneous kicks, as well as test the external weight in infants of other age groups and infants with pathologies to verify its use as a therapeutic method.

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