Effect of Training at Different Body Positions on Proximal and Distal Reaching Adjustments at the Onset of Goal-Directed Reaching: a Controlled Clinical Trial

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The objectives of this study were to verify the influence of a short-duration training session on proximal and distal adjustments at the onset of goal-directed reaching and to verify whether these adjustments change in specificity with the body position trained. Twenty-four infants aged 3–4 months were assessed in supine and reclined during pre and posttraining conditions. During the interval (4 min), 8 infants received reaching training in supine, 8 infants received reaching training in reclined, and 8 infants received no training. The frequencies of reaches, unimanual reaches and reaches with semiopen and oblique hand increased in the posttraining condition for all infants except control infants. Infants trained in the reclined position increased the frequencies of variables in the reclined position. Infants trained in the supine position increased the frequencies of variables in both positions. Few minutes of reaching training are effective to facilitate reaching behavior in infants at the onset of reaching. The effects are specific to the body position trained. As the training in supine requires higher torque to initiate reaching movements, it is more effective to facilitate reaches in both supine and reclined positions.

Keywords: training; physical therapy; motor skills; infant development

When manual reaching is acquired at around 3–5 months of age (Thelen et al., 1993), infants are able to expand their ability to explore the environment. Soon, they learn to modify the dynamics of the upper limb to facilitate the approach of their hand to an object at the midline (Bhat, Lee, & Galloway, 2007) and adjust the proximal (uni- and bimanual) and distal movements (hand orientation and opening) of the limb to touch and grasp objects more successfully (Fagard, 2000; Toledo, Soares, & Tudella, 2011).

Proximal adjustments in early reaches predominantly result from shoulder movements and are typically bimanual (Fagard, 2000), although head and trunk support may favor unimanual movements (Carvalho, Gonçalves, & Tudella, 2008a; Toledo et al., 2011). Distal adjustments are initially performed with the hand hori-
horizontally oriented (Bly, 1994), but gradually, they start being performed with the hand vertically oriented (Fagard, 2000; Toledo et al., 2011). As early as 4 months of age, infants adjust their hand opening to the object size and rigidity (Rocha, Silva, & Tudella, 2006). Thus, in the early development of reaching, the arm and hand movements can be influenced not only by the infant’s intrinsic dynamics (Bhat et al., 2007; Toledo et al., 2011), but also by extrinsic factors, such as object properties (Rocha et al., 2006; von Hofsten & Rönnqvist, 1988), additional weights (Toledo, Soares, & Tudella, 2012), body position (Carvalho, Tudella, & Savelsbergh, 2007) and training (Heathcock, Lobo, & Galloway, 2008). In this sense, we discuss whether the reaching training, being an important extrinsic factor for use in clinical practice, is able to enhance the proximal and distal adjustments in the early development of reaching behavior.

Although the role of training in improving the reaching of infants is still an emerging issue, there is evidence that after 2 weeks of daily training of interaction of hands with an object, full-term infants increased the number of contacts with the object (Lobo, Galloway, & Savelsbergh, 2004). After 3–8 weeks, full-term and preterm infants touched the object more times with open hand than untrained preterm infants (Heathcock et al., 2008). This indicates that the daily practice of reaching movements for several weeks gives the infant sensorimotor experiences able to change his intrinsic dynamics and improve the task performance. However, it is not known if a short-duration and single training session is enough to promote changes in the behavior of this skill.

The improvement of the motor skill performance after few minutes of training was demonstrated in few studies in adult humans that practiced sequences of tongue (Boudreau, Hennings, Svensson, Sessle, & Arendt-Nielsen, 2010) and finger opposition movements (Karni et al., 1995) and in mice that practiced sequence of movements in a accelerating rotarod (Costa, Cohen, & Nicolelis, 2004). In the sequential finger opposition training, this rapid process of improved task performance was attributed to the selection of specific sensorimotor representations in the cerebral cortex in the early stages of learning (Karni et al., 1995, Karni et al., 1998). According to the Neuronal Group Selection Theory, in this initial learning period, all the goal-directed motor behaviors are characterized by great primary variability, but as infants do experience the primary neuronal repertoires specific to the function, there is a selection of neural activities patterns that result in more efficient solutions for the function (Edelman, 1987; Hadders-Algra, 2000).

Besides experience, goal-directed reaching is also influenced by body position. In 4–5 month-old infants, the sitting position (45° to 90°) seems to be more effective in facilitating the reaching movements than the supine position, which generates greater muscle torque at the beginning of the reaching movement and instability in the upper limbs (Carvalho et al., 2007; Out, Van Soest, Savelsbergh, & Hopkins, 1998; Savelsbergh & van der Kamp, 1994). On the other hand, without head support, and consequently with greater postural demand, the sitting position at 90° becomes less effective in promoting successful reaching than the supine position in 4–6 month-old infants (Bakker, De Graaf Peters-Van Eykerna, Ottenb, & Hadders-Algra, 2010). Thus, it would be interesting to investigate whether the reaching practice at sitting position with head support is effective in improving the reaching performance in the supine position, and vice versa. It is known that the daily practice of postural activities and interaction of the hands with objects in
supine position for 3 weeks can facilitate the acquisition of reaching movements both in sitting and supine positions (Lobo & Galloway, 2008). However, literature shows no studies investigating how a short-duration reaching training affects the behavior of this skill as a function of the trained position.

In this context, this study aimed at: a) verifying the effect of a short-duration single training session performed in supine or sitting position (reclined at 45°) on the proximal and distal adjustments of the reaching movements shortly after the onset of goal-directed reaching and; b) verifying the occurrence of changes in these specific adjustments in relation to the trained position. Considering that only a few minutes of experience can promote the selection of cortical sensorimotor representations at the early stage of learning of a sequential finger opposition task in adults (Karni et al., 1995; Karni et al., 1998), we have hypothesized that one single short-duration training session is effective in facilitating the reaching behavior shortly after the onset of this skill. In this case, we predict that trained infants will present increased frequency of at least one of the following variables after training, compared with the control group: total reaching frequency, unimanual reaches, open hand, hand vertically oriented and successful grasps. Considering the specificity of neural processes activated after a short-duration training session in adults (Karni et al., 1995), the second hypothesis of this study is that changes in the reaching behavior of infants are specific to the trained position. Thus, we predict that infants trained in supine position will have increased frequency of variables only in the supine position, and infants trained in the reclined position will have increased frequency of variables only in the reclined position.

This is the first study to investigate clinically observable reaching behaviors and the specificity of changes of these behaviors after a few minutes of training shortly after the onset of goal-directed reaching. Thus, this study may provide empirical support so as to understand how short-duration training sessions provide the basis for the consolidation of a given skill in healthy infants for it could be applicable to infants at risk.

**Methods**

**Design and Participants**

This study is characterized as a quasi-randomized controlled clinical trial. The sample size calculation was performed for a confidence interval of 95% and power of 80%. For total reaching frequency, a number of 8 participants for each group was proposed.

The study included 24 healthy full-term infants ($M = 39.0 \pm 1.2$, weeks of gestation), with mean birth weight of $2.940 \pm 0.9$ kg, Apgar scores greater than or equal to eight in the first ($M = 8.9 \pm 0.5$) and fifth minutes ($M = 9.8 \pm 0.3$), aged 3–4 months ($M = 13.2 \pm 1.2$, weeks), from both genders (14 females and 10 males), and with mean score of $12.7 \pm 0.6$ according to the Alberta Infant Motor Scale (AIMS, Piper & Darrah, 1994).

Infants were systematically assigned to experimental group 1 ($n = 8$), receiving reaching training in supine position; experimental group 2 ($n = 8$), receiving reaching training in reclined position; and control group ($n = 8$), receiving no training. Details of the characterization of each group are shown in Table 1.
<table>
<thead>
<tr>
<th>Group</th>
<th>Gender</th>
<th>Gestational age (weeks)</th>
<th>Birth weight (kilograms)</th>
<th>1st min</th>
<th>5th min</th>
<th>Onset of Reaching (age in weeks)</th>
<th>Assessment (days after reach onset)</th>
<th>AIMS score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group Training in Supine</td>
<td>3</td>
<td>39.0 ± 0.7</td>
<td>3.245 ± 0.3</td>
<td>8.8 ± 0.6</td>
<td>9.7 ± 0.4</td>
<td>13.1 ± 1.2</td>
<td>2.5 ± 0.7</td>
<td>12.8 ± 0.8</td>
</tr>
<tr>
<td>Group Training in Reclined</td>
<td>3</td>
<td>39.7 ± 1.1</td>
<td>2.327 ± 1.4</td>
<td>9.0 ± 0.5</td>
<td>9.8 ± 0.3</td>
<td>12.9 ± 0.7</td>
<td>2.0 ± 1.3</td>
<td>12.7 ± 0.7</td>
</tr>
<tr>
<td>Control Group</td>
<td>4</td>
<td>38.3 ± 1.4</td>
<td>3.245 ± 0.4</td>
<td>8.8 ± 0.3</td>
<td>9.8 ± 0.3</td>
<td>13.7 ± 1.6</td>
<td>2.6 ± 0.7</td>
<td>12.6 ± 0.7</td>
</tr>
</tbody>
</table>

F = female; M = male. Mean value and standard deviation.
General Procedures and Equipment

The study was approved by the Ethics Research Committee (protocol no. 516/2009) and was registered in the Australian Clinical Trials Registry (no. ACTRN12610000818033).

Infants’ parents were recruited by telephone from health center records in the city of São Carlos (São Paulo, Brazil) using a stratified random sampling method. From the week before the infants’ three-month birthday, the examiner called their parents, informed them on the study nature and invited them to participate. After signing the informed consent form, parents were asked to help identifying the day their children started reaching. They were explained that reaching is the act of perceiving an object in space, fixing the eyes on it, moving one or both hands toward it and touching it, with or without grasping. To identify the precise day of the infants’ reaching onset, the examiner made home visits any day when the parents called back telling they had identified their infant’s first reaching movements and also twice a week regardless of parents’ calls. Once the reaching onset was confirmed at the home visit, the AIMS was applied and scored by a single pediatric physical therapist at the infant’s home. The AIMS is a valid and reliable tool that assesses gross motor development of infants in prone, supine, sitting with support and standing with support positions, and was used to ensure that all infants were similar in their motor development (percentile between 25 and 75 of the AIMS’s normative curve) at reaching onset. The assessment at the laboratory was then scheduled to take place no later than three days after this last visit ($M = 2.3$ days ± 0.9). The mean number of home visits made by the examiner to control the period of reaching onset computed for all infants was 3.65.

The entire experimental phase was filmed by four digital video cameras (60 Hz). Two cameras were located posterior-laterally to the infant, and one camera was located posterior-superiorly to the infant. The fourth camera, located anterior-superiorly to the infant, was used to confirm that the infant’s visual attention was directed to the toy during reaches.

The images were opened in the Dvideow 5.0 image analysis system (Carvalho et al., 2007; Carvalho, Tudella, Caljouw, & Savelsbergh, 2008b; Figueiroa, Leite, & Barros, 2003; Toledo et al., 2011) and analyzed frame by frame to identify beginning and end of reaching movements.

Testing Procedures

All infants were assessed twice in a single day. The first assessment was carried out before the training session (pretraining) and the second one was carried out immediately after the training session (posttraining). Infants from the control group were assessed under the same conditions as the experimental groups.

The pretraining assessment consisted of two testing conditions (A and B). Each condition lasted 2 min with an interval of 30 s between them:

Condition A: the infant was placed in supine position on a baby examination table (Figure 1A). The examiner used one of her hands flattened on the infant’s trunk to provide security and truncal stability. A period of 20 s was allowed for the infant to adapt to the situation. No stimulus was given to the infant during this period (Carvalho et al., 2008b). An unfamiliar, malleable rubber toy (5.0 cm smaller diameter, 12.0 cm larger diameter, 10.0 cm height) was used to elicit reaches. The
toy was held by the examiner, who was positioned in front and out of the infant’s reaching distance. The toy was presented at the infant’s midline, at xifoid process height, and at an arm length distance for 2 min. During this period, the toy was carefully taken away and presented again after each successful toy contact (reach). A 5-s interval was allowed between reaches. Thus, the total number of reaches depended on the infant. The toy was always oriented vertically along its major axis (Toledo et al., 2011). Condition B: the experimental conditions of this procedure were similar to condition A. However, a seat was coupled to the examination table used in Condition A and adjusted its inclination so that the infant was seated reclined 45° in relation to the floor (Figure 1B).

The order of conditions was assigned via flipping a coin. The posttraining assessment was identical to the pretraining assessment. The infants remained in an either inactive (eyes open, no gross movements, no crying) or active (eyes open, gross movements, no crying) alert state throughout the experiment (Prechtl & Beintema, 1964).

Figure 1 A-B: Testing procedures in supine position at 0° (A) and reclined position at 45° (B).
Reaching Training Protocol

Between pre- and posttraining assessments, the control group received no training or stimuli and remained in their parents’ lap for 4 min. Experimental group 1 received one single and short-duration (approximately 4 min) reaching training session in supine position, whereas experimental group 2 received one single and short-duration (approximately 4 min) reaching training session in reclined position (approximately 45° in relation to the floor). The training session for both groups was applied by the examiner (pediatric physical therapist).

The training session of experimental group 1 was carried out with the infant placed in supine position on a mat (Figure 2A). For the experimental group 2, which was trained in reclined position, the physical therapist sat comfortably with her trunk supported, legs slightly apart, and hips and knees flexed around 120° and 50°, respectively. A small pillow was placed on her knees. The infant’s head was placed on the pillow. This favored the infant to remain face to face with the examiner, with his neck in semiflexion, thus facilitating the alignment between head and trunk, and hands near the midline, within his visual field (Figure 2B).
The training session was composed of 3 activities. Each activity was performed 3 times to the right upper limb and 3 times to the left upper limb under blocked practice condition, i.e., the practice of each activity was completed before starting the next one (Del Rey, Whitehurst, & Wood, 1983; Jarus & Gutman, 2001; Savion-Lemieux & Penhune, 2010). The same object used for the assessments was used for training.

This training session protocol was based on studies by Lobo et al. (2004), Heathcock et al. (2008), and Soares et al. (2010) and is detailed in Table 2.

### Description of Reaching and Dependent Variables

Reaching was considered as the hand movement toward the toy resulting in touching it, regardless of grasping (Toledo et al., 2011). The infants should be directing his/her visual attention to the toy from the beginning to the end of the hand movement (object contact). The beginning of a reaching movement was defined as the first frame when the infant’s arm began an uninterrupted movement toward the toy. The end of a reaching movement was defined as the first frame when the infant’s hand touched the toy (Carvalho et al., 2008b; Corbetta & Thelen, 1996; Fallang, Saugstad, & Hadders-Algra, 2000; Toledo et al., 2011).

### Table 2  Reaching Training Protocol, Both in Supine and Seated Reclined at 45°, Composed of Three Activities:

<table>
<thead>
<tr>
<th>Activity 1</th>
<th>The researcher held the object in one hand, at the midline, and at the height of the xiphoid process of the infant, and with the other hand, held the right forearm of the infant to lead the same right hand toward the object by touching it. This procedure was performed three times for the right hand, and subsequently it was performed three times for the left hand. Duration 80 s.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Activity 2</td>
<td>The researcher held the object in one hand, at the midline and at the height of the xiphoid process of the infant, and with other hand, held the right forearm of the infant to position the right hand within their visual field for a few seconds. If the infant did not touch the object or explored it by hand spontaneously, the researcher performed tactile stimuli with the object in the right hand of the infant. This procedure was performed three times for the right hand, and subsequently it was performed three times for the left hand. Duration 80 s.</td>
</tr>
<tr>
<td>Activity 3</td>
<td>Upper limbs of the infant were positioned along the body. The researcher performed tactile stimuli with the object arm and right forearm of the infant and took the object to the middle line at the xiphoid process, within the visual field of the infant. The researcher waited a few seconds to allow the infant to perform spontaneous movements uni or multijoint upper limb. This procedure was performed three times for the right hand, and subsequently it was performed three times for the left upper limb. Each time the infant touched the object, the researcher, with a smile, praised him. If the infant were to grasp the object, the researcher let him explore it. Duration 80 s.</td>
</tr>
</tbody>
</table>
**Total Reaching Frequency.** Total number of valid reaches performed at pre- and posttraining assessment (over a period of 2 min).

**Proximal Adjustments.** Unimanual: when the infant moved only one hand toward the toy and touched it (Corbetta & Thelen, 1996; Toledo et al., 2011), or when both hands moved from the initial position with a difference of more than 20 frames (7.2 ms) between them, managing to touch the toy (Rocha et al., 2006; Toledo et al., 2011). Bimanual: when the infant moved both hands simultaneously toward the toy and touched it (Corbetta & Thelen, 1996; Toledo et al., 2011), or when both hands moved from the initial position with a difference of less than or equal to 20 frames between them and touched the toy (Rocha et al. 2006; Toledo et al., 2011). In this case, hands should move simultaneously for at least 50% of the trajectory and the toy should be touched with both hands, whether touch was synchronous or asynchronous (Rocha et al. 2006; Toledo et al., 2011).

**Distal Adjustments.** Distal adjustments were analyzed at the end of the reaching movement, that is, when the toy was touched. Hand orientation: a) **horizontal** (when the palm of the hand was faced downward in relation to the forearm), b) **vertical** (when the palm of the hand was oriented toward the infant’s midline in relation to the forearm—neutral position), and c) **oblique** [when the hand was in an intermediate position in relation to the two aforementioned positions (Rocha, Costa, Savelsbergh, & Tudella, 2009; Toledo et al., 2011), i.e., approximately 45° of hand/forearm supination in relation to horizontal hand]. Hand opening was classified as: a) **open** (when metacarpophalangeal and interphalangeal joints were fully extended; Fagard, 2000; Toledo et al., 2011), b) **closed** (when metacarpophalangeal and interphalangeal joints were fully flexed), or c) **semiopen** (when metacarpophalangeal joints were flexed [regardless of the flexion degree] and interphalangeal joints were extended, or when metacarpophalanges were extended and interphalanges were flexed [regardless of the flexion degree]; Rocha et al., 2006; Toledo et al., 2011).

**Grasping.** Successful grasping was when the infant grasped the toy with one or both hands after a valid reach; and unsuccessful grasping was when the infant reached the toy but did not grasp it (Fagard, 2000; Toledo & Tudella, 2008; Toledo et al., 2011; Van der Fits, Flikweert, Stremmelaar, Martijn, & Hadders-Algra, 1999).

The coding of the variables was performed by three observers blind to the assignment of the infants to groups to avoid bias in the results. The coders used synchronized images of the four cameras from a monitor. One of the coders was an expert examiner and instructed the others according to the description of variables. The mean value for all interrater agreement among the three coders computed for all variables studied was 92.0%. The mean value for the intrarater agreement was 93.5%. For each variable, inter- and intrarater agreements were calculated in 12.5% of the total sample using the equation \( \frac{\text{number of agreements}}{\text{number of agreements} + \text{number of disagreements}} \times 100 \).

**Statistical Analysis**

A nonparametric repeated measures analysis of variance (Friedman’s test) was used to analyze effects of assessment (pre- and posttraining) and position (supine and reclined) in each group (experimental group 1, experimental group 2, and control group). Kruskall-Wallis test was used to analyze differences among the groups in
the pre-training assessment. When interaction was significant, data were submitted to nonparametric Tukey HSD test for multiple comparisons. All inferential procedures, i.e., hypothesis testing and interval estimates (confidence intervals), were preceded by tests for outliers (Dixon-Grubbs-Neumann for outliers), normality (Shapiro-Wilk test) and homogeneity of variances (Cochran). The variables were analyzed by frequencies of their occurrence. Median values for each infant were used in all variables. Significance level was set at $p < .05$ for all analyses.

**Results**

This study analyzed 772 reaching movements: 340 at the pretraining assessment and 432 at the posttraining assessment.

**Total Reaching Frequency**

There was no difference between experimental and control groups in the total reaching frequency in the pretraining assessment in supine and reclined position ($\chi^2=2.68; p = .08$).

In relation to the group $\times$ assessment $\times$ assessed position interaction, there were no differences ($\chi^2=0.68; p = .8791$) between the total reaching frequencies observed in the pre- and posttraining assessments for the control group. For the group trained in reclined position, there were differences ($\chi^2=8.36; p = .0391$) between the total reaching frequencies observed in the pre- and posttraining, in which there was an increase in the total reaching frequency in the posttraining assessment ($14.5 \pm 3.8$) compared with the pretraining assessment ($10.5 \pm 4.9$) in the reclined position. The group trained in supine position also showed differences ($\chi^2=10.39; p = .0135$) between total reaching frequencies observed in the pre- and posttraining assessments, characterized by increased total reaching frequencies in the posttraining assessment ($12.5 \pm 4.4$) compared with pretraining assessment ($5.5 \pm 4.1$) in the reclined position, and in the posttraining ($9.0 \pm 5.8$) compared with pretraining ($5.5 \pm 6.1$) in the assessment in the supine position (Figure 3).

**Proximal Adjustments**

There were differences for the proximal adjustments ($\chi^2=7.22; p < .001$), and the frequency of unimanual reaches ($6.0 \pm 4.3$) was higher than the frequency of bimanual reaches ($1.6 \pm 2.5$).

As for the group $\times$ assessment $\times$ assessed position interaction, there were differences between control group ($\chi^2=30.26; p < .001$), group trained in reclined position ($\chi^2=28.21; p = .0002$) and group trained in supine position ($\chi^2=29.01; p = .0001$). In the control group, the differences were due to the higher frequency of unimanual reaches ($4.5 \pm 4.3$) compared with bimanual reaches ($0.5 \pm 0.8$) in both pre- and posttraining assessments and both positions. For the group trained in reclined position, the differences corresponded to: a) higher frequency of unimanual reaches ($8.6 \pm 4.2$) compared with bimanual reaches ($1.5 \pm 2.4$) in both pre- and posttraining assessments and both positions and b) increased unimanual reaches in the posttraining assessment ($11.0 \pm 4.7$) compared with the pretraining assessment ($7.5 \pm 4.2$) in the reclined position. In the group trained in supine position, these
Figure 3 — Median and quartile deviation of the total frequency of reaches in pre- and posttraining assessment in the control group, group trained in reclined position and group trained in supine position. * Significant difference between assessments ($p < .05$).
differences were characterized by: a) higher frequency of unimanual reaches (5.7 ± 2.5) compared with bimanual reaches (1.5 ± 2.5), b) increased bimanual reaches in the posttraining assessment (2.0 ± 4.8) compared with the pretraining assessment (0.0 ± 2.5) in the supine position, and c) increased unimanual reaches in the posttraining assessment (10.0 ± 4.2) compared with the pretraining assessment (5.5 ± 2.7) in the reclined position (Figure 4).

**Distal Adjustments**

As for hand orientation, there were differences ($\chi^2=67.19; p < .0001$) between classifications, which corresponded to a lower frequency of vertically oriented hand (0.0 ± 0.8) compared with horizontal (3.0 ± 2.9) and oblique orientations (3.0 ± 3.8).

In relation to the group × assessment × assessed position interaction, the control group showed no differences in hand orientation both in reclined ($\chi^2=4.73; p = .4494$) and supine positions ($\chi^2=5.56; p = .3514$). The group trained in reclined position showed differences in hand orientation both in supine ($\chi^2=19.80; p = .0014$) and reclined positions ($\chi^2=19.23; p = .0017$). These differences ($p < .05$) corresponded to the lower frequency of reaches performed with vertical hand (0.5 ± 1.1) compared with the other positions. In addition, there were differences for oblique hand, with higher frequency in the posttraining assessment (7.5 ± 4.9) compared with the pretraining assessment (5.5 ± 4.1) in the reclined position. The group trained in supine position showed differences both in reclined ($\chi^2=25.04; p = .0001$) and supine positions ($\chi^2=16.34; p = .0057$). These differences ($p < .05$) corresponded to the lower frequency of reaches performed with vertical hand (0.5 ± 1.1) compared with the other positions. There were differences for oblique hand, being more frequent in the posttraining assessment (7.0 ± 3.3) compared with pretraining assessment (1.5 ± 3.2) in the reclined position.

In relation to the hand opening, there were differences ($\chi^2=46.63; p < .001$) characterized by higher frequency of semiopen hand (4.0 ± 4.1) than closed hand (1.0 ± 2.3) and open hand (0.5 ± 1.9). The control group showed no interaction for the hand opening, both in the reclined ($\chi^2=10.13; p = .071$) and supine positions ($\chi^2=4.12; p = .531$) and both in the pre and posttraining assessments. In relation to the group × assessment × assessed position interaction, there were differences both in the supine ($\chi^2=18.29; p = .0026$) and reclined positions ($\chi^2=10.13; p = .0222$) for the group trained in reclined position. In both positions, there was a higher frequency of reaches performed with semiopen hand (7.5 ± 4.1) compared with the other classifications both in pre- and posttraining assessments. In the reclined position, there was increased frequency of reaches performed with semiopen hand in the posttraining assessment (8.0 ± 4.1) compared with pretraining assessment (3.5 ± 4.2) (Figure 5A). In the group trained in supine position, there were differences both in the reclined ($\chi^2=14.12; p = .0148$) and supine positions ($\chi^2=16.86; p = .0048$). These differences corresponded to: a) higher frequency of reaches performed with semiopen hand (6.0 ± 3.8) compared with the other classifications; b) higher frequency of reaches performed with open hand in the pretraining assessment (3.0 ± 3.1) compared with posttraining assessment (0.0 ± 2.2) in the supine position, c) higher frequency of reaches performed with semiopen hand in the posttraining assessment (10.0 ± 3.9) compared with pretraining assessment (2.0 ± 4.0) in the
Figure 4 — Median and quartile deviation of unimanual and bimanual frequency of reaches in pre- and posttraining assessment in reclined and supine position for the group trained in reclined position and the group trained in supine position. * Significant difference between assessments ($p < .05$).
reclined position, and d) higher frequency of reaches performed with semiopen hand in the posttraining assessment (9.0 ± 3.8) compared with pretraining assessment (2.5 ± 2.5) in the supine position (Figure 5B).

**Grasping**

Grasping showed differences between groups trained in supine ($\chi^2=20.94; p = .0039$) and reclined positions ($\chi^2=23.66; p = .0013$), and control group ($\chi^2=30.55; p < .0001$). These differences are due to the higher frequency of unsuccessful grasps when compared with successful grasps in the three groups (group trained in supine position: 6.5 ± 5.3; group trained in reclined position: 8.3 ± 4.1; and control group: 3.1 ± 2.5). However, there was no difference in the group × assessment × position assessed interaction between groups (2.2 ± 1.5, $p = .1484$).

**Discussion**

This study investigated the effect of a single short-duration training session carried out with the infant in supine or reclined position on the reaching frequency, proximal and distal reaching adjustments and grasp in typical infants. In addition, the changes in these parameters between assessments carried out in supine and reclined positions according to the type of training were also verified. For the spontaneous practice not to interfere in the results, the experiment was conducted up to 3 days after the onset of goal-directed reaching.

To make the discussion more instructive, firstly the discussion will be on the training effect. Subsequently, the study will discuss on the changes in the reaching behavior related to trained and assessed positions.

**Changes in the Post-Training Reaching Behavior**

We expected that training would facilitate the increase in the frequency of at least one of the following variables: total reaching frequency, unimanual reaches, open hand, hand vertically oriented and successful grasps. We found that training was effective in promoting gains in total reaching frequency and unimanual reaches. Thus, the first hypothesis of this study, that a single short-duration training session is effective in facilitating the reaching movements of infants shortly after the onset of this skill, was confirmed.

After training, the group trained in the supine position increased the reaching frequency assessed in both supine and reclined positions, and the group trained in reclined position showed an increased reaching frequency in the reclined position. Regardless of the position in which the infants were assessed, these results show that training was effective in increasing the contact of the infants’ hands with the object. Lobo et al. (2004) and Heathcock et al. (2008) found similar results in full-term and preterm infants, however, after 2–8 weeks of daily reaching training. Karni et al. (1998) suggest that although the acquisition of a task requires practice over several weeks, the selection of cortical sensorimotor maps to solve perceptual problems related to the task performance occurs in the first training session. In this study, the few minutes of training may have been sufficient to facilitate the selection of sensorimotor maps in infants, resulting in gains in the task performance shown by the increased reaching frequency.
Figure 5—A-B. Median and quartile deviation of reaches with open, closed and semiopen hand in pre- and posttraining assessment in reclined and supine position for the group trained in reclined position (A) . . .
Figure 5—The group trained in supine position (B). * Significant difference between assessments ($p < 0.05$).
For the proximal adjustments, all groups showed predominance of unimanual reaches, both in supine and reclined positions. This result is partly in agreement with the study by Carvalho et al. (2008b), who found predominance of unimanual reaches, regardless of supine position or reclined at 70° in 4-month-old infants. Fallang et al. (2000) showed that although reaches are symmetrical between 4 and 6 months of age, they are predominantly performed with only one hand. In this study, as in a previous study carried out in our laboratory (Toledo et al., 2011), the use of head and trunk support and a malleable object during reaches possibly stabilized the postural and perceptual systems of infants and thus facilitated the use of only one hand to reach the object.

After training, the predominance of unimanual reaches was even greater in all groups in the reclined position. Thus, the few minutes of training associated with stability of postural and perceptual systems during the experiment appear to have been effective in facilitating unimanual reaches at reclined position. However, for the group trained in supine position, an increase in bimanual reaches was observed, but only in the supine position. These results differ from those by Lobo and Gallo-way (2008). These authors found that infants who received training of hand-object interaction in supine or postural training for 3 weeks increased the frequency of bilateral reaches both in sitting and supine positions. In the current study, the training in the supine position modified the type of strategy used to reach the object, which was not observed with the training in reclined position. According to Corbetta and Thelen (1996), periods of synchronous activity of the arms may reflect inability to isolate and direct the force only to the upper limb necessary to the task. Moreover, the authors suggested that the effort required to direct and control the arms to reach the object promotes the recruitment of bilateral homologous muscles in the shoulder joint (Corbetta & Thelen, 1996). Thus, we believe that by providing more experience producing more muscle force in the upper limbs to overcome gravity and initiate the reaching movements, the training in supine position promoted an increased synchronous recruitment of the arm muscles, which challenged the infant to direct the force to only one limb, therefore leading to a tendency for the performance of bimanual reaches. In addition, the task variability may also have increased during the training in supine position, eliciting an increase in available strategies. The emergence phase of a skill is a fact marked by wide variability of motor patterns (Edelman, 1987; Hadders-Algra, 2000; Thelen et al., 1993). During this period, the infant experiences every available strategy to solve the function demands (Edelman, 1987; Hadders-Algra, 2000). In this study, supine training may have increased the variability of the reaching strategies in the attempt to solve the biomechanical demand imposed by the body position, resulting in increased bimanual strategy as an attempt to increase the chances of grasping the object.

As for hand orientation, both positions showed fewer reaches with vertical hand in the trained groups. Although more reaches with vertical hand after training was expected, increased oblique hand in the reclined position in both trained groups was found. Studies have shown that reaches with vertical hand at the touch of the object is present at 5 months of age (Fagard, 2000, Toledo et al., 2011). According to Toledo et al. (2011), the hand verticalization at this age may be related to the progressive adoption of supinated forearms, as observed by Bhat et al. (2007) in the period of acquisition of this ability to reach frontal objects. Thus, we believe that in the period shortly after the emergence of this skill, the changes in the forearm
dynamics are still insufficient to promote reaches with hand predominantly vertical. On the other hand, it is possible that the training has increased the adoption of strategies to activate the supinator muscles of the forearm, facilitating supination and consequently increasing the oblique orientation of the hand to reach the object.

In relation to the hand opening, a predominance of reaches with semiopen hand in the trained groups was found. After training, there was an increase of reaches with semiopen hand in the reclined position in both trained groups, and in the supine position only in the group trained in supine position. Another interesting result was the decrease of reaches with open hand in the supine position in the group trained in supine position. These results refute our hypothesis that there would be an increase of reaches with open hand after training. However, it is noteworthy that although literature reports that more effective reaches are performed with open hand (Lobo et al., 2004; Savelsbergh & van der Kamp, 1994), these studies did not differentiate between open and semiopen hand. On the other hand, Toledo et al. (2011), who investigated proximal and distal adjustments of reaching in infants, observed an increase of reaches with open hand from 5 to 7 months of age, but there was a prevalence of reaches performed with semiopen hand from 5 to 6 months of age. These authors used a small and malleable object, as in this study. We believe that the semiopen hand is a strategy compatible with the openness required for this type of object and also during the period of reaching onset. In fact, at 4 months of age, infants are able to perceive the affordances related to the object size and rigidity (Rocha et al. 2006). Therefore, the infants in this study may have perceived that the physical properties of the object did not require complete hand opening. Furthermore, we believe that the experience promoted by the training session was able to enhance the perception of the object affordances, increasing the performance of reaches with semiopen hand.

Since there were predominance of unsuccessful grasps in all groups, the training session was not efficient enough to promote reaches with successful grasps. This shows that although the training may have increased experience in the adoption of sensorimotor strategies in the attempt of selecting efficient reaching patterns, it was not enough to improve the complex grasping dynamics. To grasp an object, monkeys need to perform a wide coactivation of the hand muscles (Takei & Seki, 2010) in synergy with the arm muscles. Probably, a similar event occurs to infants and a synergistic demand becomes very difficult for infants in the period of the reaching onset. In addition, the type of training used in this study was not focused on grasping the object, but on touching it. Thus, despite having facilitated the targeting of the hand to the object, the training did not promote experience enough to improve the synergistic muscle dynamic to combine reaching and grasping efficiently, suggesting the training specificity to the task.

Changes in Reaching Behavior Between Trained and Assessed Positions

It is interesting to observe that, after training, infants trained in the reclined position showed gains in the total reaching frequency and frequency of proximal and distal adjustments only in the reclined position. Similarly, infants trained in the supine position showed gains in the frequency of variables in the supine position. At first, these results may indicate specificity of gains in the frequency of variables
studied in the trained position. Other studies with 0–18 month-old infants found that interventions on motor patterns were more beneficial when performed in a specific context (Blauw-Hospers & Hadders-Algra, 2005; Zelazo, Zelazo, Cohen, & Zelazo, 1993). Literature reports that the learning of motor tasks, such as sequential finger opposition movements, is highly context specific in the early stages of task learning (Karni et al., 1995, Karni et al., 1998), affecting only the subset of neural inputs that are active under a specific stimulus (Gilbert, Li, & Piech, 2009). In addition, Martin et al. (1996) studied the specificity of the adaptation of hits in throwing balls at a target in adults and found that the adaptation was specific to the arm position in which the movement was trained. In the current study, the training conducted may have facilitated not only the activation of neurons specific to the task, but also those specific to the position in which the task was practiced.

However, a surprising result was observed. We found that the group trained in supine position increased total reaching frequency, unimanual reaches, reaches performed with semiopen hand and with oblique hand also in the reclined position. Thus, our second hypothesis on gains in the frequency of variables be specific to the trained position was only partially confirmed. Unlike what was observed with infants trained in reclined position, the group trained in supine position showed increased frequency of the reaching variables in both positions.

As previously reported, the supine position leads to greater muscle torque at the beginning of the reaching movement while the reclined position facilitates the movement, promoting biomechanical advantage in arms to overcome gravity (Carvalho et al. 2007; Out et al. 1998). Thus, it could be considered that the reaching training in the supine position required greater muscle torque demand when compared with that performed in reclined position. Therefore, it could be inferred that the experience gained performing arm movements in a more complex biomechanics demand provided the increase in strategies not only in the trained position, but also in the reclined position. Since the reclined position shows biomechanical advantage compared with supine position, the infants showed gains in reaching performance also in the reclined position because it facilitates the movements of this skill.

**Conclusions and Limitations**

The short-duration single training session performed in both supine and reclined positions was effective in facilitating the reaching in the period shortly after the onset of the skill, providing higher total reaching frequency and unimanual reaches. In addition, the training increased the frequency of reaches with oblique and semiopen hand, which seems to be behaviors compatible with the intrinsic dynamics of infants at the period of reaching onset and with the type of object used (small and malleable). The effects were specific to the position in which the infants were trained. However, infants trained in the supine position showed changes in the reaching behavior not only in the supine position, but also in the reclined position, which may be related to the requirement of greater arm muscle torque demand in the training in supine position than in the training in reclined position.

Since body position influences reaching behavior, one limitation in this study is that the control group remained at their parents’ lap during the interval between assessments instead of positioned in supine position on the mat or reclined at the physical therapist’s lap. In addition, although the coding of the variables was made
blindly, future work must blind the examiner during the infant’s assessments as well. Finally, although it is not known whether the effects observed in the reaching behavior after training remain within hours or days, the results of this study provide empirical support for improvements clinically observed in motor behavior after a single training session. Although the retention of the effects observed cannot be affirmed, these initial changes in motor behavior after a single and short-duration training session may result from the activation of specific neural circuits (Karni et al., 1998), which will promote the learning of the task with continued training.

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