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**Feasibility of a parent-led Premalocom crawling training protocol for preterm infants
with high risk of motor deficits**

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Abstract

Background: Very preterm birth is a risk factor for children's motor development. However, few motor interventions allow active daily practice immediately after discharge from the neonatal unit. We recently developed such an intervention (Premalocom) to improve future locomotion, motor coordination, and sensorimotor integration which is based on daily stimulation of active crawling on a mini-skateboard as soon as the infant leaves the hospital. An initial study, Premalocom1 (PL1), implemented at home exclusively by professionals for preterm infants at moderate risk of motor deficits (without major brain lesion), demonstrated excellent training feasibility and beneficial effects on infant motor development. The present study, Premalocom2 (PL2), evaluated the training feasibility of a similar intervention delivered by parents under professional supervision for premature infants at higher risk of motor deficits (major brain lesion and/or extreme prematurity). We do not present the long-term effects of the PL2 training in this article, only the results related to the training feasibility, because the study is ongoing.

Methods: Twenty-two premature infants (very preterm with major brain lesion or extreme preterm with or without brain lesion) were trained at home to crawl on a mini-skateboard (10 min/day over 8 weeks). Parents delivered the intervention under professional supervision. Video-recorded parent- and professional-led sessions were analyzed for adherence to the number of sessions, protocol compliance, and infant locomotor performance.

Results: Total PL2 adherence to the number of sessions was 70% (vs. 93% in PL1), with parental adherence of 57.2%. Lower parental adherence was associated with lower socioeconomic status ($r = 0.62$, $p = 0.002$). Parents matched professionals in PL2 protocol compliance, including session duration (90% of the prescribed 10 min), with parents eliciting higher infant locomotor velocity than professionals ($p < 0.001$). PL2 infants were able to

actively propel themselves, traveling 5.21 ± 1.94 m/day, demonstrating a crawling ability equivalent to that observed in the PL1 protocol.

Conclusion: Premalocom training is feasible when delivered at home by parents to high-risk preterm infants with support from professionals. Parents' greater ability to stimulate active crawling during training supports their central role in early intervention.

Trial Registration: NCT06027645. Retrospectively registered on August 31, 2023.

Keywords: Preterm Infants, Brain Injury, Neonatology, Neurodevelopment, Physical Activity, Early Intervention, Parental Involvement, Premalocom

1. Introduction

Very preterm birth, defined as delivery before 32 weeks of gestational age (wGA), remains a global health concern as it is a major risk factor for neurodevelopmental disorders (NDDs), especially in motor domains (1–3). While severe motor impairments like Cerebral Palsy have declined in European countries over past decades (4), more subtle motor dysfunctions are still emerging later, particularly when children start school, with the progressive appearance of developmental coordination disorders (3). Mobility is essential to human development, and any dysfunction can have considerable effects not only on motor function itself, but also across sensorimotor and cognitive domains (5,6). Therefore, in populations at risk for motor disabilities, such as very premature infants, it is particularly important to stimulate motor development as early as possible to mitigate neuromotor and psychological impairments. A growing number of publications emphasize this need, promoting: i) task-specific motor training, ii) intensive and repeated training, with daily sessions, iii) active movements in infants, and iv) parental involvement in training (7,8). In particular, the first four months following the birth of

a very preterm infant represent a “sensitive period” for stimulating motor skills and locomotion, not only because of the high plasticity of their supraspinal structures (brain and corticospinal tracts) and spinal circuits (9), but also because of the high plasticity of their rapidly growing musculoskeletal structures (10,11).

Although extensive care is provided to premature infants in neonatal intensive care units (NICUs), such as the Newborn Individualized Developmental Care and Assessment Program (12) or the Kangaroo Method with skin to skin contact (13), these infants often do not continue to benefit from intervention protocols targeting their motor skills immediately after returning home. One of the main reasons is undoubtedly the lack of specialized clinical centers offering early high-intensity motor interventions (7,14,15), and the difficulty of taking these fragile infants to such centers when they leave the hospital. One solution to this problem is to follow the recommendation of involving parents in their infant's motor training at home under the regular supervision of professionals, to allow for daily and more intensive training (8). However, involving parents in the implementation of intensive home-based protocols after discharge from the NICU also presents multiple challenges, particularly at a time when parents are often overwhelmed. In addition to enabling daily training and active movements, the protocol should be easy to implement, not too time-consuming, and it should allow clinicians to monitor the infant's performance and the parents' compliance with the intervention dose and protocol.

Such a daily home-based protocol, established on the stimulation of active quadrupedal mobility of very premature infants as soon as their discharge from the hospital, was recently developed under the name Premalocom (16). The rationale to stimulate neonatal crawling very early was based on previous studies showing that, although historically characterized as a spinal reflex,

newborn crawling demonstrates much greater complexity than a simple reflex. It is modulated by visual, olfactory, and auditory information processed supra-spinally (17–19) and appears to share neural and neuromuscular substrates with later-developing crawling and walking (20,21). Because early locomotor patterns appear to serve as precursors to mature locomotion (16,22–24), actively practicing these patterns during a period of heightened neural and bodily plasticity should strengthen and shape developing locomotor circuitry rather than merely reinforce a transient reflex. Moreover, practicing active neonatal crawling could reinforce early sensorimotor integration. Such experience may have particularly valuable benefits for infants at risk for developmental delay because crawling is a self-generated, whole-body activity that coordinates multiple muscles and joints and may therefore promote not only later locomotion but also broader motor abilities that support subsequent psychological development.

We recently tested the professionally delivered Premalocom protocol on very premature infants, at moderate risk of motor deficit (i.e. without major brain lesion), immediately after their discharge from the hospital, without involving parents. In this first study Premalocom 1 (PL1) (16), the training encouraged the premature infants to propel themselves daily on all fours on a mini-skateboard, the Crawliskate, for 5 minutes per day for 8 consecutive weeks. The Crawliskate was specifically designed to facilitate the quadrupedal prone propulsion of term-delivered and premature infants by elevating their position on the belly, with small wheels allowing the infant to move actively in any direction by pushing with all four limbs. To ensure the appropriate implementation of the training protocol and to monitor any adverse effects of the training, PL1 sessions were conducted exclusively by professionals who visited the infants' homes daily. Parents were not allowed to implement the training, even though they were present at each session (see Dumuids-Vernet et al.(16) for more details). The results of this first PL1 study showed excellent parental compliance with the daily visits by the professionals. Of the

56 programmed sessions, the Crawliskate-trained group completed an average of 52 (SD = 2) sessions (adherence around 93%). Very premature infants also demonstrated the ability to use the device. Even though infants showed great intra- and inter-individual variability in their ability to propel themselves, all trained infants could move independently forward on the Crawliskate, with an average distance covered per session of 2.35 m (SD = 0.585, range 1.07 to 3.93 m). Importantly, this early daily crawling training had beneficial effects on infants' subsequent gross motor development, particularly on the ability to crawl at 9 months corrected age (CA), as well as on their general motor and cognitive development until 12 months CA.

The PL1 study demonstrated the feasibility of the Premalocom protocol when implemented by professionals and on premature infants with a moderate risk of motor deficits, suggesting it might prove effective for infants at higher risk of motor deficits. The parents' compliance in PL1 also suggested that we could potentially entrust them to deliver the training to their infants. Consequently, in this second study, called Premalocom 2 (PL2), we investigated 1) whether Premalocom could be applied to more fragile preterm infants at higher risk of motor disorders (i.e. with major brain lesion and/or extreme prematurity), and 2) whether parents could take over the implementation of the protocol, under the supervision of professionals. To address these questions, we assessed the feasibility of the PL2 training intervention in terms of the adherence to the number of sessions, compliance to the protocol, and infant's locomotor performance. We hypothesized that parental implementation would be associated with lower adherence and compliance as well as lower infant's performance compared to professional delivery, and that more fragile infants at higher risk would show reduced locomotor performance compared with less fragile PL1 infants.

The long-term effects of this PL2 training on infant motor development are not presented in this article, as the study is still ongoing. Only the results relating to the feasibility of the training are presented.

2. Methods

2.1. Premalocom2 design

This feasibility study is part of the ongoing randomized controlled trial (NCT06027645), which investigates a home-based crawling intervention, Premalocom, primarily implemented by parents for their preterm infants at high risk of motor impairment. Infants were randomly assigned to either a Crawliskate training group, or an untrained control group. Both groups are followed until 24 months CA to assess motor and general development. The study was approved by the Ile de France 3 Ethics Committee (CPP n°3465, ANSM n°2016-A01320-51). The present article focuses exclusively on the feasibility of the Crawliskate intervention in 22 infants from the training group.

2.2. Participants

2.2.1. Infant recruitment

Infants were recruited from two NICUs offering similar care (Paris, France) between April 2021 and August 2024. The inclusion criteria were: (i) very preterm infants born between 26-32 wGA with major brain lesions identified by Transfontanellar Ultrasound (TU) (e.g., Peri-Ventricular Leukomalacia (PVL), Punctate White Matter Lesion (PWML) or Intraventricular Hemorrhage grade 3 or 4 (IVH)), or extremely preterm infants born between 24-26 wGA, with or without major brain lesions, (ii) infants discharged from the NICU and able to start home-

training between 41 and 43 wGA, (iii) infants living within the geographical area covered by the research team to allow home-based follow-up.

In the case of twins, both infants were systematically randomized into the same study arm for ethical reasons. When only one twin met the inclusion criteria, both infants were trained but only the eligible infant was included in the analysis.

The non-inclusion criteria were: (i) congenital anomalies, (ii) bronchopulmonary dysplasia with oxygen dependence beyond 36 wGA, (iii) hearing disorders as detected by routine hearing Otoacoustic Emission (OAE) or Automated Auditory Evoked Potentials (AAEP) tests, (iv) visual disorders such as retinopathy greater than stage 2, (v) limb malformations and any problem preventing the use of the Crawlskate. The neonatologists (VB, LB, AH) and the radiologist (MA) determined the eligibility of each infant for inclusion in the PL2 study. After the research team presented the protocol to the parents, they were given two weeks to consider participation before providing written informed consent.

2.2.2. Families' and infants' characteristics

Infant characteristics included sex, gestational age, birth weight and presence or not of brain injury. Brain injury status was confirmed based on an MRI performed at term equivalent age and categorized as presence or absence of major brain lesion. Parental socioeconomic status (SES) was assessed using a questionnaire covering income, education and occupation (25–27) (see Additional file 1). To ensure robustness, SES was computed using three established indices (Hollingshead score (28), Potijk method (25) and Social Positioning Index (SPI) (29)).

2.3. Intervention

2.3.1. Material

During the first home visit, the professional and the parents agreed on the room and training setup arrangement, to ensure consistency across sessions.

The experimental training setup consisted of a training mat (180 cm x 80 cm x 1.5 cm), the Crawliskate device, and video recording equipment (two GoPro Hero Session 4 cameras /wide angle, 1080p30 resolution, 60 frames per second) (Figure 1). The Crawliskate is a mini-skateboard adapted to premature and young infants, that permits a comfortable elevated positioning on the belly, with small wheels allowing the infant to move actively in any direction by pushing with all four limbs, and a system of fabric fins and straps securing the infant (see (16) for detailed description). Two Crawliskate sizes were available: size 1 (42 cm long, for infants < 5 kg), and size 2 (50 cm long, for infants > 5 kg). A temperature sensor (Metabases temperature sensor) placed inside the Crawliskate allowed accurate verification that a training session occurred (based on an increase in temperature measured by the sensor), and that the Crawliskate was not overused. Parents were provided with a standardized kit including materials, hygiene supplies, and written instructions to ensure safe and consistent implementation of the training sessions at home.

2.3.2. Training Protocol

The protocol was designed to be carried out primarily by the parents and consisted of training their infant's quadrupedal propulsion on the Crawliskate for 10 minutes per day, every day for 8 consecutive weeks. The duration of the daily session was increased to 10 minutes, compared to 5 minutes in PL1 study in order to increase the chances of a positive effect of the training on the motor development of the PL2 infants at higher risk. Physical therapists (here after referred

to as “professionals”) supported the implementation of the protocol through scheduled home visits (see below 2.3.2.2. Role of professionals in relation to parents). The time of day at which the session was performed was left to parental discretion and could change across days. Parents were asked not to feed their infant for at least one hour before the start of the session due to the prone position on the Crawliskate during training.

2.3.2.1. *Training sequence*

Typical parent-led training sequences are shown in Figure 1. An additional movie file shows this in more detail (see Additional file 2). Briefly, once the infant was secured on the Crawliskate, parents had to start the timer and initiate the training by encouraging forward propulsion. If necessary, they could assist by placing their thumb just behind the infant’s feet to provide a surface to push against, without applying forward pressure (but refer to “*section 2.4.3. Distance traveled per session*” to see how we exclude of our analyses the rare cases where parents were applying forward pressure).

If the infant became too tired during a session, parents were advised to take a break by holding the infant in their arms without removing them from the Crawliskate and then resume the session afterwards. In this case, break time was not included in the total training.

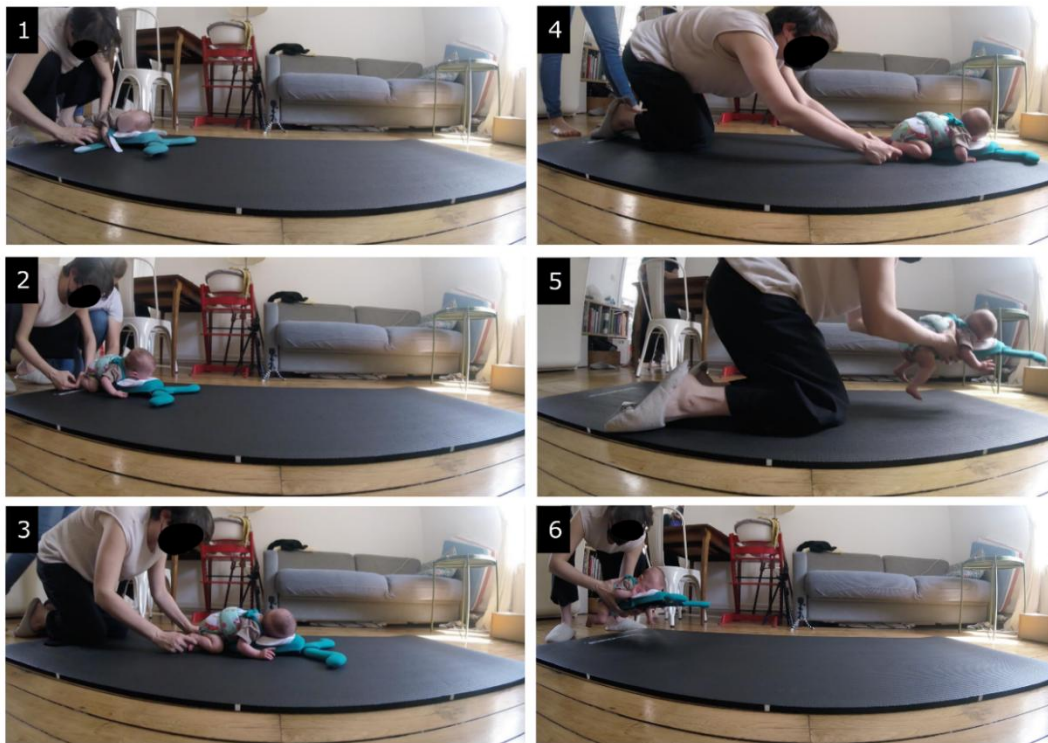
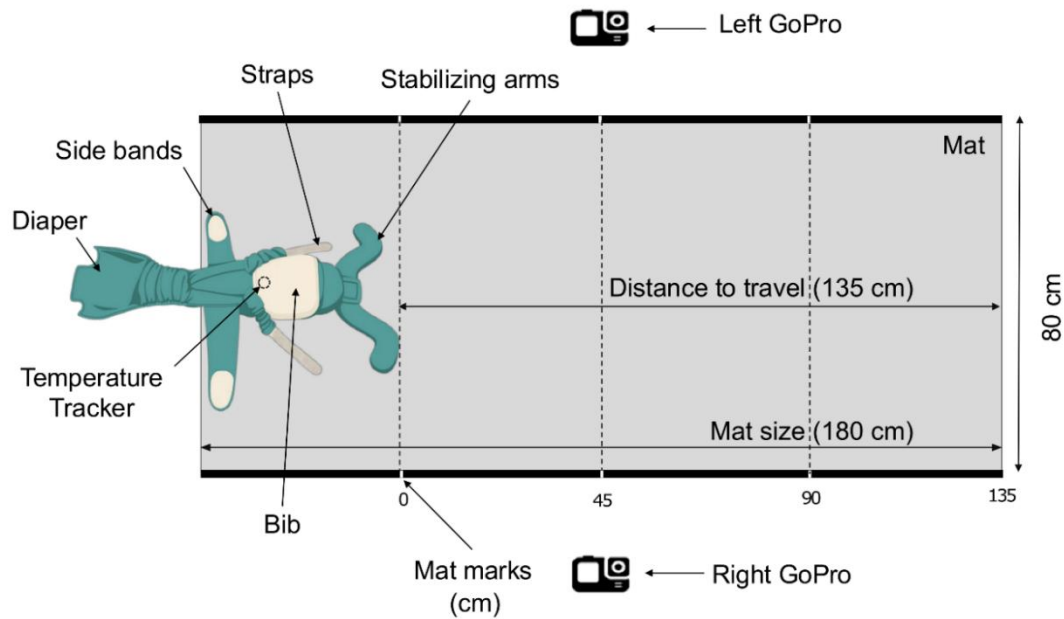


Figure 1. Experimental setup and procedure for training at home. **Top panel.** Schematic representation of the setup as installed at home before each infant training trial. The Crawliskate was positioned at the beginning of a 180 × 80 cm mat in its open configuration with a temperature tracker placed inside and a clean bib placed on top of the head rest platform. Two GoPro cameras were positioned laterally (left and right) approximately 30 cm apart on either side of the center of the mat to record the trials. Distance marks were placed along the sides of the mat (at 0, 45, and 90 cm) to allow quantification of forward displacement during subsequent video analysis. **Bottom panel.** Training sequence. (1) The parent places the infant prone on the Crawliskate while securing the straps around the infant trunk over the diaper, allowing maintenance of postural alignment during assisted forward displacement. (2) The parent checks and stabilizes that the infant is securely fastened and adjusts the straps on the Crawliskate over the diaper. (3) The parent assists forward displacement and, if needed, provides a stable support surface behind the infant's feet (without pushing), against which the infant can actively push. (4) The infant reaches the end of the mat. (5) The parent lifts the infant to reposition them at the start of the mat. (6) The infant is placed again at the beginning of the mat and will soon be ready to initiate a new traversal.

2.3.2.2. *Role of professionals in relation to parents*

Four professionals, members of the PL2 project, all specifically trained in the use of the Crawliskate and in the standardized training procedure, were responsible for monitoring parental implementation of the protocol. During the first week, professionals conducted at least three home visits, including two consecutive visits at the start of training, to allow for the demonstration of the protocol and hands-on training of the parents. From the second week onward, professionals conducted a minimum of one home session per week. During each visit, professionals took care of the training session themselves (including the video recording of their own session), collected the prior sessions data (i.e. video recordings, and data from the Crawliskate temperature sensor).

2.4. Data processing

2.4.1. Confirmation that a session occurred, prevention of potential overuse and documentation of missed sessions

All parental-led and professional-led sessions were continuously monitored throughout the intervention period using video recordings and temperature tracking data, allowing the assessment of parental and professional adherence. Data were processed weekly to allow for objective confirmation that a session occurred and to monitor for potential overuse of the device. Adherence was also monitored through regular communication with families (every two days) to track session completion and document the reason for non-completion. Reasons were grouped into two categories: parental or non-parental. Parental reasons were further classified as “lack of time”, “parental health issues” and “no explanation”. Non-parental reasons included “infants’ health problems”, “infants’ medical appointments”, “protocol constraints” and “technical issues”.

2.4.2. Adherence to the training sessions

Three indicators were computed to assess adherence:

2.4.2.1. Total adherence (TA)

TA was defined as the proportion of completed sessions (parents and professionals combined) relative to the 56 planned sessions.

2.4.2.2. Absolute parental adherence (APA)

APA was defined as the total number of training sessions delivered by parents during the intervention period.

2.4.2.3. Relative parental adherence (RPA)

RPA was defined as the proportion of training sessions delivered by parents relative to the number of sessions they were effectively expected and able to complete. Formally:

$$RPA = \frac{APA}{W_i - P_i - C_i}$$

With the term $W_i - P_i - C_i$ representing the total number of feasible sessions:

- W_i : number of days within the individual intervention window during which a session was expected (varying due to early discontinuation or due to the exact scheduling of pre- and post-intervention MRI)
- P_i : predefined minimum number of professional visits embedded in the protocol,
- C_i : number of sessions not feasible due to non-parental reasons (e.g., infant health issues).
-

2.4.3. Video processing and extraction of training quality metrics and arousal

Video recordings were analyzed offline using Windows Media Player (Microsoft Corporation, 11.2512.10.0 version) to extract the following variables:

Effective session duration (reported in minutes) was defined as the total duration during which the infant was positioned and secured on the Crawliskate, and in a position to crawl. Periods during which the infant was lifted off the mat or was asleep were excluded.

Distance travelled per session (reported in meters) was estimated using the 45-cm markers printed along the sides of the mat and the position of the Crawliskate front stabilizers (Figure 1). Each mattress run started with the stabilizers aligned to the first marker, and one 45-cm segment was counted each time a new marker was crossed (maximum three per run). A size-specific correction was applied depending on Crawliskate size. Runs in which forward movement of the trainer's hand suggested external assistance were excluded.

Locomotor velocity was defined as the distance divided by effective training duration (in meters per minute).

An **infant arousal index** was calculated based on the crying duration divided by the training duration, over the whole course of the training. A value of 0.5 (50%) indicates that the infant was in high state of excitation during 50% of the entire training duration (i.e. over the 8 weeks).

2.4.4. Parental feedback on the training protocol

In the 19 families who completed sufficient training, parental feedback was collected via a questionnaire administered by phone at 27 months CA (see Additional file 3). Satisfaction was rated on a 0-10 scale. Other items, addressing the protocol (parental stress, parental perception on the training effects, parental perspectives on clinical application and parental feedback on the use of the Crawliskate), were dichotomized (positive/negative) and expressed as percentages.

2.5. Data analysis

2.5.1. Adherence

TA, APA and RPA were described using descriptive statistics on the entire sample (N=22). RPA was used as the primary outcome to assess parental adherence, as it accounts for the number of sessions parents were effectively expected and able to complete. As such, potential determinants of RPA were explored, including SES, infant characteristics and infant arousal index.

2.5.2. Training quality

Data for infants who completed a minimum of 5 sessions with parents and 5 sessions with professionals were included in the training quality analysis (N=19).

2.5.2.1. Descriptive analysis and determinants of training duration, traveled distance and locomotor velocity

Training metrics were first computed by pooling both parent- and professional-led sessions for descriptive analysis. Training duration, travelled distance and locomotor velocity were summarized at different temporal scales, including daily values (averaged only across days on which a training session was performed), weekly averages (computed across weeks whether all sessions of the week were performed or not), or total cumulative values across the entire training period. Potential determinants of training quality were explored, including parental SES, infant characteristics and infant arousal index.

2.5.2.2. Comparison between parent-led and professional-led sessions

Next, training quality metrics were computed separately for parent-led and professional-led sessions. As professionals conducted at least three sessions during the first week and one per

week thereafter, within-infant comparisons were performed to assess whether parents achieved comparable training duration, distance, and locomotor velocity.

2.5.2.3. Comparison with the PL1 study

Finally, to estimate the impact of parental involvement, average locomotor velocity over the intervention was compared with the previous professional-only protocol (PL1(16)). The locomotor velocity was chosen over to the distance since different training durations were prescribed across protocols (i.e. 5 min/day in PL1 vs 10 min/day in PL2). As infants of the PL2 cohort were at higher risk of motor deficits, we also investigated whether average locomotor velocity was different at the beginning of the protocol relative to that of PL1, based on the first two sessions conducted by professionals during the first week of PL1 and PL2 training.

2.5.3. Statistical Analysis

All analyses were performed in MATLAB (The MathWorks, Natick, MA, USA). Data are reported as mean $\pm$ standard deviation (SD). Medians and interquartile ranges (IQR) are also reported when relevant. All statistical tests were two-tailed, and statistical significance was set at $p < 0.05$. Normality was assessed using the Lilliefors test. Parametric analyses were used when assumptions were met. Group comparisons were performed using paired or independent Student's t-tests as appropriate, whereas Wilcoxon signed-rank or Mann–Whitney U tests were used when normality assumptions were violated. Ninety-five percent confidence intervals (95% CI) of means were systematically reported. Associations between variables were assessed using Pearson correlation coefficients, with corresponding 95% CI computed using Fisher's z-transformation.

3. Results

3.1. Participants

Twenty-two infants from the intervention arm of the PL2 study were included in the present feasibility analysis (12 males, two pairs of twins). Thirteen infants had an identified brain lesion, while nine were recruited based on gestational age criteria (born before 26 wGA). Details of the infant characteristics and parental SES are summarized in Table 1.

Table 1. Sociodemographic characteristics of the 22 participants

Population characteristics (N=22)	Mean (SD) / Number (Percentage)
Sex (boys)	12 (55%)
Gestational age at birth (wGA)	27.6 (2.7)
Infants born < 26 wGA	11 (50%)
Birth weight (g)	1067 (396)
Cranial birth perimeter (cm)	25 (2.9)
No visible brain lesion	9 (41%)
IVH 3	2 (9%)
IVH 4	3 (14%)
PVLM	6 (27%)
PWML	2 (9%)
Family Socio-Economic Index*	43.4 (14.9)

CA = Corrected Age. wGA = Week of Gestation Age. IVH = Intra Ventricular Haemorrhage. PVLM = Periventricular Leukomalacia. PWML = Punctuate White Matter lesion. Percentages or standard deviation are given in parentheses. *Socioeconomic Index is calculated through Hollingshead score.

All 22 infants initiated the intervention, starting at 7.22 ± 4.80 days of the term age. Four infants discontinued the intervention before completing the full planned training period (Figure 2). One infant stopped due to intestinal surgery, and two twins stopped since one twin had inguinal surgery, resulting in the discontinuation of training for the other twin. One additional discontinuation occurred due to environmental constraints at home (bedbug infestation).

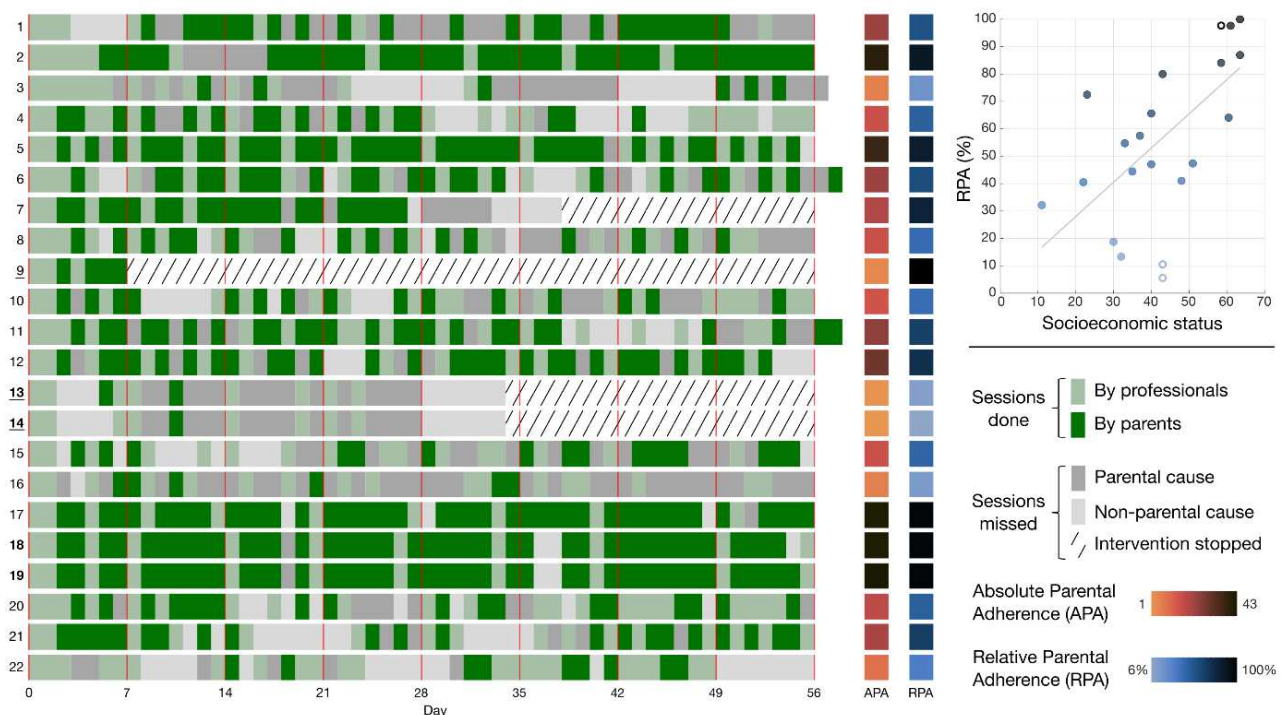


Figure 2. Daily training adherence and parental involvement across the intervention period. Left panel. Daily training sessions over the 8-week intervention (days 0–56) for each infant (rows 1–22). Green shades indicate sessions performed by parents (dark green) or by professionals (light green). Grey areas represent missed sessions due to parental (dark grey) or non-parental (light grey) causes. Hatched areas indicate periods during which the intervention was discontinued and no training sessions were requested from either parents or professionals. Red vertical lines mark weekly boundaries. Twins are indicated by bold numbers. The three infants who were excluded from training quality analysis are underlined. **Middle panel.** Individual Absolute Parental Adherence (APA; orange scale) and Relative Parental Adherence (RPA; blue scale) values for each infant. Color scales indicate the observed range. **Right panel (top).** Association between Relative Parental Adherence (RPA) and parental socioeconomic status. Each marker represents one infant; twins are displayed as open circles (rings). Two twin observations are superimposed due to identical values (S18 and S19, dark ring). The solid line indicates the linear regression fit. Dot color corresponds to RPA.

3.2. Data included in the analysis

Overall, 745 sessions were logged across 22 infants, among which 730 could be analyzed by video. As analyses focusing on training quality were conducted only in infants who completed a minimum of 5 training sessions with parents and 5 training sessions with professionals ($N = 19$), a total of 705 sessions were included to assess quality. Remarkably, parents had no problems collecting videos, as only 2.5% of the sessions completed by parents were not recorded (but were confirmed thanks to the sensor). Among the 430 videos recorded by the parents, only 1.4% (i.e. 6 sessions) were of poor quality. No instances of Crawliskate overuse by the parents were detected using temperature tracking data. Most outcome variables were complete for the entire cohort. Missing data were limited to SES indicators, with availability ranging from 91% (household income and paternal education) to 100% (all other indicators).

3.3. Implementation and adherence

Daily training delivery is illustrated in Figure 2. Considerable inter-individual variability was observed in both the frequency and temporal distribution of sessions. Overall, mean TA, reflecting the combined proportion of sessions delivered by parents and professionals, was $60.5\% \pm 25.6\%$ (corresponding to 33.86 ± 14.35 sessions out of 56 planned sessions). On average, 30% were delivered by professionals. Non-observance represents 39.5% of the sessions (6.6% for the 4 infants who stopped training, 18.5% for non-parental reasons and 14.4% for parental reasons). For parental reasons, 73% had no explanations, yet this result was not correlated with SES metrics ($r = -0.259$, $p > 0.2$). APA, defined as the total number of sessions conducted by parents during the intervention period, ranged from 1 to 42 sessions (mean $\pm$ SD = 20.18 ± 13.32). RPA, defined as the proportion of parent-delivered sessions relative to the number of sessions parents were effectively expected and able to complete,

ranged from 5.6% to 100% (mean $\pm$ SD = 57.2% $\pm$ 30.1%). Adherence data and reasons for missing sessions are summarized in Table 2.

Table 2. Adherence during the eight weeks of training and reasons for missing sessions

	N = 22	Mean (SD)
Adherence		
Total Adherence (TA)		60.5 (25.6)
Absolute Parental Adherence (APA)		20.18 (13.32)
Relative Parental Adherence (RPA)		57.2 (30.1)
Missing sessions		
Parental reasons		%
		43.8
Lack of time		26
Parental health issues		1
No explanation		73
Non parental reasons		56.2
Infants' health problems		92
Protocol constraints		4
Infant's medical appointments		3
Technical issues		1

TA (%) reflects the combined proportion of sessions delivered by parents and professionals. APA corresponds to the total number of sessions conducted by parents during the 56-day intervention period. RPA (%) is defined as the proportion of parent-delivered sessions relative to the number of sessions parents were effectively expected and able to complete.

3.4. Determinants of relative parental adherence

RPA was significantly correlated with SES based on the Hollingshead score (Figure 2, $r = 0.62$, $p = 0.002$). This effect was consistent across other SES metrics. In contrast, no significant associations were observed between RPA and infant characteristics or infant arousal index. Results are detailed in Table 3.

Table 3. RPA, daily session duration, travelled distance and locomotor velocity compared to demographic and clinical variables.

Factors associated with Relative Parental Adherence (N=22)

Variables	Test	Statistic	95% CI	p-value	Significance
SES (Hollingshead score)	Pearson	r = 0.62	[0.26; 0.82]	0.002	**
SES (SPI)	Pearson	r = 0.62	[0.28; 0.83]	0.002	**
SES (Potijk method)	Pearson	r = 0.52	[0.12; 0.77]	0.013	*
Arousal Index	Pearson	r = 0.24	[-0.20; 0.60]	0.284	ns
GA	Pearson	r = 0.28	[-0.16; 0.63]	0.199	ns
BW	Pearson	r = 0.18	[-0.26; 0.56]	0.424	ns
Sex	T-test	t = -1.09	[-0.40; 0.13]	0.289	ns
Brain lesion	T-test	t = -0.77	[-0.39; 0.18]	0.450	ns

Factors associated with Session Duration (N=19)

Variables	Test	Statistic	95% CI	p-value	Significance
Travelled Distance	Pearson	r = -0.07	[-0.51; 0.40]	0.776	ns
SES (Hollingshead score)	Pearson	r = -0.19	[-0.59; 0.29]	0.447	ns
Arousal Index	Pearson	r = -0.47	[-0.76; -0.01]	0.045	*
GA	Pearson	r = 0.02	[-0.44; 0.47]	0.926	ns
BW	Pearson	r = -0.04	[-0.48; 0.42]	0.878	ns
Sex	T-test	t = -0.79	[-1.54; 0.70]	0.439	ns
Brain lesion	T-test	t = 1.45	[-0.35; 1.83]	0.170	ns

Factors associated with Travelled Distance (N=19)

Variables	Test	Statistic	95% CI	p-value	Significance
Session Duration	Pearson	r = -0.07	[-0.51; 0.40]	0.776	ns
SES (Hollingshead score)	Pearson	r = 0.33	[-0.15; 0.68]	0.170	ns
Arousal Index	Pearson	r = 0.62	[0.23; 0.84]	0.005	**
GA	Pearson	r = 0.16	[-0.32; 0.57]	0.520	ns
BW	Pearson	r = 0.03	[-0.43; 0.47]	0.916	ns
Sex	t-test	t = -1.19	[-2.89; 0.80]	0.250	ns
Brain lesion	Mann-Whitney U test	U = 35	[-2.56; 2.28]	0.592	ns

Factors associated with Locomotor Velocity (N=19)

Variables	Test	Statistic	95% CI	p-value	Significance
SES (Hollingshead score)	Pearson	r = 0.35	[-0.12; 0.69]	0.144	ns
Arousal Index	Pearson	r = 0.72	[0.39; 0.88]	<0.001	***
GA	Pearson	r = 0.19	[-0.29; 0.59]	0.441	ns
BW	Pearson	r = 0.11	[-0.37; 0.53]	0.667	ns
Sex	t-test	t = -0.71	[-0.32; 0.16]	0.490	ns
Brain lesion	Mann-Whitney U test	U = 31	[-0.37; 0.23]	0.384	ns

SES = SocioEconomic Status; SPI = Social Positioning Index; GA = Gestational Age at birth; BW = Birth Weight; BL= Brain Lesion. Statistical analyses were performed as indicated in the table (Significant differences and tendency are in bold; * for p<0.05; ** for p<0.01; *** for p<0.001). ns: non-significant.

3.5. Training quality

3.5.1. Training metrics on parent- and professional-led sessions combined

All results regarding the 19 infants included in these analyses are presented in Table 4.

Table 4. Training quality analyses were conducted on 19 subjects.

Daily Training duration (minutes)						
	Mean (SD)	95% CI	Test	Statistic	p-value	Significance
Parents & Pros	9.01 (1.12)	[8.47; 9.56]				
Parents	8.69 (1.18)	[8.12; 9.26]				
Professionals	9.31 (1.42)	[8.63; 10]				
Parents versus Pros		[-0.07; 1.32]	t-test	t = 1.89	0.074	ns
Daily Travelled distance (meters)						
Total	5.21 (1.94)	[4.27; 6.14]				
Parents	5.62 (2.14)	[4.59; 6.66]				
Professionals	4.47 (1.95)	[3.53; 5.41]				
Parents versus Pros		[-1.79; -0.52]	t-test	t = -3.80	0.0013	**
Locomotor Velocity (meters/minutes)						
Total	0.616 (0.241)	[0.500; 0.732]				
Parents	0.690 (0.279)	[0.556; 0.824]				
Professionals	0.506 (0.239)	[0.391; 0.622]				
Parents versus Pros		[-0.27; -0.10]	t-test	t = -4.41	<0.001	***

Pros represent professionals. Results are reported through daily mean and standard deviation (SD) either in pooling parent- and professional- led sessions (Total), or separately for parent-led and professional-led sessions. A comparison between parental and professional training quality was performed (Parents/Pros) using parametric test of student. Significant differences are in bold; * p<0.05; ** p<0.01; *** p<0.001). ns: non-significant.

3.5.1.1. *Training Duration*

The average effective training daily duration was around 90% of the prescribed 10 minutes duration. This daily effective training duration showed relatively limited dispersion across infants (range: 7–11.1 minutes, Figure 3a). At the weekly level, inter-individual variability was more pronounced, reflecting differences in the number of training days completed per week rather than systematic shortening of individual sessions (Figure 3b). The total effective training duration achieved over the intervention period was 335 ± 117 minutes, corresponding to 60% of the prescribed total duration.

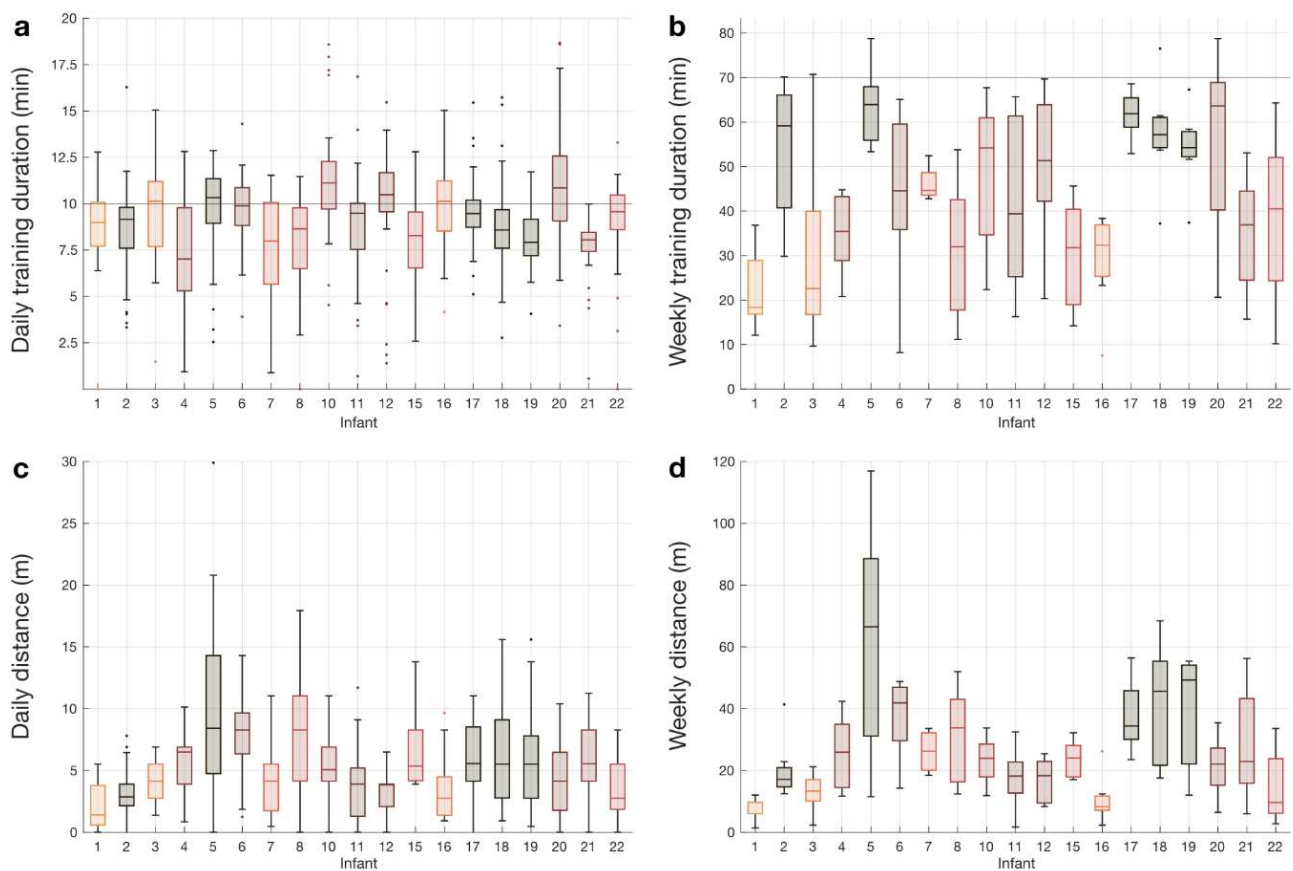
3.5.1.2. *Traveled distance*

On training days, the mean daily distance was 5.21 ± 1.94 meters. Mean daily distance ranged from 2.16 to 9.63 meters, reflecting substantial inter-individual variability in distance despite relatively homogeneous session durations (Figure 3c). Finally, weekly distance (Figure 3d) further amplified these differences, reflecting the combined effects of variability in both session frequency and daily travelled distance. On average, infants covered a total distance of 203.25 ± 115.28 meters over the intervention period.

3.5.1.3. *Locomotor velocity*

The mean distance normalized by effective training duration was 0.616 ± 0.241 m/min when averaged across days.

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513 **Figure 3. Individual variability in daily and weekly adherence and achieved training volume.** Box color
514 corresponds to Absolute Parental Adherence (APA). **(a)** Daily training duration (in minutes) for each infant across
515 the intervention period. Boxplots represent the distribution of daily values (median and interquartile range). The
516 horizontal line indicates the prescribed daily training duration. **(b)** Weekly training duration (in minutes) for each
517 infant. Boxplots summarize the distribution of weekly totals across the intervention. The horizontal line indicates
518 the prescribed weekly training duration derived from the daily target. **(c)** Daily distance covered (in meters) for
519 each infant. Boxplots represent the distribution of daily achieved distance (median and interquartile range). **(d)**
520 Weekly distance covered (in meters) for each infant. Boxplots summarize the distribution of weekly totals across
521 the intervention period.

3.5.2. Determinants of training results on parent- and professional-led sessions combined

Mean training duration was not correlated with parental SES and infant characteristics but negatively correlated with infant arousal index ($r=-0.47$, $p=0.045$) suggesting that higher average arousal levels were associated with reduced training duration. Mean daily distance travelled was not associated with average daily training duration suggesting that distance traveled did not simply reflect longer exposure to training (Figure 4a). In contrast, a significant positive association was observed between mean daily distance travelled and mean arousal levels computed across sessions for each infant ($r = 0.62$, $p = 0.005$), suggesting that higher average arousal levels were associated with greater distance travelled (Figure 4b). Similar association was observed between arousal and locomotor velocity ($r = 0.72$, $p < 0.001$). No significant associations were found between daily distance travelled or locomotor velocity and infant characteristics or parental SES. All results are detailed in Table 3.

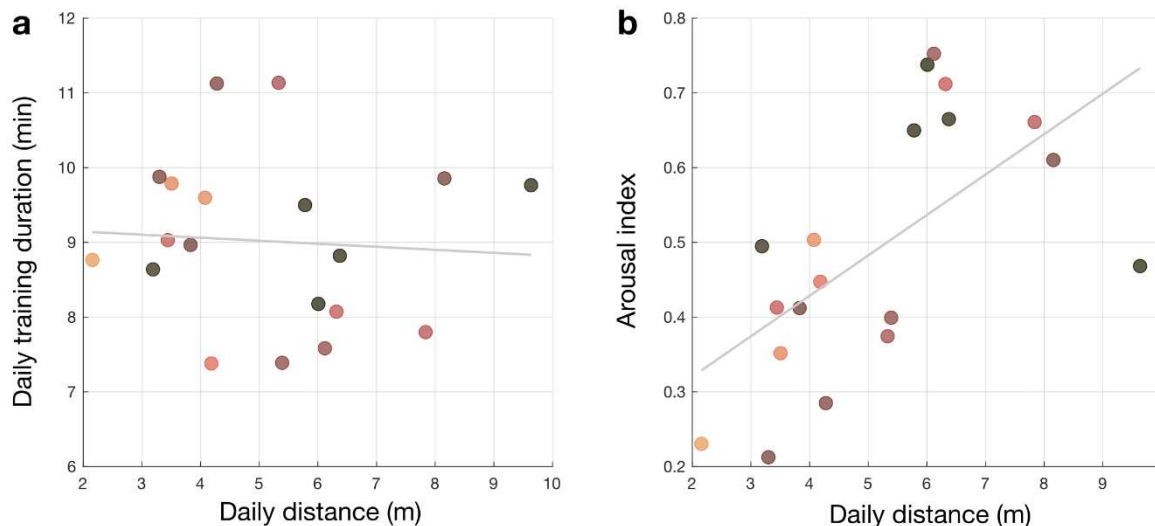


Figure 4. Associations between average daily distance, average daily training duration, and arousal. Each dot represents one infant (mean values computed across the intervention period). Dot color corresponds to Absolute Parental Adherence (APA). **(a)** Association between average daily distance covered (m) and average daily effective training duration (min). The solid line represents the linear regression fit but no significant association was observed ($r = -0.07$, $p = 0.776$). **(b)** Association between average daily distance covered (m) and mean arousal level across sessions (crying index calculated as crying duration divided by training duration). The solid line represents the linear regression fit. A significant positive association was observed ($r = 0.62$, $p = 0.005$).

3.5.3. Comparison between parents and professionals

Results regarding comparisons between parents and professionals are presented in Table 4 and Figure 5.

3.5.3.1. Training duration

No significant difference was observed between parent- and professional-led sessions in terms of average daily effective training duration (8.69 ± 1.18 min vs 9.31 ± 1.42 min, respectively; paired t-test, $p = 0.126$, Figure 5a). A positive but non-significant association was observed between mean duration achieved in parent- and professional-led sessions ($r = 0.40$, $p = 0.090$), suggesting moderate within-infant consistency across trainers (Figure 5b).

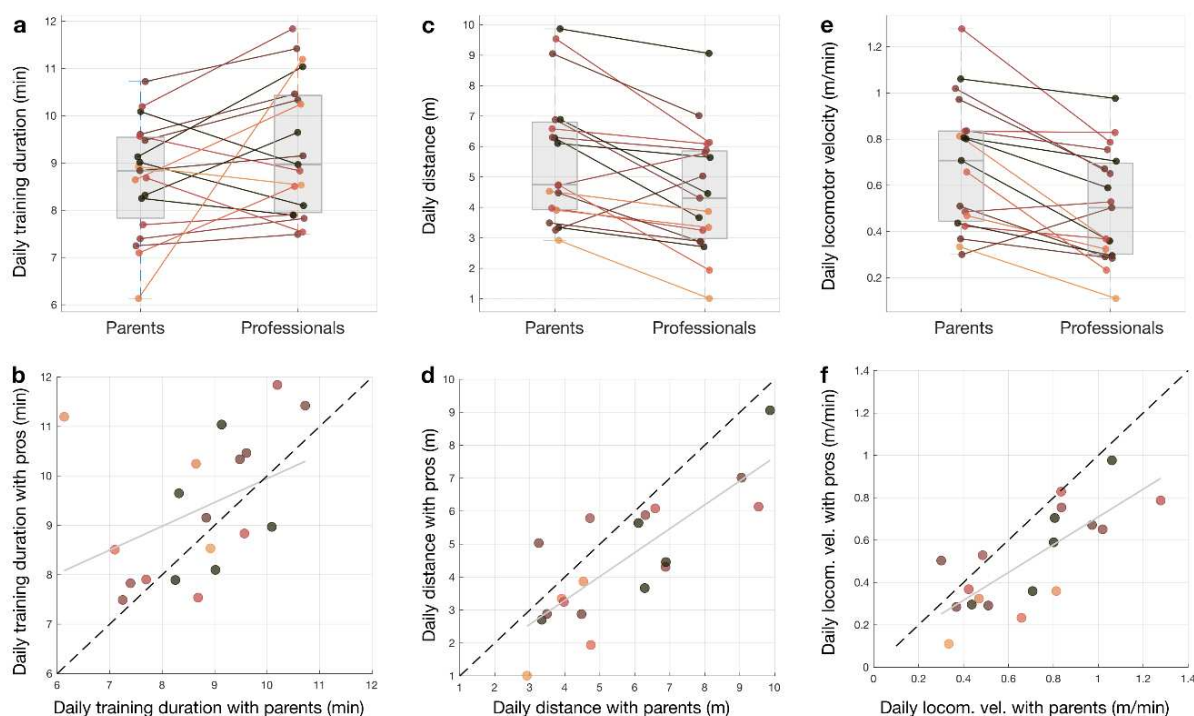
3.5.3.2. Traveled distance

Average daily distance covered during parent-led sessions was significantly greater than that achieved during professional-led sessions (5.62 ± 2.14 m vs 4.47 ± 1.95 m, respectively; paired t-test, $p = 0.0013$, Figure 5c). A strong positive correlation was observed between mean daily distance in parent- and professional-led sessions ($r = 0.80$, $p < 0.001$), indicating high within-infant consistency across trainers (Figure 5d).

3.5.3.3. Locomotor velocity

Infants exhibited a significantly higher average velocity during parent-led sessions (0.690 ± 0.279 m/min) compared to professional-led sessions (0.506 ± 0.239 m/min; paired t-test, $p < 0.001$, Figure 5e). A strong positive association was observed between velocities achieved with parents and with professionals ($r = 0.76$, $p < 0.001$), indicating that infants who moved faster under professional supervision also tended to move faster during parent-led sessions (Figure 5f).

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Figure 5. Comparison of training duration and distance traveled between parent- and professional-led sessions. Dot color corresponds to Absolute Parental Adherence (APA). In panels A, C and E, lines connect values from the same infant and boxplots represent the group distribution (median and interquartile range). In panels B, D and F, each dot represents one infant; solid lines indicate linear regression fits and dashed lines indicate the identity line ($y = x$), corresponding to equal distance in parent- and professional-led sessions. **(a)** Average daily training duration (min) in parent- and professional-led sessions. **(b)** Association between average daily training duration achieved with parents (x-axis) and professionals (y-axis). **(c)** Average daily distance covered (m) in parent- and professional-led sessions. **(d)** Association between average daily distance achieved with parents (x-axis) and professionals (y-axis). **(e)** Average locomotor velocity (m/min) in parent- and professional-led sessions. **(f)** Association between average locomotor velocity achieved with parents (x-axis) and professionals (y-axis).

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584 3.5.4. Comparisons with the PL1 study

585 No significant difference was found when comparing the mean initial locomotor velocity over
586 the first two consecutive PL2 and PL1 training sessions led by professionals (t-test for
587 independent samples, $p = 0.488$; Figure 6a; Table 5) as well as for mean locomotor velocity
588 over the entire training period between PL1 (in which all training sessions were conducted under
589 exclusive professional supervision (16)) and PL2 (current protocol)(independent samples t-test,
590 $p = 0.214$; Figure 6b; Table 5).

Table 5. Locomotor velocity of PL2 infants in comparison with PL1 infants.

Initial locomotor velocity with pros (m/min)						
Protocol	Number of subjects	Mean (SD)	Statistic	95% CI	p-value	Significance
PL1	15	0.386 (0.210)		[0.270; 0.503]		
PL2	19	0.329 (0.264)		[0.202; 0.456]		
Comparison		Mean diff				
PL1 versus PL2		0.06	t = 0.70	[-0.11; 0.22]	0.488	ns
Average locomotor velocity (m/min)						
Protocol	Number of subjects	Mean (SD)	Statistic	95% CI	p-value	Significance
PL1	15	0.514 (0.228)		[0.388; 0.640]		
PL2	19	0.616 (0.241)		[0.500; 0.732]		
Comparison		Mean diff				
PL1 versus PL2		-0.10	t = -1.27	[-0.27; 0.06]	0.214	ns

Results are given through mean and standard deviation, statistical analysis was performed with t-test for independent sample (Significant differences and tendency are in bold; * for $p < 0.05$; ** for $p < 0.01$; *** for $p < 0.001$). Ns: non-significant.

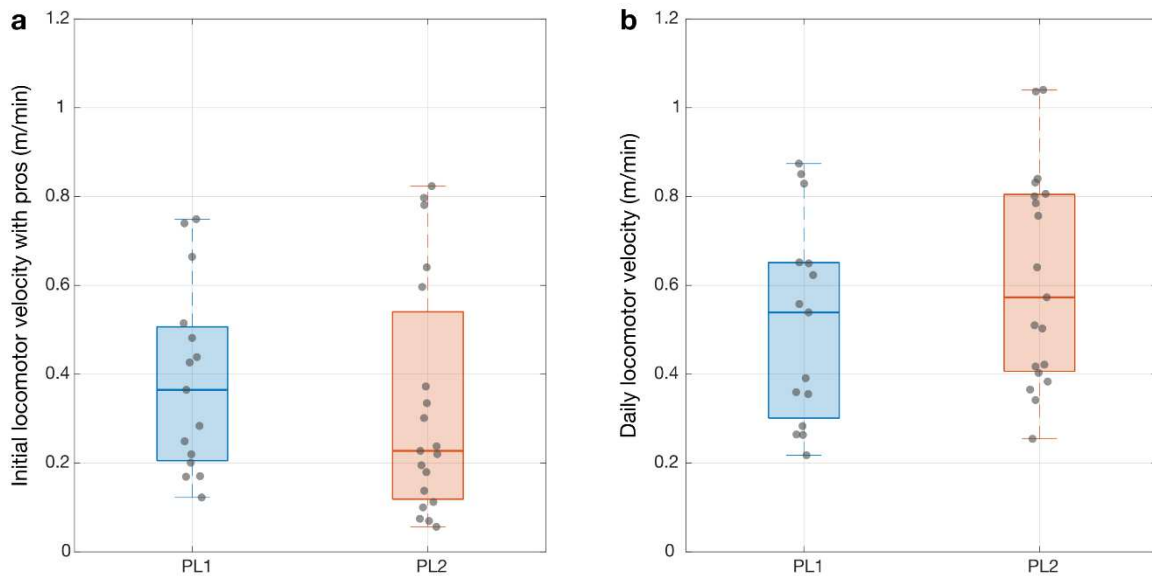


Figure 6. Comparison of average locomotor velocity between PL1 and PL2 protocols. PL1 corresponds to the previously published protocol (Dumuids-Vernet et al., 2023), in which all sessions were supervised exclusively by professionals. PL2 corresponds to the present cohort. Performance was defined as average locomotor velocity, calculated as distance covered divided by training duration (m/min). Boxplots represent the distribution (median and interquartile range), and dots indicate individual infant values. **(a)** Initial locomotor velocity (m/min) for the first two training sessions conducted by professionals during the first week of training in PL1 and PL2 protocols. **(b)** Average locomotor velocity (m/min) for all the 8 weeks of training between PL1 and PL2.

3.5.5. Parental feedback

Parental feedback was obtained from 16 of the 19 eligible families. Overall, parents reported high satisfaction with the intervention ($8.3 \pm 1.6/10$), despite initial stress that decreased as sessions progressed. Although infants' crying was sometimes important, parents noted that infants could be easily calmed. Importantly, more than half perceived that the training enhanced parents-infants or sibling interactions. While all parents rejected the idea of reducing the number of planned professional home visits (around one per week), many were not in favor of increasing them. Similarly, although nearly half perceived the daily 10-minutes dose as too long, more than half of the families reported that they would have complied with an additional month if it had been requested. Finally, parents were mostly satisfied (around 80% to 100%) with the use of the Crawliskate. Detailed results of the satisfaction questionnaire are reported in Table 6.

Table 6. Parental feedback on the protocol (N=16).

Parental Stress

Items	Statement	Agreement (%)	Disagreement (%)
B2	feel stress during the first session at home	69%	31%
B3	gain confidence as sessions progressed	94%	6%
B6	feel stress during the 2 months of training	44%	56%

Parental perception on training effects on their infant

Items	Statement	Agreement (%)	Disagreement (%)
B9-B10 B20-B23 C1-C7	no adverse effect feeding routine, security, set up	62.5-100%	37.5-0%
B12	excessive crying	68.8%	31.2%
B15	excessive tiredness	50%	50%
B13-14	easy to calm (breaks, after session)	75-87.5%	25-12.5%
B11	increase interaction with parents/siblings	56%	44%

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624 **Parental perspectives on clinical application**

Items	Statement	Agreement (%)	Disagreement (%)
B7	less professionals home visits		100%
B8	more professionals home visits	37.5%	62.5%
B16	protocol perceived too long	44%	56%
B17	increase of training duration	66%	34%
B24	postpone the start of training	37.5%	62.5%
B25-26	continuation of training beyond 2 months	62.5%	37.5%

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626 **Parental feedback on the use of the Crawliskate**

Items	Statement	Agreement (%)	Disagreement (%)
C21	efforts appropriate for infants' age	50%	50%

Responses were recorded through 4-point Likert Scale. Scale of items B: 1 = yes, 2 = a little, 3 = not really and 4 = no. Scale of items C :1 = strongly disagree, 2 = rather disagree, 3 = rather agree and 4 = strongly agree. Results are expressed in percentages of agreement or disagreement responses. "Agreement" is a combination of positive responses: items B ("yes" and "a little") and items C ("strongly agree" and "rather agree"). "Disagreement" is a combination of negative responses: items B ("no" and "not really") and items C ("strongly disagree" and "rather disagree").

627 **4. Discussion**

628 The main purpose of this study was to determine whether preterm infants at high risk for motor
629 deficits could participate in the Premalocom crawling training intervention and whether parents
630 could take over this training under professional supervision. The feasibility of a similar protocol
631 had already been demonstrated in preterm infants at moderate risk who were trained exclusively
632 by professionals (PL1 study). As expected, parental implementation was associated with lower
633 adherence compared to the PL1 study. However, in contrast to our hypotheses, parents showed
634 excellent compliance with the protocol and were even better than professionals at eliciting
635 active crawling in their infant. Moreover, PL2 infants demonstrated a crawling ability
636 equivalent to that observed in the PL1 protocol from the start of the intervention.

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Adherence to the number of sessions

Despite the clinical fragility of the infants, only a small proportion (4 out of 22, i.e. 18%) discontinued the intervention for reasons beyond parents' control. This result is similar to that obtained in the PL1 study (12%; 2 out of 17) and falls within the range of results obtained in other similar intervention studies (8% (30) to 22% (31)). Total adherence (TA) reached approximately 60 % of the planned 56 sessions and increased to around 70% when excluding early dropouts.

This TA is lower in comparison to the previous professional-led implementation (PL1), in which it reached 93% when excluding early dropouts. This difference most likely reflects the additional burden placed on PL2 parents conducting sessions independently. Raghupathy and colleagues highlighted the importance of considering parental adherence barriers, which may be linked to parents' lack of understanding of the training exercises, fear of handling their infant, mental load, fatigue, and time constraints (32). However, in this study, most of the reasons for parental missed sessions were not identified (73%) despite regular communication with the families. This lack of explanation was not correlated with the SES, suggesting that these barriers may be broadly shared across families. A major challenge lies in balancing adherence monitoring, reminders to perform the sessions, and parental burden, as frequent reminders may be perceived as intrusive. Future approaches should aim to facilitate monitoring while remaining acceptable and user-friendly for families (e.g., mobile app to track missing sessions, progress and enhance motivation). Importantly, the difference in TA between PL1 and PL2 could also be linked to the greater clinical vulnerability of the PL2 population (11/22 infants born before 26 wGA vs 1/15 in PL1 and 13/22 infants with major brain lesion vs 0/15 in PL1). This hypothesis is supported by the fact that approximately 56% of total missed sessions were due to factors beyond the parents' control, the majority of which (95% of cases) were related to infant's health.

As professionals conducted scheduled sessions and could compensate when needed, TA does not fully reflect parental engagement. We therefore computed a Relative Parental Adherence (RPA) index, defined as the proportion of sessions completed by parents among the feasible ones. On average, 57.2% of feasible sessions were completed by parents. While RPA was not associated with infant characteristics, it was strongly correlated with SES, with families of lower SES completing a lower proportion of sessions. This is in line with the literature showing that parents with low SES have a higher tendency to miss their infant's medical appointments, and that low parental SES is associated with poorer infant growth, more complications, and fewer environmental stimuli (33–35). To increase parental adherence, it could be advisable to reduce the number of sessions from 7 to 5-6 per week while increasing the total duration of the protocol or increasing the session time per day (see previous recommendations (8,11)). Another solution could be to increase professional visits. However, even if all parents rejected the idea of reducing the number of planned professional home visits (around one per week), many were not in favor of increasing them. The optimal dose of professional intervention in such a hybrid implementation remains to be established in clinical routine.

Parents compliance with the tasks

Overall, the average effective daily training duration was around 90% of the prescribed duration and did not differ significantly between parent- and professional-led sessions, suggesting that variability reflected environmental or infant-related factors rather than how sessions were conducted.

Infants' compliance with the task

Despite their vulnerability, all infants were able to propel themselves. Out of the 19 infants included in this analysis, the average distance traversed per session ranged between 2.16 and

9.63 meters. Furthermore, mean distance per session was strongly correlated with delivery agents. Finally, it was not correlated with daily training duration, suggesting that propulsion ability was not related to the amount of exposure, but positively associated with infant general behavioral state (averaged arousal). This is in line with previous studies, showing that highly aroused infants perform higher numbers of steps and propel themselves further (17,36–38) , although future work should further investigate the factors underlying inter-individual difference in baseline arousal levels.

Surprisingly, infants' performance on the task was higher with parents than with professionals. Indeed, mean travelled distance, but also mean locomotor velocity, were significantly higher under parent-led sessions. This result is not due to any overuse of the Crawliskate, as controlled via the temperature sensor, nor to parents pushing on their infant's feet, as we excluded from our analyses the few video clips in which we observed this behavior. This result is not due either to different arousal states during parental versus professional led session as there was no significant difference in arousal for each type of session ($p = 0.224$). This phenomenon could be explained by the fact that parents might have provided more encouragement to their infants to crawl than professionals. Furthermore, even for an equivalent number of encouragements, infants could have been stimulated more by their parents' voice. Other parental factors could act as a stimulating. For instance, in a previous study of typically developing newborns, maternal odor increased infants' propulsion efficiency on the Crawliskate, with newborns moving greater distances although performing fewer locomotor movements (19). It will be interesting in the future to perform more detailed analyses of interaction patterns during training to clarify the mechanisms underlying the observed effect.

To further estimate the ability of high-risk infants to perform the task under the intervention conditions, we compared PL2 infants' locomotor velocity with the velocity of PL1 infants, who were moderate-risk infants, exclusively trained by professionals. In contrast to our hypotheses,

infants in the present study achieved similar crawling velocities than those in the PL1 study whether at the beginning of training (comparing the first two PL2 and PL1 sessions led by professionals) or over the entire training period. This result highlights that even premature infants with higher fragility are able to move on the Crawliskate and plaid in favor of starting Premalocom intervention as soon as premature infants leave the hospital. It will be interesting in the future to perform more detailed longitudinal analyses, including a finer characterization of the evolution of movement patterns (e.g., 3D crawling kinematics before and after training) in order to follow the evolution of crawling efficiency.

Limitations of the study

The small sample size limits the generalization of our results, although it reflects the complexity of recruiting a population that is inherently so vulnerable(39). Expanding to more NICU centers could allow for a larger sample size. Another significant limitation concerns the evaluation of parents' satisfaction with the protocol, which was assessed retrospectively at 27 months CA. It would have been better to collect these data at the end of the training and/or within professional home visits using standardized measures, especially for stress level (40–42). However, it was challenging to add other tasks to the parents during the training or shortly after. An important recommendation is to use digital tools to measure stress, enhance motivation, provide advice and collect more data (39,43–46).

5. Conclusion

Our results highlight the feasibility of early crawling training led by parents in premature infants at high risk of motor deficits. These findings are especially encouraging for the future implementation of the Premalocom protocol in clinical practice. The main message of our study

is that although parents showed lower adherence to the number of sessions compared to the professionally led PL1 protocol, this was balanced by their greater ability than professionals to elicit active propulsion of their infants during training. However, in addition to video recording, regular professional follow-up remains essential to monitor parents' compliance with the sessions and to reinforce their motivation.

Declarations

- **List of abbreviations**

AAEP: Automated Auditory Evoked Potentials

APA: Absolute Parental Adherence

CA: Corrected Age

CI: Confidence Interval

IVH: Intraventricular Haemorrhage

IQR: interquartile ranges

MRI: Magnetic Resonance Imaging

NDDs: Neurodevelopmental Disorders

NICU: Neonatal Intensive Care Unit

OAE: Otoacoustic Emission

PL1: Premalocom 1

PL2: Premalocom 2

PVLM: Peri-Ventricular Leukomalacia

PWML: Punctuate White Matter Lesion

RPA: Relative Parental Adherence

SD: Standard Deviation

SES: SocioEconomic Status

763 TA: Total Adherence

764 TU: Transfontanellar Ultrasound

765 wGA: week of gestational age

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767 • **Ethics approval and consent to participate**

768 All the authors confirm that the study was conducted in accordance with the principles of the
769 Declaration of Helsinki. The study was approved by the Ile de France 3 Ethics Committee for
770 the Protection of Persons (CPP n°3465, ANSM n°2016-A01320-51). Written informed consent
771 was obtained from the parents or legal guardians of all participating children in the study.

772 • **Consent for publication**

773 Written consent has been obtained from the individuals and/or their legal guardians for the
774 publication of the manuscript.

775

776 • **Availability of data and materials**

777 The datasets generated and/or analysed during the current study are available from the
778 corresponding author on reasonable request.

779

780 • **Competing interests**

781 The authors declare that they have no competing interests.

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• **Authors' contributions**

MBR*, JD, VB, DIA: conception and design of the study

VB*, AH, LB: NICU preemies recruitment & acquisition of clinical characteristics data

MA*, VB, LB, JD: UT and IRM brain lesion data

LG*, EH, MVD, ALF: training supervision and training data acquisition

EH*, MBR, LG: analysis and interpretation of data

EH*, MBR*, LG drafted the manuscript

JD, ST, VH, JP, DIA, SN, CT, FG critically revised the manuscript.

All authors approved the final version before submission.

*The asterisk indicates the primary contributor

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• **Authors' information (optional)**

LG and VB, first authors, contribute equally. MBR and EH, last authors, contribute equally.

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964 **Additional files**

965

966 **Additional file 1.pdf: SocioEconomic Questionnaire.** Parental questionnaire to collect socio
967 economic information.

968

969 **Additional file 2.mov: Home Crawli training video.** Video of a premature boy on the
970 Crawliskate during a parent-led training session at home. The father positions the infant, helps
971 by repositioning his feet and hands on the mattress during crawling, and returns the infant to
972 the initial position when the end of the mat is reached. When repositioning the feet, the parent
973 never pushes the infant forward but may place his hands behind the infant's feet to provide a
974 stable support surface allowing him to propel himself.

975

976 **Additional file 3.pdf: Parental Feedback Questionnaire.** Parental questionnaire collected at
977 27 months of corrected age to gather parents' feedback on the training they performed at home.

978

Supplementary Files

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