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Does late preterm birth impact trunk control and early reaching behavior?

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ABSTRACT

The aims of the study were to 1) verify the level of trunk control longitudinally and reaching behavior while sitting in two positions in late preterm (LPT) and full-term (FT) infants, 2) determine whether the level of trunk control relates to reaching outcomes. Twenty LPT infants and 36 infants born FT were assessed via three in-lab visits: at 6, 7, and 8 months. At each visit, the Segmental Assessment of Trunk Control (SATCo) and reaching assessment were performed, where the infants were positioned sitting in the ring and at 90° of flexion of hips, knees, and ankles. Accurate manual support to the trunk was provided in each visit. LPT infants presented a lower level of trunk control over time. LPT infants presented a higher percentage of unimanual reaches and successful grasping at 7 months' visit, and a higher number of reaches at 8 months' visit compared to FT infants. The sitting positions did not influence reaching performance. The level of trunk control relates to functional reaching strategies only in FT infants. This study might provide insights for clinicians for understanding the level of trunk control, the importance of reaching behaviors for exploration, and considering these behaviors as strategies for intervention.

What does this paper add?

First, this study's longitudinal design permitted a comprehensive picture of the level of trunk control and reaching behaviors using different sitting positions in typically developing infants and late preterm infants (LPT). Second, LPT may exhibit delays in the level of trunk control and different reaching strategies during the first months of life, and they might be at risk for developmental delays. Third, the level of trunk control might play a role in reaching strategies that best facilitate the exploration of the object in full-term infants. This study might provide insights for clinicians to understand the level of trunk control, the importance of reaching behaviors for object exploration, and considering these behaviors as strategies for intervention.

1. Introduction

In the first year of life, infants acquire a varied repertoire of skills, such as the ability to control the head, to reach for and

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manipulate objects, and to sit independently, which is strictly related to the improvement of trunk control (Hopkins & Rönnqvist, 2002; Rachwani et al., 2013). It allows infants to maintain the vertical's trunk alignment to perform functional activities and explore the environment (Rachwani et al., 2013).

Thus, a relationship between trunk control and manual behaviors has been recently highlighted. For example, for successful reaching performance, the muscles of the trunk have to be recruited to maintain the infant's balance (Rachwani, Santamaria, Saavedra, & Woollacott, 2015). The level of trunk control gradually emerges from two to nine months of age in typically developing infants (Butler, Saavedra, Sofranac, Jarvis, & Woollacott, 2010), with specific recruitment and synergy of the cervical, thoracic and lumbar muscles (Van Balen, Dijkstra, & Hadders-Algra, 2012).

However, moderate to late preterm (LPT) infants demonstrated a lower level on segmental trunk control at 6–8 months of corrected age (Righetto Greco, da S. Sato, Cazotti, & Tudella, 2019; Sato & Tudella, 2018) when compared to their full-term (FT) peers. Most FT infants demonstrated the total level of trunk control at 8 months of age, while only 10 % of LPT infants presented the same level of trunk control at 8 months of corrected age (Sato & Tudella, 2018). Thus, preterm (PT) infants might be at risk for delays on trunk control, and consequently on reaching behavior (Guimaraes, Cunha, Soares, de, & Tudella, 2013; Sato & Tudella, 2018).

1.1. *Differences in reaching behaviors in PT vs. FT infant*

Heathcock, Lobo, and Galloway (2008) showed that preterm infants with <33 weeks of gestational age and < 2.500 g of birth weight had a delay on the onset of reaching, reached less for objects, and less often with open and ventral hands compared to FT infants. The onset of reaching in LPT infants (born at 34 to <37 weeks of gestation age) was also delayed compared to their peers [16.2 ± 2.3 weeks vs. 13.9 ± 1.8 weeks of age (de A. Soares, Cunha, & Tudella, 2014)]. Moreover, they reached less often with both and open hands, presented less successful grasping and hand oriented vertically later than FT infants (de Toledo, de A. Soares, & Tudella, 2011; de A. Soares et al., 2014).

These delays of the onset and reaching development in PT infants may be related to a deficit in the head and trunk control caused due to muscle tone regulation, and delayed synergistic recruitment of trunk muscles (Van Der Fits, Otten, Klip, Van Eykern, & Hadders-Algra, 1999). It is known that vertical segmental trunk control and motor skills in sitting position are closely related and likely interdependent (Pin, Butler, Cheung, & Shum, 2019; Pin, Butler, Cheung, & Shum, 2019; Pin, Butler, Cheung, & Shum, 2019; Rachwani et al., 2013, 2015). For example, typically developing infants fully mastered upright control two to three months after most of them can sit independently (Pin et al., 2019a, 2019b, 2019c). Moreover, PT infants had a significant delay in motor skills in supine, prone, and sitting positions due to delayed development of trunk control compared with FT infants (Pin et al., 2019a, 2019b, 2019c). Thus, the level of trunk control is strictly related to the sitting ability, which both are associated with better reaching performance (Harbourne, Lobo, Karst, & Galloway, 2013; Rochat & Goubet, 1995).

1.2. *Influence of sitting positions on reaching behaviors*

Previous researchers have been shown that providing external support during sitting impacts positively reaching behavior in typically developing infants (Bertenthal & von Hofsten, 1998; Grenier, 1981), and a greater level of sitting ability may be associated with better reaching performance (Harbourne et al., 2013; Rochat & Goubet, 1995). However, the development of reaching and sitting ability has extensively been studied as separate behaviors in infants at risk for delays (de Toledo et al., 2011; Hadders-Algra et al., 2007; Heathcock et al., 2008).

Few studies have been shown that different sitting positions (i.e., sitting in ring and 90° flexion of hips, knees, and ankles) may influence reaching behaviors in FT and LPT infants at 6–8 months old (Moreira da Silva, Lopes dos Santos, Righetto Greco, & Tudella, 2017; Sato & Tudella, 2018). Typically developing infants while sitting in a ring position at 6 months old had better reaching performance, such as more straight and fluent movements indicating better coordination of the upper limb than sitting in the 90° flexion position. Moreover, FT infants with a higher level of trunk control showed fluent reaching movements, regardless of sitting position and age. That suggested it was due to the greater support base of the lower limbs and, consequently, greater trunk stability (Moreira da Silva et al., 2017). Interestingly, when infants were provided with accurate manual support in relation to their level of trunk control, no differences were found in the spatial-temporal variables during reaching between these two positions (Sato & Tudella, 2018). Thus, not only the sitting position should be considered, but also the level of trunk control.

To our knowledge, few studies explored the level of trunk control at different age range. However, they did not use the level of trunk control as a strategy for supporting the trunk of LPT and FT infants while reaching in different sitting positions as well did not explore its relationship with reaching performance. The present study aimed to 1) verify the level of trunk control and reaching outcomes (reaching frequency, distal and proximal adjustments, and grasping) in LPT infants while seating in two positions (e.g., sitting in the ring and 90° flexion of hips, knees, and ankles) at 6–8 months of corrected age compared to their FT peers, 2) determine whether the level of trunk control relates to reaching outcomes in LPT and FT infants.

Thus, it was hypothesized that: 1) LPT infants would present a lower level of trunk control than FT infants, 2) LPT infants would perform fewer reaching behaviors than FT infants, 3) the two sitting positions would not influence differently reaching behaviors due to the accurate manual support to the trunk provided; 4) the higher level of trunk control would be associated to functional reaching strategies (e.g., bimanual reaches, open and vertical hands, and successful grasping). The study might provide relevant information for clinicians to identify delays and to design early intervention for enhancing reaching performance based on the level of trunk control and using sitting positions as a strategy.

2. Materials and methods

2.1. Study design and setting

Data collection for this longitudinal study was completed in accordance with the recommendations set by the Research Ethics Committee of the Federal University of São Carlos (CEP/UFSCar), protocol number 1.350.978. Parents of participating infants provided informed consent. Infants were assessed at the Laboratory of Research in Movement Analysis of the Department of Physical Therapy, Federal University of Sao Carlos.

2.2. Participants

Fifty-six infants participated in this study: 20 infants born late preterm [LPT, (*Mean* = 35.3, SD = 0.9 weeks of gestational age); "moderate to late preterm": 32 to <37 weeks of gestational age] and 36 infants born full-term [FT, *Mean* = 39.4, SD = 1.3 weeks of gestational age); 37–41 weeks and 6 days of gestational age].

The infants were recruited from February to October 2016 from health care centers and maternity hospital of the Sao Carlos city. The eligibility criteria were: a) adequate birth weight for gestational age, and b) Apgar score from 7 to 10 in the first and fifth minutes. Infants who medical records and/or their neonatologist's report presented at least one of the following conditions were excluded from the study: (a) anoxia/hypoxia, (b) signs of neurological complications, (c) hyperbilirubinemia, (d) congenital malformations), (e) syndromes, (f) sensory alterations, (g) cardiopulmonary dysfunctions, (h) intra-uterine or post-natal growth restriction, and (i) hospitalization at Neonatal Intensive Care Unit (NICU).

2.3. Procedures

FT infants were assessed at 6, 7 e 8 months of chronological age (*Mean* = 25.14 weeks, SD = 0.9; *Mean* = 28.85 weeks, SD = 1.07; *Mean* = 33 weeks, SD = 1.25, respectively) and LPT infants were evaluated considering their corrected age (*Mean* = 25.14 weeks, SD = 1.34; *Mean* = 29.85 weeks, SD = 1.48; *Mean* = 34 weeks, SD = 1.2, respectively).

On the first day of the assessment, the parents/ caregivers were informed again about the procedures and aims of the study. They completed a demographic and health-related information questionnaire.

In all monthly visits, assessments were video recorded. Firstly, the Alberta Infant Motor Scale (AIMS), a valid and reliable assessment tool widely used to assess infants from birth to 18 months of age (Piper & Darrah, 1994), was used to characterize the gross motor performance across age. It was also performed to ensure that FT infants had at least 25 percentile ranking score [percentile ranking below 10th and 5th, more likely the infants are to be exhibiting motor delays (Campos et al., 2006; Piper & Darrah, 1994)].

Then, infants were tested using the Segmental Assessment of Trunk Control (SATCo) to determine the level of trunk control. A reaching assessment was also performed, where the infants were encouraged to interact with interesting toys in two different sitting positions. The Qualisys system was used, and data were collected in each visit.

2.4. Trunk control assessment

To identify the level of trunk control, a first assessor sat behind the infant with her hands positioned horizontally around the infant's trunk, as described in the SATCo (Butler et al., 2010; dos S. C. de Sá, Fávero, Voos, Choren, & de P. Carvalho, 2017). A second assessor was seated in front of the infant and presented attractive objects to get his/her visual attention and keep the infant's upper limbs free from external support.

The SATCo includes three tests: 1) static: infant was able to maintain a neutral vertical position in the sagittal and frontal plane for five seconds; 2) active: infant could turn its head to each side and be able to keep a neutral alignment in the trunk during head movement; and 3) reactive: a nudge was applied by the second assessor, and the infant was able to maintain or regain trunk control. The presence or absence of trunk control during static, active, and reactive tests was assessed progressively from the higher to lower levels.

The same evaluators performed all assessments. Both assessors had been trained in the previous pilot study, and these infants were not included in this study. The level of trunk control was assessed using SATCo scores for each infant. For SATCo, the inter-rater agreement was 90 % calculated for 20 % of the total sample using the equation: number of agreements/ (number of agreements + number of disagreements) × 100.

2.4.1. Description of dependent variable of level of trunk control

The score reflects the region in which the infant is able to maintain trunk control: scores (1): head control, (2): upper thoracic, (3): mid thoracic, (4): lower thoracic, (5): upper lumbar, (6): lower lumbar (7): total trunk control (Butler et al., 2010; dos S. C. de Sá et al., 2017).

In this study, the level of trunk control was considered complete when the presence of control was scored in the three tests. If the infant presented control only in the static test or static and active test, the level of trunk control considered as the previous one to what was being tested.

2.5. Reaching assessment

To identify the beginning and the end of each reaching movement, two reflexive passive spherical markers (12 mm diameter) were placed on the wrists (between the radial and ulnar styloid process) of the infants. All the infants were positioned on a wooden bench in two different conditions: A) ring position (Fig. 1A) and at 90◦ flexion of hips, knees, and ankles (Fig. 1B). Both conditions were alternated from one infant to another, so half of the infants started the assessment in the ring sitting position. The other half began the assessment in the sitting position at 90◦ of flexion.

While the infant remained seated in both conditions, an assessor seated behind the infant provided accurate manual support to the trunk, according to the level of trunk control assessed by the SATCo in each monthly visit. An initial 10-s period was allowed for the infants to adapt to the position. To elicit reaching behaviors, another assessor who was positioned in front of the infant presented an attractive object (rattle, weight: 21.5 g; length: 19 cm; smallest diameter: 5.0 cm; largest diameter: 17.0 cm) for 2 min at the midline of the infant's trunk (xiphoid process and shoulder level). The distance between the infants and the object corresponded to each infant's upper limb length. The assessor also made a mark indicating the midline of the infant's body on the wooden bench and positioned herself in the same place in all evaluations. The assessor moved the object momentarily to get the infant's attention to it and elicit reaching movements. The object was presented for two minutes in each condition, and it was taken away carefully and presented again after each reach, within a 5-s interval between the reaches. Thus, the total number of trials depended on the infant. The infants remained in either inactive or active alert state throughout the experiment (Prechtl & Beintema, 1964).

The same assessors performed the assessments. Both assessors were trained in the experimental procedures and how to identify, frame by frame, the beginning, and end of the reaching movement. The inter-rater agreement was 97.46 %, from 20 % of the total sample. It was assessed by the equation: number of agreements/ (number of agreements + number of disagreements) × 100, considering the initial and final frame of each reach.

2.5.1. Data analysis system

The Kinovea 0.8.21 software and the Qualisys Track Manager (QTM) software were used to analyze the frequency of reaches and track the first and final frames of the reaches. The experimental setup comprised five cameras (Qualisys Oqus 300 - frequency of 200 Hz.): four for the analysis of the beginning and end of each reaching movement, and for the purpose of this study, it was possible to estimate the total number of reaches (total reaching frequency), and one for coding reaching behaviors (i.e., proximal and distal adjustments, and grasping). These cameras were coupled to a 2.8 GHz Pentium 4 computer.

Reaching was considered valid when the infant touched the object with one or both hands, without necessarily holding it (Cunha, Soares, Ferro, & Tudella, 2013; de Toledo et al., 2011; Savelsbergh & van der Kamp, 1994; Thelen, Corbetta, & Spencer, 1996). The beginning of a reach was defined as the first frame when the infant's arm began an uninterrupted movement toward the object. The end of a reach was defined as the first frame when the infant's hand touched the object (Carvalho, Tudella, Caljouw, & Savelsbergh, 2008; Cunha et al., 2013; de A. Soares, van der Kamp, Savelsbergh, & Tudella, 2013; de Toledo et al., 2011).

2.5.2. Description of dependent variables of reaching behaviors

2.5.2.1. Total reaching frequency. It was calculated as the number of reaches considered valid for 2 min in each sitting condition.

2.5.2.2. Proximal adjustments. Proximal adjustments were categorized as: *unimanual*: the infant moved one hand toward the object and touched it (Thelen et al., 1996); and *bimanual*: the infant moved both hands simultaneously towards the object and touched it (Thelen et al., 1996), or when both hands were moved from the initial position with a difference less than or equal to 67 frames toward the toy (Rocha, dos S. Silva, & Tudella, 2006; Thelen et al., 1996). In this case, the hands should move simultaneously for at least 50 % of the movement trajectory, and the object could be touched with both hands or only one of them (de Toledo et al., 2011; de A. Soares et al., 2014; Thelen et al., 1996).

2.5.2.3. Distal adjustments. Distal adjustments were coded at the end of each reaching movement, in other words, when the infant

Fig. 1. Experimental setup for the Reaching Assessment: A) Infant in the ring position and b) Infant at 90° of flexion of hips, knees and ankles.

touched the object. It was coded the percentage of reaches with each hand orientation and hand opening.

Hand orientation: *1) horizontal hand* – when the forearm was in pronation, and the palm of the hand was faced downward (Cunha et al., 2013); 2) *vertical hand* – when the forearm was in the neutral position, and the palm was oriented toward the infant's midline (Cunha et al., 2013); and 3) *oblique hand* – when the hand was in an intermediate position in relation to the two aforementioned, approximately 45° of hand/forearm supination in relation to horizontal hand (Cunha, Lobo, Kokkoni, Galloway, & Tudella, 2016; de Toledo et al., 2011).

Hand opening: 1) *open hand* – when the metacarpophalangeal and interphalangeal joints were extended; 2) *semiopen hand* -when the metacaphalangeal joints were flexed (regardless of flexion degree), while the interphalangeal joints were extended, or when the metacarpophalangeal were extended and the interphalangeal were flexed; and 3) *closed hand* when the metacarpophalangeal and interphalangeal joints were flexed (de A. Soares et al., 2013; de Toledo et al., 2011).

2.5.2.4. Grasping. Successful grasping: when the infant grasped the object or part of it, or unsuccessful grasping: when the infant touched the object but did not grab it (de A. Soares et al., 2013; Fagard, 2000; Rocha et al., 2006; Van Der Fits et al., 1999).

2.6. Statistical analysis

Analyses were carried out using the Statistical Package for the Social Sciences (SPSS) software version 20.0. Inferential procedures for testing homogeneity (Levene test) and normality of variances (Shapiro-Wilk and Kolmogorov-Smirnov tests) were used.

2.6.1. Participants' characteristics

For the participant's health characteristics (gestational age, birth weight, Apgar 1st and 5th minute and total score of the gross motor performance at 6, 7, 8 months visits), independent-samples t-tests and descriptive analysis were used to compare both groups. Descriptive analysis was also performed for total score, the four subscales' scores, and specific gross motor behaviors, related to mobility (e.g., reciprocal crawling; four-point kneeling to sitting or half-sitting; reciprocal creeping; sitting to prone; sitting to four-point kneeling; pulling to stand, etc.). The percentage of infants performing those behaviors in the four subscales were calculated at 6,7, and 8 months visit for both groups.

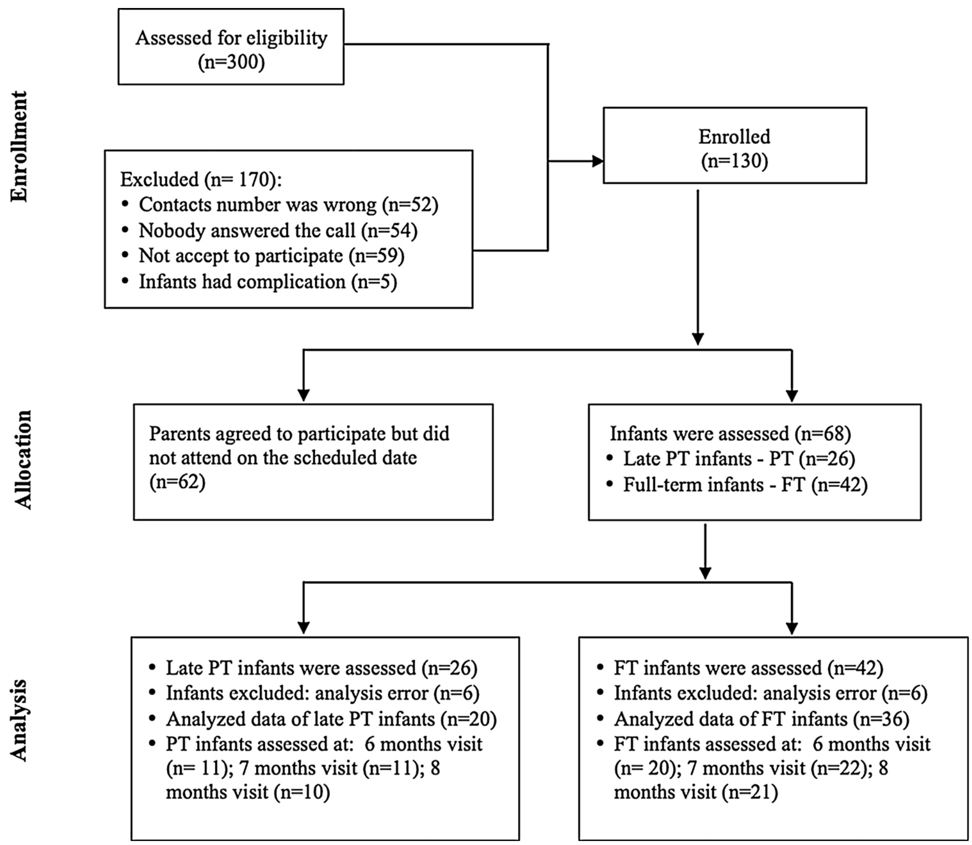

Fig. 2. Process of participants' recruitment and assignment to groups.

2.6.2. Level of trunk control

This variable was not normally distributed, and transformations did not satisfy the normality assumption. Thus, the Mann-Whitney test was performed to compare both groups at each time (visit). The Friedman test was performed to compare the time in each group; if the Friedman test was significant, the Wilcoxon test was applied. The level of significance was considered $\alpha \leq 0.008$, using Bonferroni adjustment to account for multiple comparisons.

2.6.3. Reaching behavior

The total reaching frequency (number of reaches) met the assumptions of normality. Thus, the Mixed Linear Model was performed, and Bonferroni adjustment was used for multiple comparisons. The factors considered were: group (FT and LPT), time (visits at 6, 7, and 8 months), condition (sitting in a ring position and at 90° of flexion), and interaction among these components (group by time and condition; time by group; time by condition; and group by condition). The level of significance was $\alpha \leq 0.05$.

The percentage of the frequency (proportions of their occurrence in relation to the number of reaches) was calculated for the behavioral variables (proximal adjustments, distal adjustments, and grasping). These variables were not normally distributed, and transformations did not satisfy the normality assumption. Thus, the Wilcoxon test was performed to compare the conditions (sitting in a ring position and at 90° of flexion) at each group (FT and LPT) and each time (visits at 6, 7, and 8 months). The Mann-Whitney test was performed to compare both groups at each time (visit). The level of significance was considered $\alpha \leq 0.008$, using Bonferroni adjustment to account for multiple comparisons.

Cohen's d effect sizes were calculated for the parametric tests ($d < 0.2$, small effect; $0.2 > d < 0.5$, moderate effect; $d > 0.5$, large effect). For the non-parametric tests, r (r = z score / $\sqrt{}$ total sample) was used, where $r \leq 0.2$ indicates a small effect; $0.2 > r \leq 0.4$, indicates moderate effect; and $r \geq 0.5$, large effect.

2.6.4. Relationship between the level of trunk control and reaching behavior

Spearman correlation coefficient was used to verify the relationship between the level of trunk control and reaching outcomes considered to best facilitate exploration of the object (number of reaches; unimanual and bimanual reaches; vertical hand; oblique and vertical hands; and successful grasping). The magnitude of the correlation was considered as moderate [0.40–0.59], strong [0.60–0.79], and very strong [0.80–1.00] (Field, 2013).

3. Results

The process of participants' recruitment and assignment to both groups are presented in Fig. 2. From the total participants were 20 LPT and 36 FT infants, but not infants all were assessed longitudinally. For the LPT group, three were tested in all three visits, four at least in two visits and 11 in only one visit. For the FT infants, eight were tested in all three visits, 11 at least in two visits and 16 in only one visit (more details are provided in online supplementary materials Tables S1–S3).

3.1. Participant's characteristics

The sample characteristics are presented in Table 1. There were differences between the group's characteristics for gestational age and birth weight.

In Table 2, LPT infants presented a lower score and percentage of specific gross motor behaviors (related to mobility) in each position when compared to FT infants at 6 and 8 months. Interestingly, LPT infants had a lower percentage of more complex mobility skills, such as reciprocal crawling; four-point kneeling to sitting or half-sitting; four-point kneeling; reciprocal creeping; sitting to prone; sitting to four-point kneeling; sitting without arm support, pulling to stand with support at 8 months compared to FT infants.

3.2. Level of trunk control

LPT infants presented lower level of trunk control compared to FT infants at 6 (U = 30.000; z=−3.508; $p < 0.0001$; r=−0.64), 7 (U = 56.000; z=−2.568; p = 0.01; r=−0.48) and 8 (U = 26.000; z=−3.676; $p < 0.0001$; r=−0.59) months visits (Table 3).

Moreover, there was a significant difference for time for LPT ($\chi^2(3) = 6.000$; p = 0.050) and FT infants ($\chi^2(8) = 16.000$; p <

Table 1
Health-related information (mean and standard deviation) for FT and LPT participants.

Infants	FT	LPT
Gestational age (weeks)	39.48 ± 1.280*	35.11 ± 0.88*
Birth weight (kilograms)	3.451 ± 865*	2.552 ± 476*
Apgar 1 st minute	8.75 ± 1.40	8.31 ± 1.56
Apgar 5th minute	9.67 ± 0.72	9.21 ± 1.61
Total Score Gross motor performance at 6 months (AIMS)	27.80 ± 5.54	26.45 ± 6.89
Total Score Gross motor performance at 7 months (AIMS)	34.31 ± 6.57	37.09 ± 7.20
Total Score Gross motor performance at 8 months (AIMS)	43.0 ± 7.16	37.10 ± 9.82

FT: full-term; LPT: late preterm; AIMS: Alberta Infant Motor Scale.
* Significant difference for group $p < 0.05$.

Table 2
Gross motor scores and mobility behaviors at 6, 7 and 8 months in FT and LPT infants.

	FT			LPT		
	6	7	8	6	7	8
Percentil (CRO)	54 ± 30	62 ± 26	69 ± 26	31.55 ± 30.27	53 ± 32	33 ± 32
Percentil (CO)				48.82 ± 31.45	70 ± 21	45 ± 34
Prone Subscale Score	10.25 ± 2.29	13.04 ± 3.39	17.33 ± 4.07	9.45 ± 3.30	14.63 ± 3.26	14.5 ± 4.14
Supine Subscale Score	8.15 ± 1.22	8.40 ± 1.28	8.80 ± 0.60	8 ± 1.61	9 ± 0	8.8 ± 0.63
Sit Subscale Score	6.7 ± 3.21	9.5 ± 2.35	11.57 ± 1.07	6.18 ± 3.06	9.27 ± 2.79	9.3 ± 3.59
Stand Subscale Score	2.7 ± 0.65	3.36 ± 1.20	5.28 ± 2.66	2.82 ± 0.60	4.18 ± 1.99	4.4 ± 2.79
Pivoting	55 %	86 %	100 %	45 %	91 %	100 %
Rolling prone to supine with rotation	30 %	64 %	95 %	27 %	73 %	80 %
Reciprocal crawling	0 %	27 %	67 %	0 %	45 %	30 %
Four-point kneeling to sitting or half-sitting	0 %	23 %	67 %	0 %	45 %	30 %
Reciprocal creeping (1)	0 %	18 %	62 %	0 %	27 %	30 %
Four-point kneeling (2)	0 %	9 %	52 %	0 %	27 %	30 %
Reciprocal creeping (2)	0 %	5 %	48 %	0 %	0 %	20 %
Rolling supine to prone with rotation	65 %	77 %	90 %	64 %	100 %	90 %
Sitting to prone	20 %	50 %	86 %	18 %	64 %	40 %
Sitting to four-point kneeling	10 %	27 %	81 %	9 %	36 %	30 %
Sitting without arm support (2)	10 %	32 %	86 %	0 %	27 %	50 %
Pulls to stand with support	10 %	23 %	62 %	9 %	36 %	30 %
Pulls to stand/stands	0 %	9 %	38 %	0 %	27 %	30 %
Half-kneeling	0 %	0 %	33 %	0 %	18 %	20 %
Controlled lowering from standing	0 %	0 %	24 %	0 %	0 %	20 %

AIMS: Alberta Infant Motor Scale; FT: full-term; LPT: late preterm; CRO: chronological age; CO: corrected age.

Table 3
Level of trunk control in each group in each Visit.

	Visits		
	6 months Med (Q3-Q1)	7 months Med (Q3-Q1)	8 months Med (Q3-Q1)
FT	4 (4–3) †	5 (5.25–4) †	7 (7.50–6) †
LPT	2 (3–2)*,†	4 (4–3) *,†	5 (6–3)*

FT: full-term; LPT:late preterm; Med: median; Q3-Q1: quartiles; 2: Upper thoracic; 3: Mid thoracic; 4: Low thoracic; 5: Upper lumbar; 6: lower lumbar; 7: Full trunk control.
* Significant difference between groups at each visit.
† Significant difference among visits in each group. $\alpha \leq 0.008$.

0.0001). Both PT and FT infants presented lower level of trunk control at 6 months when compared to 7 months visit, respectively (Z= −2.333; p = 0.02; r=−0.71; Z= −3.002; p = 0.003; r=−0.75) (Table 3). FT infants presented lower level of trunk control at 7 months when compared to 8 months (Z= −3.464; p = 0.001; r=−0.72) (Table 3).

There was no significant difference in LPT infants at 6 and 7 months when compared to 8 months (Z= −1.857; p = 0.06; Z= −1.169;

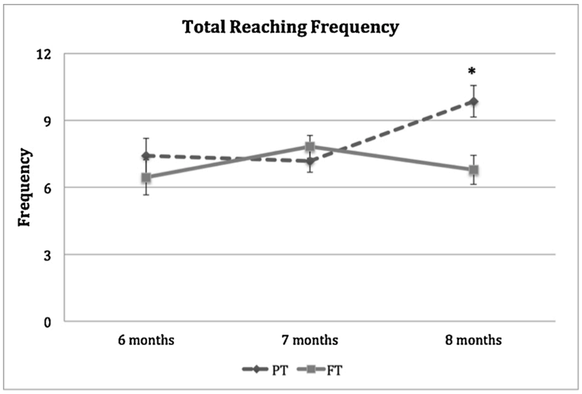

Fig. 3. Total Reaching Frequency: differences with time (Visits at 6, 7 and 8 months) and between the two groups (PT: Preterm infants, and FT: full-term infants). Error bars represent of the variability of data. * Significant difference for group vs. time $p < 0.05$.

p = 0.24, respectively).

3.3. Reaching behaviors in LPT vs. FT infants

Infants performed a total number of 1.708 reaches. Furthermore, it was considered valid a total of 1.384 reaches, 874 performed by FT infants and 510 by LPT at the corrected age.

3.3.1. Total reaching frequency

There was a significant difference for a group vs. time interaction ($F[2,177] = 3.154$; $p = 0.04$) (see online supplementary materials Table S1). LPT infants ($M = 9.85 \pm 0.87$) presented higher number of reaches when compared to FT infants ($M = 6.78 \pm 0.61$) at 8 months visit [($p = 0.00$; $d = 4.08$, (Fig. 3)].

3.3.2. Proximal and distal adjustments

Detailed information on statistical parameters can be found in Supplementary Materials - Table S2. LPT infants presented a higher frequency of unimanual reaches (88.11 %) when compared to FT infants (50.98 %) in the ring sitting condition at 7 months visit [$U = 32.000$; $p = 0.001$; $r = -0.45$, (Fig. 4)]. No differences for bimanual reaches and for any of the distal adjustments' outcomes between LPT vs. FT infants were found.

3.3.3. Successful grasping

The LPT infants presented a higher frequency of successful grasping (90.37 %) when compared to FT infants (67.50 %) in the sitting condition at 90∘ of flexion at 7 months visit [$U = 51.500$; $p = 0.007$; $r = -0.35$, (Fig. 5)].

3.3.4. Influence of sitting positions on reaching behaviors

Detailed information on statistical parameters can be found in supplementary materials Table S3. There was no significant difference between both sitting conditions for proximal adjustments, distal adjustments, and grasping outcomes.

3.4. Relationship between the level of trunk control and reaching behavior

There was no significant correlation in LPT infants. However, there was moderate and positive correlation between the level of trunk control and percentage of reaches with vertical hand at 7 months ($r(22) = 0.495$; $p = 0.019$), unimanual reaches ($r(21) = 0.462$; $p = 0.035$), and bimanual reaches ($r(21) = -0.462$; $p = 0.035$) at 8 months in FT infants (Table 4).

4. Discussion

The purpose of this study was to verify the level of trunk control, as well as reaching behavior in LPT infants while seating in two positions (e.g., sitting in the ring and 90° flexion of hips, knees, and ankles) at 6–8 months of corrected age compared to FT infants. Moreover, we explored the relationship between the level of trunk control and functional reaching outcomes in LPT and FT infants.

First, we explored the equivalence between the LPT and FT samples. Lower birth weight and gestational age were found in LPT infants. In general, LPT infants presented lower scores and percentage of mobility behaviors than FT infants at 6 and 8 months. Previous studies have associated low gestational age/ birth weight with low motor and cognitive outcomes (De Kieviet, Piek, Aarnoudse-Moens, & Oosterlaan, 2009; Linsell, Malouf, Morris, Kurinczuk, & Marlow, 2015), highlighting the importance of investigating LPT populations.

Our hypothesis that LPT infants would present a lower level of trunk control, perform fewer reaching behaviors than FT infants, the two sitting positions would not influence differently reaching behaviors, and a higher level of trunk control would be associated with functional reaching strategies were partially confirmed. Below we discuss the main findings of this study separately.

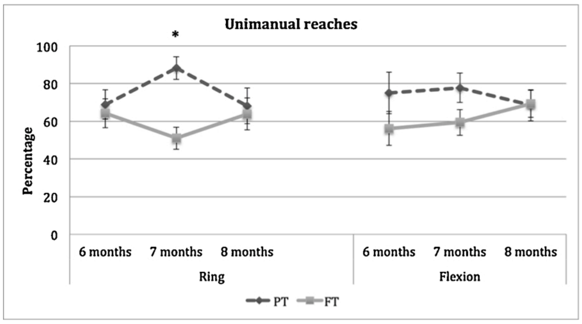

Fig. 4. Percentage of unimanual reaches between the two groups (PT: Preterm infants, and FT: full-term infants) in each sitting condition (Ring sitting condition, and 90∘ of Flexion sitting condition). Error bars represent of the variability of data.

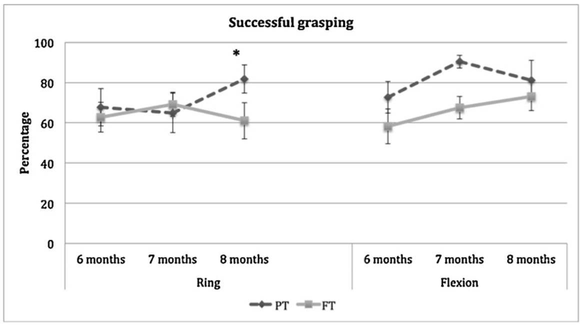

Fig. 5. Percentage of successful grasping between the two groups (PT: Preterm infants, and FT: full-term infants) in each sitting condition (Ring sitting condition, and 90◦ of Flexion sitting condition). Error bars represent of the variability of data.* Significant difference for group $p < 0.05$.

Table 4
Bivariate (two-tailed) Spearman correlations between level of trunk control (SATCo) and reaching behaviors at each group (LPT and FT) and visits (6, 7 and 8 months).

Level of trunk control		Reaching behaviors						
Monthly visits	Frequency	Unimanual	Bimanual	Open	Semiopen	Vertical	Oblique	Successful grasping
FT								
6	r(20)=−0.003; p = 0.991	r(20)=−0.131; p = 0.581	r(20)=−0.143; p = 0.548	r(20) = 0.054; p = 0.821	r(20)=−0.228; p = 0.334	r(20) = 0.214; p = 0.365	r(20)=−0.070; p = 0.769	r(20)=−0.245; p = 0.299
7	r(22) = 0.223; p = 0.318	r(22)=−0.331; p = 0.132	r(22) = 0.331; p = 0.132	r(22)=−0.195; p = 0.383	r(22) = 0.099; p = 0.662	r(22) = 0.495; p = 0.019*	r(22)=−0.059; p = 0.793	r(22) = 0.111; p = 0.621
8	r(21) = 0.091; p = 0.694	r(21) = 0.462; p = 0.035*	r(21) = 0.462; p = 0.035*	r(21)=−0.137; p = 0.554	r(21) = 0.125; p = 0.588	r(21) = 0.273; p = 0.230	r(21)=−0.345; p = 0.125	r(21) = 0.101; p = 0.664
LPT								
6	r(11) = 0.096; p = 0.779	r(11) = 0.183; p = 0.591	r(11)=−0.183; p = 0.591	r(11)=−0.467; p = 0.148	r(11) = 0.427; p = 0.190	r(11) = 0.010; p = 0.977	r(11) = 0.271; p = 0.420	r(11)=−0.080; p = 0.814
7	r(11) = 0.257; p = 0.445	r(11)=−0.169; p = 0.620	r(11) = 0.169; p = 0.620	r(11) = 0.062; p = 0.856	r(11)=−0.048; p = 0.889	r(11) = 0.19; p = 0.572	r(11) = 0.258; p = 0.444	r(11) = 0.089; p = 0.794
8	r(10)=−0.123; p = 0.736	r(10) = 0.226; p = 0.530	r(10)=−0.226; p = 0.530	r(10)=−0.050; p = 0.890	r(10) = 0.013; p = 0.972	r(10)=−0.376; p = 0.284	r(10) = 0.226; p = 0.530	r(10) = 0.140; p = 0.700

LPT: late preterm; FT: full-term.
* Significant correlation $p < 0.05$.

4.1. Level of trunk control

It was hypothesized that LPT infants would present a lower level of trunk control than FT infants. Our results indicated late preterm infants had a lower level of trunk control than FT infants over time. Furthermore, it is important to emphasize that 8 months of corrected age, while most FT infants had total trunk control (level 7), PT infants had upper lumbar trunk control (level 5). Similarly, in typically developing infants, the level of trunk control gradually emerges from 2 to 9 months of age (Butler et al., 2010), and most of these infants presented total trunk control at 8 months of age (Greco, da Costa, & Tudella, 2018; Pin et al., 2019a, 2019b, 2019c; Sato & Tudella, 2018). In addition, it can be observed that the trunk control increased with age in both groups, presenting a progressive and descending order.

This has been shown previously that LPT infants might be at risk for delays on the level of trunk control (Righetto Greco et al., 2019; Sato & Tudella, 2018). Similar results were also found in Pin et al. (2019a, 2019b) that assessed PT and FT infants from 4 to 12 months of age. The authors observed that FT infants at 6–9 months had a quick development of the level of trunk control due to the development of static and active trunk control at 9 months and reactive control at 12 months, while in preterm infants the development of static and active trunk control occurs at 12 months and reactive control at later age. The delay in the level of trunk control in LPT infants might be related to the postural stiffness patterns, an adaptation which consists of an active reduction of the degrees of freedom in the body (Fallang, Saugstad, & Hadders-Algra, 2003), low activation in muscle tone, poor head control and trunk rotation (Gorga, Stern, Ross, & Nagler, 1988; Plantinga, Perdock, & de Groot, 1997), which may negatively influence the improvement of postural and trunk control and the late acquisition of motor skills.

4.2. Reaching behaviors in LPT vs. FT infants

It was hypothesized that LPT infants would perform fewer reaching behaviors than FT infants. However, results indicated that LPT infants presented a higher number of reaches than FT infants at 8 months of corrected age. Furthermore, LPT infants presented a higher percentage of unimanual reaches in the ring position and successful grasping in the 90° of flexion position at 7 months of corrected age. One might argue that LPT had performed more reaches and grasping than the FT infants due to the timing of the study. In typically developing, reaching onset occurs around 3 months of age in FT infants (Cunha et al., 2013) and 4 months of age in LPT infants (de A. Soares et al., 2013). Thus, more sophisticated manual exploratory behaviors (e.g., rotating, waving, and transferring of objects) would be expected from 6 months of age (Lobo, Kokkoni, de Campos, & Galloway, 2014) as well as new mobility skills at 7–12 months of age to explore the environment in FT infants (Valentini, Pereira, dos S. Chiquetti, Formiga, & Linhares, 2019).

The evidence of gross motor performance provided by the AIMS might help to understand these findings. We noticed that most FT infants were more motivated to explore the toy, instead of reaching for the toy and/or move to explore the environment (e.g., most FT infants were performing reciprocal crawling; four-point kneeling to sitting or half-sitting; four-point kneeling; sitting to prone; sitting to four-point kneeling; pulling to stand with support, while a lower percentage of LPT infants presented those mobility skills). These findings corroborate with previous studies that showed that PT infants have reduced postural complexity compared to typically developing infants, resulting in limited exploration of the environment and contributing to motor delays (Dusing, Thacker, Stergiou, & Galloway, 2012; Dusing, Izzo, Thacker, & Galloway, 2014; Dusing, Thacker, & Galloway, 2016). Still, typically developing infants around 7–8 months of age may be in a transition phase to acquire complex new motor skills, as evidenced by increased trunk control in sitting posture and visual exploration (Harbourne & Stergiou, 2003).

In addition, the higher percentage of unimanual reaches in the ring position at 7 months of corrected age might be related to LPT infants having a lower trunk control level than FT infants (low thoracic control vs. upper lumbar control, respectively). Consequently, these infants may have higher trunk instability in independent sitting positions during reaching performance, using one hand for reaching objects and the contralateral one for support. That is in line with Marcinowski, Tripathi, Hsu, Westcott McCoy, and Dusing (2019), which reported that infants who sit without hand support explored objects more than those who sit with hand support. These results echo previous findings that infants used both hands more to reach objects and less for support over time (Harbourne et al., 2013). In contrast to our study, de Toledo et al. (2011) found no differences in unimanual and bimanual reaches between LPT and FT infants at 5, 6, and 7 months of age. However, the authors inferred that because infants were assessed in a trunk-supported, reclined sitting position, it might be influenced by no differences in reaching performance.

4.3. Influence of sitting positions on reaching behaviors

It was hypothesized that the two sitting positions would not influence differently reaching behaviors, and it was confirmed. We believe there were no differences between the two sitting postures (ring and 90° flexion) because the exact manual trunk support was provided for each infant. Likewise, Sato and Tudella (2018) showed no differences in reaching spatial-temporal performance between these two sitting positions when providing exact manual support to the infant's trunk. The authors inferred that the exact manual support might have minimized the effect of sitting positions and provided greater trunk stability during the reaching performance (Sato & Tudella, 2018).

In contrast to our study, Moreira da Silva et al. (2017) found differences in the reaching spatial-temporal performance between the sitting postures in a ring and at 90° of flexion in FT infants at 6 months of age, suggesting that the ring sitting position would favor more straight and smooth movements due to its larger support base. However, manual pelvic support was provided for all infants, even for those who did not have trunk control at this level (Moreira da Silva et al., 2017). Future studies should further explore the effects of sitting positions and the level of trunk control on reaching behavior.

4.4. Relationship between the level of trunk control and reaching behavior

The hypothesis of a higher level of trunk control would be associated with reaching outcomes that best facilitate exploration of the object was partially confirmed. A positive relationship was observed between the level of trunk control and vertical hands at 7 months and unimanual and bimanual reaches at 8 months only for FT infants. No differences for PT infants might stem from lower variability in the level of trunk control in this population at 6–8 months. These results suggest that level 5 (upper lumbar control) of trunk control is related to a higher percentage of reaches with vertical hands. Level 7 (full trunk control) is related to a greater percentage of reaches with one hand or both hands. In line with these results, Moreira da Silva et al. (2017) observed that FT infants with a higher level of trunk control presented fluently reaching movements, regardless of sitting positions (ring and at 90° flexion).

We believe that the acquisition of lumbar trunk control may impact infants' strategies to reach for an object. Biomechanically, lumbar control will check trunk stability for better control of the upper limbs while also allow hands-free sitting (Butler & Major, 2003). These findings echo studies showing the relationship between vertical trunk control and acquisition of gross motor milestones starting from 8 months of age (Pin et al., 2019a, 2019b, 2019c). These authors inferred that at 8 months of age, infants were able to start sitting independently, which emerged coincidently with acquisition at the lower lumbar segment or full trunk of static, active, and reactive trunk segmental control. Thus, trunk control and gross motor performance were closely related (Pin et al., 2019a, 2019b, 2019c). Thus, future research should evaluate whether interventions targeting improving trunk control might influence specific skills, such as reaching behavior, in infants at risk motor delay.

4.5. Limitations of the study

Not all infants were assessed longitudinally at 6–8 months of age, and a small sample of FT and LPT infants. Future research should explore the effects of providing different levels of trunk support and different sitting positions in a larger sample.

5. Conclusions and implications

LPT infants presented a lower level of trunk control over time. However, they presented a higher number of reaches at 8 months visit compared to FT infants. Moreover, LPT infants presented a higher percentage of unimanual reaches in the ring sitting condition and successful grasping in the 90◦ of flexion sitting condition at 7 months visit when compared to FT infants. The sitting positions did not influence differently, reaching performance when accurate support of the trunk is provided. A higher level of trunk control was related to a higher percentage of reaches with vertical hands and with one or both hands only in FT infants.

This study might provide insights for clinicians for understanding the level of trunk control, the importance of reaching behaviors for object exploration, and considering sitting positions and these behaviors as strategies for early intervention. Although LPT infants seem to perform similarly reaching behavior to FT infants related in the first months of life, it is also important to follow-up these infants at later ages, when more complex skills would emerge, and delays in motor development might be identified.

Author statement

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Appendix A. Supplementary data

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