ISSN 1413-3555
Rev Bras Fisioter, São Carlos, v. 12, n. 3, p. 195-203, may/june 2008
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Influence of skill level and body position on infants' reaching

Influência do nível de habilidade e posição corporal no alcance de lactentes

Carvalho RP, Gonçalves H, Tudella E

Abstract

Background: Although the development of reaching under different body position conditions has been widely studied, little research has addressed this issue considering the infant's skill level. **Objective:** To investigate how different body positions affect proximal and distal reaching adjustments among four to six-month-old infants. **Methods:** Ten infants classified as less (n=6) and more skilled (n=4) were evaluated both in the month when they acquired reaching abilities (M1) and after one month of spontaneous practice (M2), in the supine (0º), reclined (45º) and seated (70º) positions. Proximal (one or two-hand reaching) and distal (open, half-open or closed hand) adjustments, arm starting position (next to or away from the body) and grasping movements were analyzed. **Results:** One-hand reaching predominated among the more skilled infants. Less skilled infants showed higher frequency of one-hand reaching in M1 (seated) and M2 (supine and seated). Reaching with the hands half-open predominated, except among the more skilled infants in M2 in the reclined position. The less skilled infants presented hands next to the body in M1 (reclined and seated) and in M2 (reclined), while the more skilled ones started their reaching with hands away from the body in M2 (supine). The more skilled infants performed more reaching followed by grasping in M2, in the supine and seated positions. **Conclusions:** Body position affects proximal and distal adjustments to reaching maneuvers, according to the infant's skill level.
Clinical Trial Registration Number (in a register validated according to the criteria established by WHO and ICMJE): ACTRN12607000507482.

Key words: reaching; posture; manual dexterity; child development.

Resumo

Contextualização: Embora o desenvolvimento do alcance em diferentes posições corporais tem sido amplamente estudado, há poucas pesquisas sobre este assunto, considerando o nível de habilidade do lactente. **Objetivo:** Verificar como as posições corporais afetam os ajustes proximais e distais do alcance manual de lactentes de quatro a seis meses. **Materiais e método:** Dez lactentes classificados como menos (n=6) e mais habilidosos (n=4) foram avaliados no mês de aquisição do alcance (M1) e após um mês de prática espontânea (M2), nas posições supina (0º), reclinada (45º) e sentada (70º). Foram analisados os ajustes proximais (alcances uni ou bimanuais) e distais (mão aberta, semi-aberta ou fechada), posição das mãos no início do movimento (perto ou longe do corpo) e movimentos de preensão. **Resultados:** Houve predomínio de alcances unimanuais para os lactentes mais habilidosos. Os lactentes menos habilidosos apresentaram maior freqüência de alcances unimanuais em M1 (sentado) e M2 (supino e sentado). Houve predomínio de alcances com as mãos semi-abertas, exceto para lactentes mais habilidosos em M2 na posição reclinada. Lactentes menos habilidosos apresentaram mãos próximas ao corpo em M1 (reclinado e sentado) e M2 (reclinado), enquanto os mais habilidosos iniciaram seus alcances com as mãos longe do corpo em M2 (supino). Lactentes mais habilidosos fizeram mais alcances seguidos de preensão em M2 nas posições supina e sentada. **Conclusões:** A posição corporal afeta os ajustes proximais e distais do alcance, de acordo com o nível de habilidade do lactente.
Número de identificação em um dos Registros de Ensaios Clínicos validados pelos critérios estabelecidos pela Organização Mundial da Saúde (OMS) e International Committee of Medical Journal Editors (ICMJE): ACTRN12607000507482.

Palavras-chave: alcance; postura; destreza manual; desenvolvimento infantil.

Received: 29/06/2007 – **Revised:** 14/11/2007 – **Accepted:** 22/02/2008

Physical Therapy Department, Universidade Federal de São Carlos (UFSCar) – São Carlos (SP), Brazil
Correspondence to: Raquel de Paula Carvalho, Rua Jatobá, 275, Vila Queiroz, CEP 13485-021, Limeira (SP), Brazil, e-mail: raquelpcarvalho@gmail.com
Financial Support: Coordenação de Aperfeiçoamento de Pesoal de Nível Superior (CAPES)

Introduction

The first year of life is marked by many skill acquisitions. Development takes place as the infants learn how to control movements through exploration of their capabilities and the information available in the environment. Reaching is an important way to explore the environment and incorporate knowledge, and is developed between the third and sixth month of life[1,2].

Reaching is defined as the extension of the upper extremity towards the object and is completed when the hand touches the object[3-5]. In order to reach, infants must be able to coordinate and control movements, by making proximal and distal adjustments of their upper extremities. Proximal adjustments refer to the voluntary guiding of one or both upper extremities to reach the object in unimanual or bimanual reaching, respectively, while distal adjustments refer to the positioning of the hand and fingers to touch and grasp the object[6].

During development of reaching, factors that are intrinsic or extrinsic to the organism can influence the control and coordination of action. These factors are defined as constraints[7]. The literature indicates that constraints intrinsic to the organism can influence proximal adjustments used for reaching. These influences are evidenced by the alternation of unimanual and bimanual reaches during the first year of life[8,9]. Constraints extrinsic to the organism, such as the use of objects of different sizes[10] and textures[4] and different body positions[11-13] can also influence both proximal and distal adjustments for reaching.

Based on the concept of constraints, Carvalho et al.[14] verified that during the period of acquisition of reaching, infants classified as less skilled, demonstrated lower mean velocity, velocity peak and frequency of reaches in the supine position compared to more skilled infants of the same age. This study also demonstrated that more skilled infants were able to adapt to constraints imposed by body positions, so that no differences in the frequency and kinematic parameters of reaching were observed between the supine, reclined and seated positions. The authors concluded that skill level is an important factor to be considered in studies that document the development of reaching. It is important to point out that studies that investigate the influence of skill level on the development of reaching are scarce in the literature, especially in the context of extrinsic constraints imposed on actions.

Therefore, the aim of this study was to verify how body orientation affected proximal and distal adjustments for reaching of infants considered to be more or less skilled in two different moments: the period of acquisition of reaching and after spontaneous practice of the movement. The hypothesis to be tested was that proximal and distal adjustments for reaching will be affected by body orientation, especially for infants considered less skilled in reaching.

Materials and methods

Subjects

The sample of this study was composed of ten healthy infants with typical development at four months of age. They were eight boys and two girls, with gestational age superior to 37 weeks and Apgar scores equal or superior to 8 in the first and fifth minutes. The infants were selected according to information available from medical records of public health centers in the city. The age of four months was chosen for the first assessment because most infants learn to reach at this age[5,15,16]. Abnormalities in motor, sensory or cognitive development, prematurity or lack of consent of the parents were criteria of exclusion from the study. The study was approved by the research ethics committee of the Universidade Federal de São Carlos (UFSCar), protocol number 092/2002, and the parents or adults responsible for the infants signed an informed consent form to authorize their participation in the study.

General procedures

The assessment room was prepared to maintain light and temperature conditions adequate to observe the procedures. Lamps were directed to the wall to avoid influences of direct light on the behavior of the infants. An air conditioner was adjusted to maintain room temperature at 27ºC. Infants were assessed longitudinally on the dates at which they completed four, five and six months, or within a tolerance interval of seven days before or after the exact date. Assessments were performed during the intervals between feeding times so that hunger or fullness did not interfere with the behavior of the infants. The mothers stayed in the room during the assessment, in a place where the infants could not see them.

The experimental phase was video recorded with three digital cameras. One camera was placed in a postero-superior position and the other two were positioned in the left and right diagonals in front of the infant[17]. The software Dvideow[18] was used to analyze frame by frame the digitalized images. Inter-rater reliability was investigated in order to increase confidence in the results. The percent of agreement between the three observers was 83.46% thus allowing the image analyses to begin.

To stimulate the infant to perform unimanual reaches spontaneously, three toys were selected which were considered

to be attractive. They were similar in size, small and adequate for the age of the infants, according to pilot tests. The toy was presented to the infant at the height of the manubrium of the sternum, at a distance equivalent to the length between the shoulder and the wrist of the infant.

Test procedures

After the infants were undressed by the mothers and wore only diapers, they were placed in an infant chair in three different body positions: supine (0º of inclination in regard to the horizontal), reclined (45º) and seated (70º)[3,14]. The chair was equipped with a system of belts to stabilize the infants at the height of the nipples and provide safety and adequate body alignment, a support to control the distance from the toy, and a protractor to ensure precision in determining the inclination of the support for the trunk. The three different positions were tested in random order and for each position, the infants had a period of adaptation of 20 seconds.

The toy was offered to the infants for two minutes in each body position. After each reach, the toy was gently taken from the hands of the infants and offered again. During this period, the infants were free to reach the toys as many times as they wanted. The same procedure was repeated for the second toy. In case the infant did not show any interest for any of the two toys presented, a third toy was offered to allow continuation of the assessment. The total duration of the assessment was 13 minutes.

Description of independent variables

In order to evaluate the effect of experience on reaching behavior, assessments were performed at two moments: moment 1 (M1), when the infant first attempted the reaching movements, that is, in the period of acquisition of reaching, and moment 2 (M2), one month after M1. Therefore, although the infants were assessed three times, at four, five and six months, only two assessments were considered: at the month of acquisition of reaching movements (M1) and one month later after spontaneous practice of reaching (M2). Parents or other adults responsible for the infants did not receive any information or instructions on how to stimulate reaching at home, and thus it was considered that between M1 and M2 the infant spontaneously practiced reaching.

The infants were classified as more or less skilled at reaching[14] through the analyses of movements performed in M1. This classification was based on the frequency of reaches in the supine position compared to the reclined and seated positions. Thus, the infants who demonstrated lower frequencies of reaches in the supine position and showed differences in kinematic movement parameters between body positions[14] were classified as less skilled. Infants who demonstrated similarities in the frequency and kinematic reaching parameters between positions were classified as more skilled infants.

Description of dependent variables

Reaching movements were considered for analysis when the infants directed and fixated their vision on the object, moved one or both upper limbs towards the object and touched it. The beginning of the reaching movement was determined by the first movement of the upper limb towards the toy and the end of the movement was defined by the moment when the infant touched the toy[3,4,8,11].

Proximal adjustments refer to the type of inter-limb coordination (unimanual or bimanual) used by the infant during reaching. Reaching movements were considered unimanual when one of the upper extremities reached for the object while the other was still, performed small movements not directed to the object or performed a reaching movement with a time lag greater than 0.33 seconds[4,8,19]. Reaching movements were considered bimanual when the upper extremities moved simultaneously, or with a time lag smaller than 0.33 seconds, towards the toy. Additionally, the hands should have moved simultaneously for at least half of the movement amplitude (50% of the trajectory) and the object could be touched simultaneously or alternately by the hands[4,19].

Distal adjustments referred to the degree of opening and closing of the hands. The hands were considered to be open when the metacarpophalangeal and interphalangeal joints were extended, closed when the metacarpophalangeal and interphalangeal joints were flexed, and semi-open when the metacarpophalangeal joints were flexed (regardless of the degree of flexion) and the interphalangeal joints were extended or the metacarpophalangeal joints were extended and the interphalangeal joints were flexed[4]. This variable was analyzed in the beginning of each reaching movement.

The position of the hands in the beginning of reaching was analyzed as a complement to the measures of proximal adjustments, because the hand position was dependent on the position of the proximal joints, shoulder and elbow. Hand positions were classified as next to the body or far from the body[20]. Reaching movements were also classified as "with or without prehension". Prehension was defined as the flexion of one or more fingers around the toy[21]. This variable was related to the distal adjustments.

Statistical analyses

The Mann-Whitney was used to compare the ages of both groups of the infants at M1 and M2. The chi-square test was used to compare the observed and expected frequencies of the dependent variables, and when the expected frequency was lower than 5, the exact Fisher test was used. Initially, the test was used to compare the frequencies of the dependent variables in each position (supine, reclined and seated) and assessment moment (M1 and M2), both for more and less skilled infants. Later, the frequencies of the dependent variables were compared between M1 and M2, for the less skilled and more skilled infants in each position. For all analyses, the level of significance was 5%.

Results

Based on the frequencies of reaches in the supine position, six infants were considered less skilled (five learned to reach at four months and one at five months) and four were considered more skilled (one learned to reach at four months and three at five months). The mean ages at M1 were 129 days (sd=12) and 147 days (sd=14) for the less and more skilled infants, respectively. Comparisons between the ages of less and more skilled infants did not demonstrate any significant differences between groups at M1 (U=3; p=0.054) or M2 (U=8; p=0.386) assessments.

The seven first reaches performed by the infants in each body position were considered for the analyses of the dependent variables (proximal and distal adjustments). The total number of reaching movements analyzed was 368, of which the less skilled performed 85 at M1 (supine=15, reclined=32, seated=38) and 116 at M2 (supine=37, reclined=37 and seated=42) and the more skilled performed 83 at M1 (supine=28, reclined=28 and seated=27) and 84 at M2 (supine=28, reclined=28 and seated=28).

Figure 1 demonstrates the proximal adjustments in the three body positions at M1 and M2 for the less and more skilled groups of infants. When the frequencies in each position and assessment were compared, for the less and more skilled infants, the frequency of unimanual reaches was significantly larger at M1 in the seated position ($X^2(1)=6.737$; p=0.009), at M2 in the supine ($X^2(1)=6.081$; p=0.014) and in the seated positions ($X^2(1)=7.714$; p=0.005). For the more skilled infants, the frequency of unimanual reaches was larger at M1 in the supine ($X^2(1)=20.571$; p<0.01) and seated positions ($X^2(1)=23.148$; p<0.01), and at M2, in the supine ($X^2(1)=20.571$; p<0.01), reclined ($X^2(1)=7$; p=0.008) and seated positions ($X^2(1)=17.286$; p<0.01). In the reclined position at M1, the more skilled infants performed only unimanual reaches and statistical comparisons were therefore not possible.

When M1 and M2 were compared in each position, there was a significant difference only for the more skilled infants in the seated position (Fisher exact test, p=0.01). The more

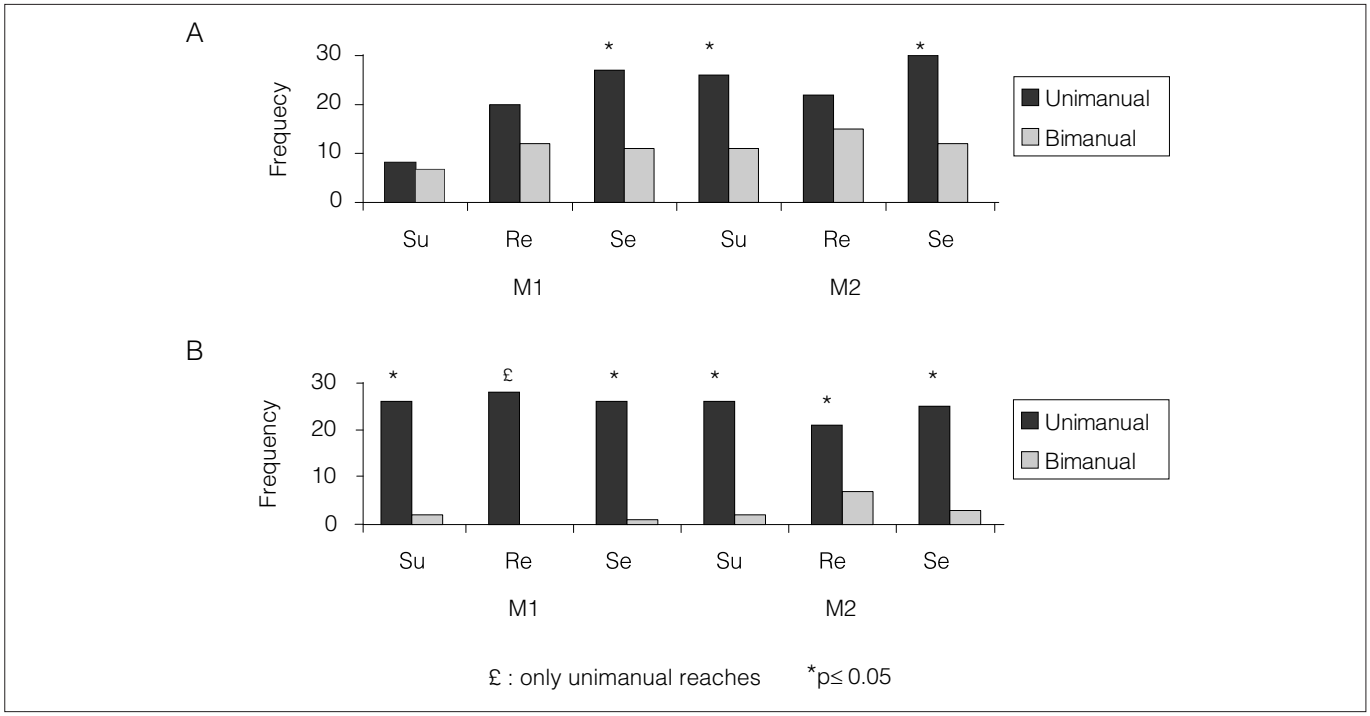

Figure 1. Frequency of uni and bimanual reaching in supine (Su), reclined (Re) and seated (Se) positions, at the acquisition of reaching (M1) and after spontaneous practice (M2) for less- (A) and more-skilled (B) infants.

skilled infants performed only unimanual reaches at M1 and bimanual as well as unimanual reaches at M2. However, unimanual reaches were predominant at M1 as well as at M2. No other significant differences were found.

Figure 2 demonstrates the distal adjustments at the beginning of the reaching movements for less skilled infants, at M1 and M2. When the frequencies in each position and assessment were compared for the less and more skilled infants, there was a predominance of open hands in all positions: at M1 in the supine ($X^2(2)=11.2$; p=0.004), reclined ($X^2(2)=18.25$; p<0.01) and seated ($X^2(2)=19.158$; p<0.01) positions, and at M2, in the supine ($X^2(2)=17.568$; p<0.01), reclined ($X^2(2)=14.297$; p<0.01) and seated ($X^2(2)=36$; p<0.01) positions. For the more skilled infants, there was a predominance of semi-open hands at M1, in the supine ($X^2(2)=26.643$; p<0.01), reclined ($X^2(2)=23.214$; p<0.01) and seated ($X^2(2)=21.556$; p<0.01) positions, and at M2 in the supine ($X^2(2)=7$; p<0.008) and seated ($X^2(2)=5.143$; p=0.023) positions. However, in the reclined position, there were no significant differences between the frequency of open and semi-open hands ($X^2(2)=2.286$; p=0.131). When M1 and M2 were compared in each position, no significant differences were found for both groups of infants, indicating that practice did not influence this variable.

Figure 3 shows the frequency of reaches initiated with the hands near and far from the body for the less and more skilled infants, at M1 and M2, in the three studied positions. When frequencies in each position and assessment were compared, the less skilled infants demonstrated significantly greater frequencies of reaches initiated with the hands near the body at M1, in the reclined ($X^2(1)=8$; p=0.005) and seated ($X^2(1)=8.526$; p=0.004) positions. For the more skilled infants, the frequency of reaches initiated with the hands far from the body was greater for the supine position at M2 ($X^2(1)=9.143$; p=0.002). When M1 and M2 were compared in each position, no significant differences were found for both groups of infants, indicating that practice did not influence this variable.

Figure 4 shows the frequency of reaches followed and not followed by prehension of the toy at M1 and M2, for the less and more skilled infants. When the frequencies in each position and assessment were compared, the less skilled infants demonstrated a frequency of reaches without prehension significantly greater at M1 only in the seated position ($X^2(1)=8.526$; p=0.004). For more skilled infants, the frequency of reaches without prehension was significantly greater at M1 in the supine position ($X^2(2)=14.286$; p<0.01), while at M2 the frequency of reaches with prehension was greater in the seated position ($X^2(2)=5.143$; p=0.023).

When M1 and M2 were compared in each position, there was a significant difference for the more skilled infants in supine ($X^2(1)=14.674$; p<0.01) and seated ($X^2(1)=6.557$; p=0.01) positions. In both positions there was an increase in the frequency of reaches with prehension after practice. Other comparisons did not demonstrate significant differences.

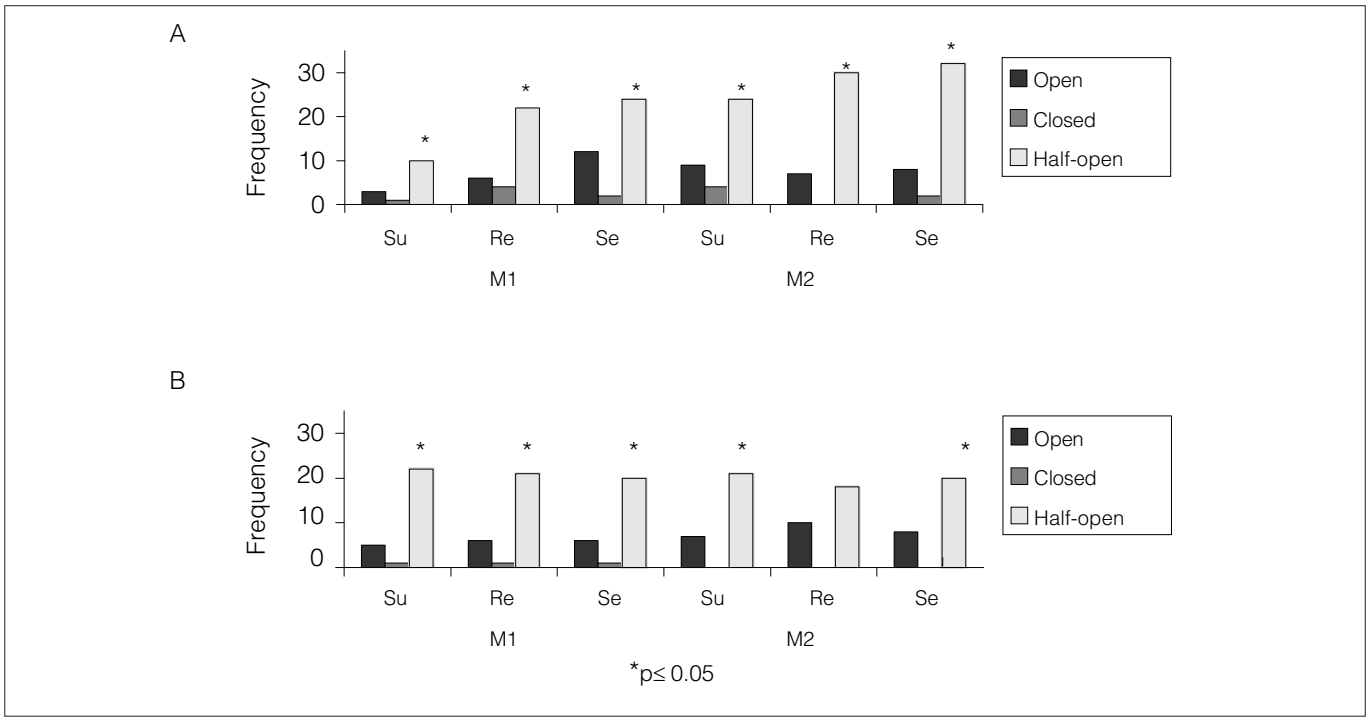

Figure 2. Frequency of open, closed and half-open hand in the beginning of reaching in supine (Su), reclined (Re) and seated (Se) positions, at the acquisition of reaching (M1) and after spontaneous practice (M2) for less- (A) and more-skilled (B) infants.

Discussion

In order to investigate the influences of different body positions in the coordination of upper limbs during the performance of reaching movements, the present study analyzed proximal and distal adjustments for reaching. Two groups of infants, classified as less and more skilled, were assessed in the month of acquisition of reaching and after one month of spontaneous practice. Results demonstrated that both the body position and practice influenced reaching movements of both groups of infants.

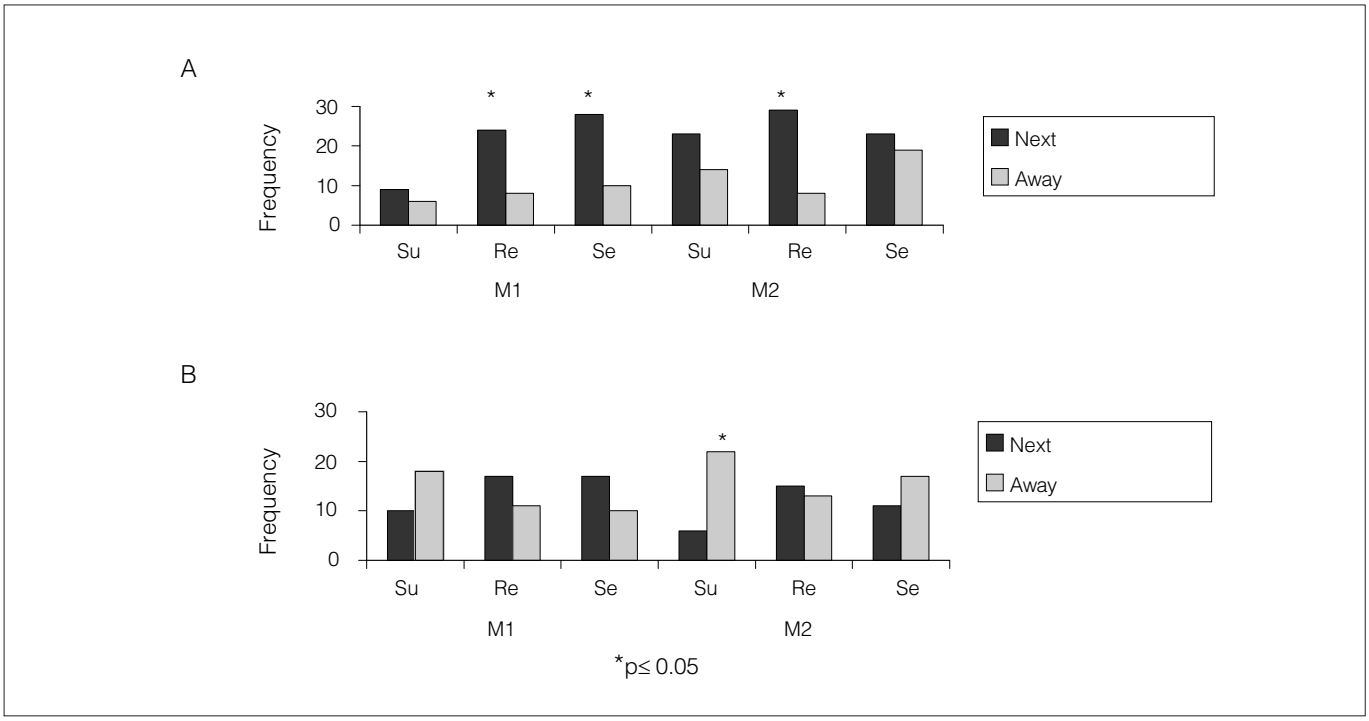

Figure 3. Frequency of arm position starting next to and away from the body in supine (Su), reclined (Re) and seated (Se) positions, at the acquisition of reaching (M1) and after spontaneous practice (M2) for less- (A) and more-skilled (B) infants.

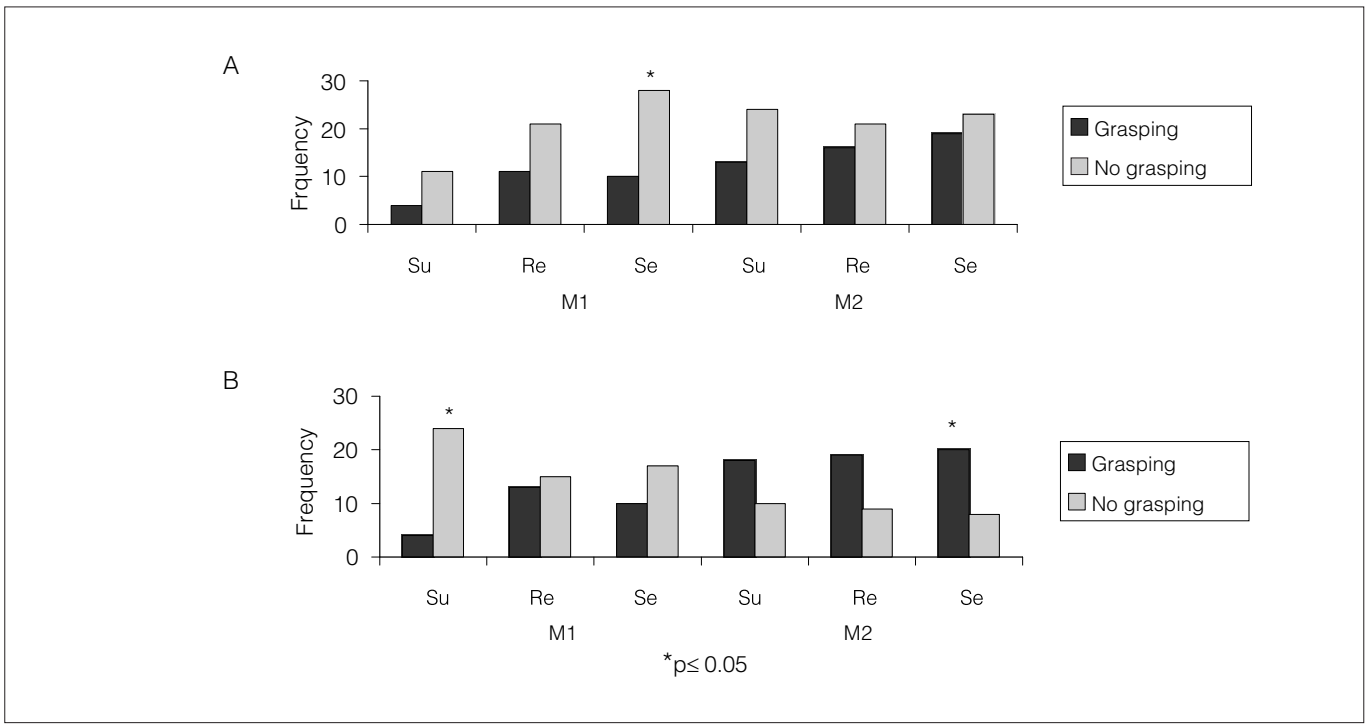

Figure 4. Frequency of reaching followed and not followed by grasping in supine (Su), reclined (Re) and seated (Se) positions, at the acquisition of reaching (M1) and after spontaneous practice (M2) for less- (A) and more-skilled (B) infants.

Results regarding proximal adjustments for reaching demonstrated that after a month of spontaneous practice the less skilled infants altered their proximal adjustments in the supine position, changing from a similarity in the frequency of unimanual and bimanual reaches to a predominance of unimanual reaches. In the reclined and seated positions, the proximal adjustments remained unaltered after spontaneous practice, that is, the frequencies of unimanual and bimanual reaches were similar in the reclined position and unimanual reaches were predominant in the seated position at both assessment moments.

For infants to be able to reach for an object, they need to find solutions for problems related to the tendency of the upper extremity to oscillate[22] and the production of an adequate amount of muscle torque in the arm in the presence of unknown external torques such as those caused by gravity[23]. These problems are increased in the supine position due to the need of greater muscle torques at the arm to initiate movements, and also because gravity amplifies the oscillation of the upper limb in this position. With the increase of age and consequently the increase of experience, infants develop strategies to deal with these biomechanical restrictions. Thus, these results suggested that the alterations demonstrated by the less skilled infants in their proximal adjustments for reaching in the supine position reflected adaptive responses to restrictions imposed by the organism and the environment. Another interesting result found for the less skilled infants was the predominance of unimanual reaches in the seated position. The literature reports that the seated position favors the performance of unimanual reaches in infants with poor postural control[12]. Additionally, infants aged 12 to 19 weeks of life, when seated, demonstrate reaching and prehension patterns comparable to those demonstrated by infants aged 20 to 27 weeks in any position[20]. Thus, proximal adjustments, represented by unimanual and bimanual reaches, were influenced by body position in the group of less skilled infants. Additionally, these results demonstrated that the seated position facilitated the performance of unimanual reaches in the group of less skilled infants and that one month of spontaneous practice was sufficient for the same group of infants to demonstrate unimanual reaches in the supine position.

For the more skilled infants, there was a predominance of unimanual reaches in the supine, reclined and seated positions, both during the month of acquisition of reaching movements and after one month of spontaneous practice. Similar results were found by Rochat[12], who verified that infants with better postural control demonstrated a predominance of unimanual reaches in the supine, reclined, seated and prone positions. However, Rochat[12] used the level of postural control in the seated position (infants who did or did not seat independently) instead of the level of skill in reaching to classify the infants, as in the present study. Nevertheless, these results were similar, confirming the existence of a strong connection between postural control and skill in reaching[12,13,16,24]. Thus, the body position did not influence proximal adjustments for reaching in the more skilled infants. Therefore, the level of skill was a determining factor for the influence or lack of influence of body positions on the proximal adjustments for reaching.

The level of skill did not alter distal adjustments in the month of acquisition of reaching as both groups of infants demonstrated greater frequency of reaches with semi-open hands in all three body positions. After a month of spontaneous practice, the behaviors were the same, except for the more skilled infants in the reclined position, who demonstrated similar frequencies of reaches with open and semi-open hands. Thus, the body positions influenced distal adjustments only for the more skilled infants. It is important to point that although Figure 2 demonstrates an increased frequency of distal adjustments after a month of practice, the proportion of open, semi-open and closed hands remained the same. This increased frequency is a consequence of the lower number of reaches performed by the less skilled infants in the month of acquisition of this ability, and this can be observed also for the other variables in the study. Another interesting observation is that the toys shown to the children were small, and because of that, may have stimulated a greater frequency of reaches with semi-open hands, in addition to initiating a greater frequency of unimanual reaches[4,19]. More skilled infants did not perform any reaching movement with closed hands after spontaneous practice, in any of the assessed positions. The same was observed for the less skilled infants only in the reclined position. Although the infants could use the strategy of co-contraction between agonists and antagonists to produce the greater torques needed for reaching in the supine position, which would result in closing of the hands, these results suggested that this was not a strategy used by the infants to facilitate their reaching.

Less skilled infants demonstrated a greater frequency of hands near the body at the initiation of the reaching movements in the reclined and seated positions at M1 and in the seated position at M2. These results indicated that the level of skill influenced the positioning of the hands, since the more and less skilled infants demonstrated different behaviors. Besides that, practice did not influence the positioning of the hands at the initiation of the reaching movements. It was expected that the infants, especially those less skilled, would use as a strategy the approximation of the hand to the body in order to decrease the perpendicular distance between the position of the weight vector and the axis of rotation in order to facilitate the performance of the movement. It was also expected that this strategy would be abandoned after spontaneous practice. However, this behavior was observed only in the reclined and

seated positions for the less skilled infants and seems to be a consequence of the vertical position of the trunk and not a strategy to facilitate execution of the movement. Therefore, these results indicated that body position influenced the preferences for hand position of the less and more skilled infants. It does not seem that whether the hands were near or far from the body were used as strategies to facilitate reaching in any of the assessed positions.

The frequency of reaches with and without prehension was influenced by the level of skill and body position. The most significant result was the greater frequency of reaches followed by prehension of the object for more skilled infants in the seated position, after spontaneous practice. This result was not observed for the less skilled infants in any of the assessed body positions. Prehension movements involve greater complexity in the control of the intrinsic and extrinsic hand muscles. In this way, the seated position favored greater control of the upper extremities and resulted in a greater frequency of reaches followed by prehension for the less skilled infants. Additionally, after a month of practice, there was an increase in the proportion of reaches followed by prehension in the group of the more skilled infants, indicating that practice influenced prehension behavior only for this group of infants. Therefore, prehension was influenced by body position, according to the level of skill of the infant.

Because level of skill instead of age was considered in this study, it does not follow that one factor was considered to be more important than the other. It is known that aging and the consequent development of greater visual acuity, postural control, cognition, eye-hand coordination[4,10,11,25], besides motor learning[26,27], are important factors that influence the acquisition and refinement of reaching. According to Thelen[28], the organization of a behavior and its development depend on the relations between the elements of the organism (for example body composition and degree of maturation of the nervous system) and the relation of the organism with the environment. Thus, the present study emphasized the complexity of infant development and its importance on the practice of the physical therapist specialized in neuropediatrics.

In conclusion, the different body positions and the level of skill influenced the manual reaches of infants. Additionally, the period of one month of spontaneous practice resulted in alteration of proximal adjustments and the frequency of reaches with prehension only for the more skilled infants. Considering that both groups of infants demonstrated adequate motor, sensory and cognitive development, what would explain the fact that infants of the same age demonstrated different levels of skill in reaching? These differences in the level of skill may be related to of the intrinsic dynamics of the infant, which reflects the spontaneous tendency of coordination of the individual[29]. Another factor that could explain these differences is the number of opportunities offered to the infant to practice the movement. It is possible that the more skilled infants have practiced reaching in their homes with a greater frequency than the less skilled infants, although this factor was not controlled in this study.

Some limitations were faced during this study. One of them was the sample size, which was different between the two groups of infants because of discontinuation and lack of adaptation of some infants to the chair and the assessment environment. Another limitation was the fact that the authors were not able to assess the infants close to the days that they really performed their first reaching movement, for that would have been difficult to accomplish and would result in greater sample losses. In spite of this, the present study offers relevant information that can contribute to the work on the early stimulation of babies. For example, some modifications, such as placing the infant in the seated position for the performance of reaching movements, can favor the use of unimanual reaches and promote weight acceptance on the opposite upper extremity and thus simulate postural control. This position can also favor reaching movements followed by prehension in experienced infants. Body position affects proximal and distal adjustments for reaching, according to the level of ability of the infant. Therefore, such factors must be considered during the assessment and stimulation of reaching movements of infants.

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