

# Physiotherapy-led sensory-motor stimulation promotes growth in preterm infants: a randomised controlled trial

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**Abstract:** Preterm infants admitted to neonatal intensive care units are exposed to environments that differ substantially from the intrauterine setting, with limited opportunities for positive sensory input. This randomised controlled trial examined whether a physiotherapy-led sensory–motor stimulation program could improve early growth outcomes among clinically stable preterm infants in a Malaysian NICU. Eighty-four infants born between 30 and 34 weeks’ gestation (birth weight 1.3–1.8 kg) were randomly assigned to receive either a combined massage therapy and kinaesthetic stimulation protocol (MT + KS) or kinaesthetic stimulation alone (KS). Mothers were trained and supervised by physiotherapists to deliver three daily sessions until discharge at a target weight of 1.8 kg. Average daily weight gain (ADWG) was the primary outcome, while study weight gain (StWG) and length of hospital stay (LOS) were secondary outcomes. Infants in the MT + KS group demonstrated higher ADWG compared with the KS-only group (mean difference +7.7 g/day,  $p=0.024$ ), exceeding the predefined minimal clinically important difference of 5 g/day. Differences in StWG and LOS did not reach statistical significance, although both outcomes favoured the intervention group. No adverse events were observed, and caregiver adherence to the protocol was high. In this setting, a physiotherapy-supervised, mother-assisted MT + KS program was safe, feasible, and associated with improved growth velocity. The findings support incorporating structured sensory–motor stimulation into routine NICU care, particularly in resource-limited contexts.

**Keywords:** Preterm infants; Sensory–motor stimulation; Massage therapy; Neuroplasticity; Physiotherapy.

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## 1.0 INTRODUCTION

Preterm birth occurs during late gestation, a period marked by rapid and ongoing brain maturation. When infants are born early and admitted to the neonatal intensive care unit, this developmental phase continues in a clinical environment that differs substantially from the intrauterine setting. In the NICU, preterm infants are frequently exposed to repeated handling, bright lighting, alarms, and routine medical procedures, while opportunities for positive, developmentally supportive sensory input may be limited. Over time, this pattern of exposure may influence early physiological regulation and neurodevelopmental maturation. In response, developmental care strategies in NICUs increasingly focus on providing structured sensory–motor experiences that support physiological stability and early neurodevelopment in preterm infants ([Lockridge, 2018](#)).

Massage therapy (MT) and tactile kinesthetic stimulation (KS) have been shown to support somatic growth and early neurophysiological development in preterm infants ([Diego et al., 2005](#); [Elmoneim et al., 2021](#); [Field et al., 1986](#)). Controlled tactile stimulation has also been associated with increased vagal activity in preterm infants, which may contribute to improved physiological regulation and weight gain ([Diego et al., 2005, 2014](#)). This parasympathetic response may contribute to downstream effects, including improved gastric motility, modulation of insulin-like growth factor-1 levels, and subsequent weight gain ([Elmoneim et al., 2021](#); [Field et al., 1986](#)). Previous reviews report consistent improvements in weight gain, behavioural organisation, and sleep regulation among preterm infants exposed to structured MT or KS protocols ([Mrlijak et al., 2022](#)). However, the field remains divided into the safest and the most effective delivery methods. Early studies used oil-based massage in prone or mixed positions, reporting variable results and occasional complications such as apnea or infection ([Arora et al., 2005](#)). Conversely, later trials without oil demonstrated comparable or superior growth effects, suggesting that mechanosensory input, rather than topical absorption, drives physiological responses ([Elmoneim et al., 2021](#); [Kulkarni et al., 2010](#)).

However, limitations remain in the application of these protocols within routine NICU care. First, many massage and tactile-kinesthetic stimulation protocols have primarily been conducted in controlled research settings rather than integrated clinical practice, and often lack the level of standardisation and monitoring required for routine neonatal intensive care implementation ([Álvarez](#)

[et al., 2017](#); [Elmoneim et al., 2021](#); [Field et al., 1986](#)). Second, relatively few interventions have been designed and supervised by physiotherapists, despite their expertise in motor control, sensory modulation, and caregiver training ([Montaseri et al., 2020](#); [Yoanita et al., 2021](#)). In addition, several earlier protocols incorporated prone or mixed positioning during massage sessions, which may increase the risk of respiratory instability or aspiration in medically vulnerable preterm infants ([Diego et al., 2005](#); [Taheri et al., 2018](#)). Consequently, contemporary neonatal care practices increasingly favour supine positioning to support physiological stability and safety during routine handling ([Prescott et al., 2024](#)).

The present study aimed to evaluate the effectiveness of a physiotherapy-led, oil-free, supine-only combined massage therapy and kinesthetic stimulation (MT + KS) protocol in clinically stable preterm infants in a Malaysian neonatal intensive care unit. It was hypothesised that repeated tactile proprioceptive stimulation would enhance growth trajectories, particularly average daily weight gain (ADWG), through vagal activation and IGF-1–mediated anabolic mechanisms, reflecting a broader effect on neuroplastic growth. Physiotherapy-supervised sensorimotor programs have the potential to achieve clinically meaningful improvements in growth and represent a practical, neuroprotective strategy for resource-constrained neonatal settings.

This study aimed to determine the effectiveness of a combined massage therapy and kinesthetic stimulation (MT + KS) protocol on growth and hospitalisation outcomes among preterm infants in a Malaysian neonatal intensive care unit. Specifically, the objectives were as follows: (1) to compare the Average Daily Weight Gain (ADWG), Study Weight Gain (StWG), and Length of Stay (LOS) between the MT + KS and KS-only groups; (2) to evaluate the safety, tolerability, and adherence associated with the intervention; and (3) to assess the feasibility of physiotherapist-supervised, mother-assisted implementation within routine neonatal care.

## 2.0 MATERIALS AND METHODS

### 2.1 Study design and setting

A randomised controlled trial was conducted in the Neonatal Intensive Care Unit (NICU) of Sabah Women's and Children's Hospital (HWKKS), Kota Kinabalu, Malaysia, between October 2023 and October 2024. This study compared the effects of combined massage

therapy and kinesthetic stimulation (MT + KS) with kinesthetic stimulation alone on the growth outcomes of preterm infants. The outcome assessor was blinded to the group allocation, and the trial adhered to the Consolidated Standards of Reporting Trials (CONSORT) guidelines.

## **2.2 Participants**

### ***Inclusion criteria***

A total of 360 preterm infants admitted to the Neonatal Intensive Care Unit (NICU) of Sabah Women's and Children's Hospital (SWACH) were screened for eligibility. Eligible infants were preterm neonates born between 30 and 34 weeks of gestation with a birth weight between 1.30 and 1.80 kg and Malaysian parentage. Only clinically stable infants breathing room air, free from congenital anomalies, sepsis, oxygen dependence, or neurological complications, who had achieved full enteral feeding in accordance with the SWACH NICU protocol, were included. All infants were awaiting weight gain to the standard 1.8 kg discharge threshold. Written informed consent was obtained from the parents or primary caregivers before enrolment.

### ***Exclusion criteria***

Infants were excluded if they exhibited hemodynamic instability, major congenital malformations, or musculoskeletal abnormalities such as bilateral hip dysplasia or other congenital joint deformities. Additional exclusion criteria were applied to infants with medical conditions known to impair normal weight gain, including congenital heart disease, chronic lung disease, and gastrointestinal surgical conditions. Infants with positive maternal or neonatal screening for syphilis or HIV, skin disorders, open wounds, or significant birth complications, such as shoulder dystocia, were also excluded from the study. Only infants who met all medical suitability requirements were included in the randomisation stage.

### ***Sample size calculation***

The sample size was calculated using the statistical formula proposed by Dupont and Plummer ([1990](#)) to compare two independent means. This ensured adequate power to detect clinically meaningful differences in weight gain between the intervention and the control groups. The calculation parameters included a 95% confidence level ( $Z_{\alpha/2} = 1.96$ ), 80% statistical power ( $Z_{\beta} = 0.84$ ), a standard deviation ( $\sigma$ ) of 536.2 g derived from Álvarez et al. ([2017](#)), and a minimum detectable difference ( $d$ ) of 350 g in mean weight gain. Based on these inputs, the required sample size was approximately 36.84 participants per group, which was

rounded up to 37 for practical implementation. To enhance the study's robustness and account for potential attrition due to medical exclusion or early discharge, a 10% dropout rate was anticipated. Therefore, the total sample size was increased from 74 to 82 to account for potential attrition. For ease of block randomisation and balanced group allocation, the final sample size was rounded to 84 participants, arranged in blocks of 10 (five intervention and five control assignments per block). This adjustment improved statistical reliability and ensured balanced comparisons between the two study arms.

### ***Blinding***

A single-blind design was used to minimise assessment bias. An independent researcher, blinded to group allocation, conducted all outcome assessments, including measurements of weight gain and length of hospital stay. As the intervention required direct handling, the blinding of the therapist, caregivers, and parents was not feasible. Nevertheless, they underwent standardised training and maintained intervention logs to ensure consistent adherence to the protocol. The outcome assessors were not given access to treatment records or group information. The data analyst was blinded to the coded datasets used in statistical analysis. These measures ensured objectivity and strengthened the internal validity of this study.

### ***Randomisation and allocation***

Following eligibility screening, block randomisation was used to maintain equal group allocation throughout the study period and to minimise potential imbalance in participant recruitment over time. An independent researcher, who was not involved in recruitment, intervention, or outcome assessment, generated the randomisation sequence using a validated computer-based tool. In total, 84 allocations were arranged in randomly ordered blocks to ensure balanced assignment between the two study groups.

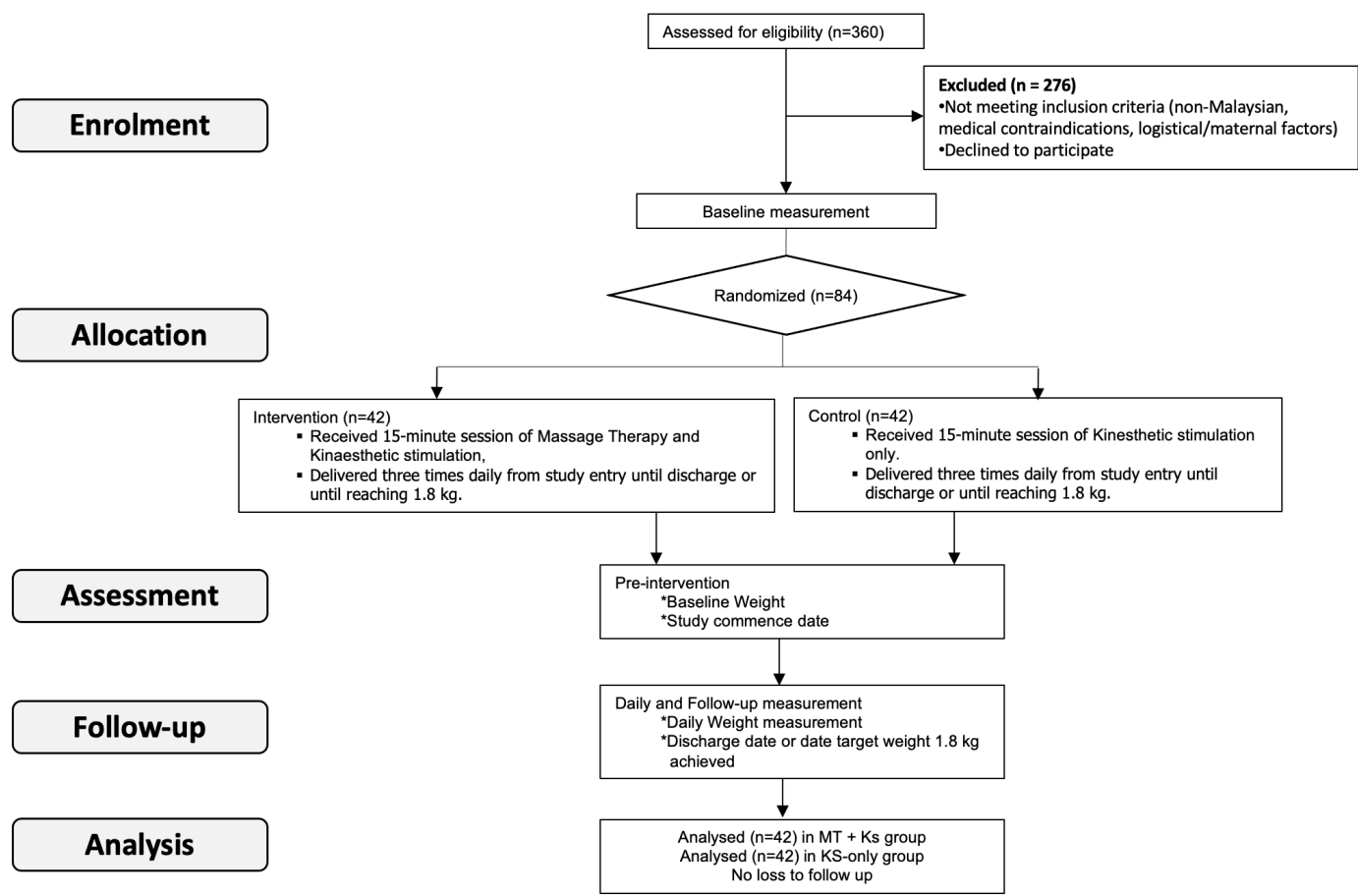
Each group assignment was placed in a sealed, double-layered, opaque envelope, sequentially numbered, and stored securely. Envelopes were opened only after enrolment and completion of baseline data collection to preserve allocation concealment. This process prevented selection bias and strengthened the trial's internal validity. Participants in the intervention group received a combined massage therapy (MT) and kinesthetic stimulation (KS) protocol, whereas the control group received KS alone. Both interventions were administered for 15 minutes, three times daily, by a trained physiotherapist, parent, or caregiver.

Recruitment and randomisation continued until the target sample size of 84 participants was reached, as determined by a sample size calculation.

**Participant**

Eligible participants were preterm infants admitted to the SWACH NICU and referred for physiotherapy. Among the 360 infants screened, exclusions included: 100 non-Malaysian nationality, 10 parental refusal, 156 maternal or logistical reasons, and 10 medical contraindications, yielding a final sample of 84 infants (**Figure 1**). Infants were randomised in a 1:1 allocation using a computer-generated block randomisation sequence prepared by

an independent researcher. Allocation concealment was ensured by using sealed, opaque, sequentially numbered envelopes that were opened only after baseline assessments. A total of 42 infants were assigned to the massage therapy plus kinesthetic stimulation (MT + KS) group, and 42 to the kinesthetic stimulation–only (KS-only) control group. All infants completed their assigned interventions and outcome assessments, and no participants were lost to follow-up, allowing all 84 randomised infants to be included in the final analysis, as reflected in the CONSORT flow diagram (**Figure 1**).



**Figure 1.** CONSORT flow diagram of preterm infants recruited for the study

**Anthropometric measurements**

Infant body weight was recorded while the neonate was fully undressed. Each measurement was taken twice if the readings were identical, or three times if any discrepancy occurred, and the average value was used. A calibrated baby scale (Seca®, Germany) with a precision of 10 g was used for all the weight assessments. Thigh circumference was measured by a

trained therapist using a non-stretchable measuring tape (0–150 cm; 0.01 cm divisions). With the infant’s left knee fully extended and the foot in a neutral position, a point 6 cm above the patella was marked as the mid-thigh reference. Girth was recorded at this landmark at baseline and discharge using a standardised technique applied uniformly across all participants, and

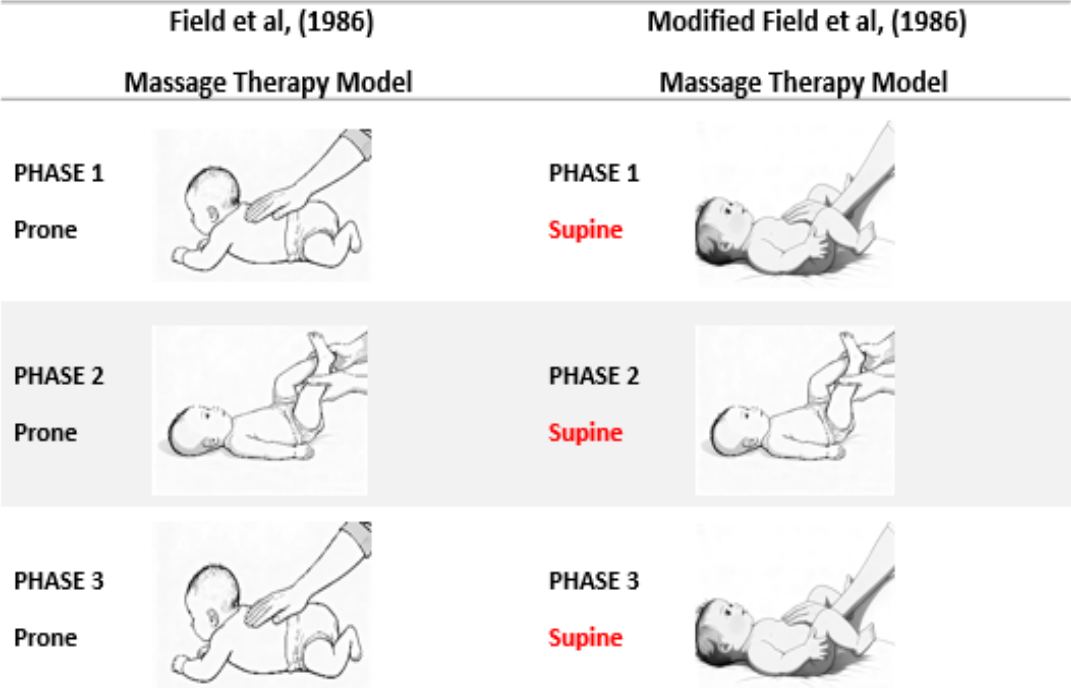
measurements were recorded in centimetres ([Fenton & Kim, 2013](#)).

2.3 Intervention protocol

Intervention group (IG)

Participants in the intervention group received a structured 15-minute session consisting of combined massage therapy (MT) and kinesthetic stimulation (KS), delivered three times daily (morning, midday, and evening) from study enrolment until hospital discharge or attainment of the target weight. All intervention sessions were scheduled either before feeds or at least two hours after feeding to reduce the risk of gastroesophageal reflux or regurgitation and to ensure physiological stability during handling. The protocol was adapted from established methodologies ([Álvarez et al., 2017](#); [Field et al., 2010](#); [Scafidi et al., 1986](#); [Yoanita et al.,](#)

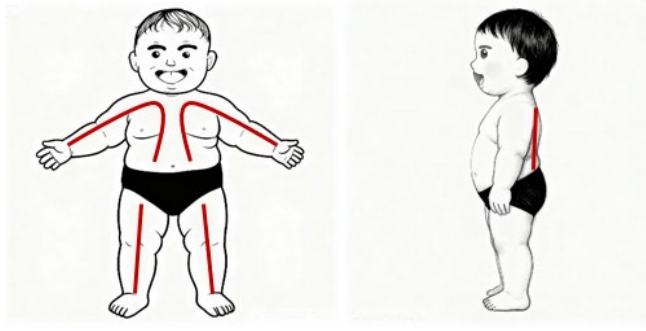
[2021](#)) and refined for feasibility in Malaysian NICUs (**Figure 1**). Each session comprised three stages beginning with five minutes of MT, followed by five minutes of KS, and concluding with an additional five minutes of MT. The massage component was performed predominantly in the supine position, using moderate-pressure strokes applied to the ventral surfaces of the fingers, with brief dorsal strokes delivered in the side-lying position. Each body region received three strokes lasting approximately 10 s each, following a standardised sequence illustrated in **Figure 2**: from above the umbilicus to the neck, from the neck across the shoulders, from the shoulder to the hand, including the fingers, from the thigh to the foot, including the toes, and from the upper back down to the waist on both sides.



**Figure 2. First local physiotherapy-led adaptation of Field’s (1986) massage therapy protocol.** The original Field tactile–kinesthetic stimulation model alternated prone and supine positions across three sequential phases. The modified version used in this trial was performed entirely in the **supine position**, eliminating prone handling to minimise respiratory and aspiration risks, comply with Malaysian NICU guidelines, and enable physiotherapist-supervised maternal participation.

The kinesthetic stimulation illustrated in **Figure 3** involved passive flexion–extension movements of the limbs in a supine position, performed in a consistent order of right arm, left arm, right leg, left leg, and bilateral leg cycling with three repetitions per joint and a five-second rest interval between repetitions (**Figure 4**). Interventions were delivered either by the physiotherapist or trained parents or caregivers to

ensure consistent technique and adherence to the protocol, and sessions continued until the infants met the discharge criteria or reached a pre-established weight threshold. Physiotherapists initiated and supervised all sessions while providing hands-on training to the mothers to ensure consistent techniques and uniform application of the protocol.



**Figure 3.** This figure depicts the standardised massage stroke pathways used in the adapted protocol, performed predominantly in the supine position. Strokes were applied from the abdomen to the neck, across the shoulders, down the arms and legs, with a brief side-lying position used solely for dorsal strokes from the upper back to the waist.

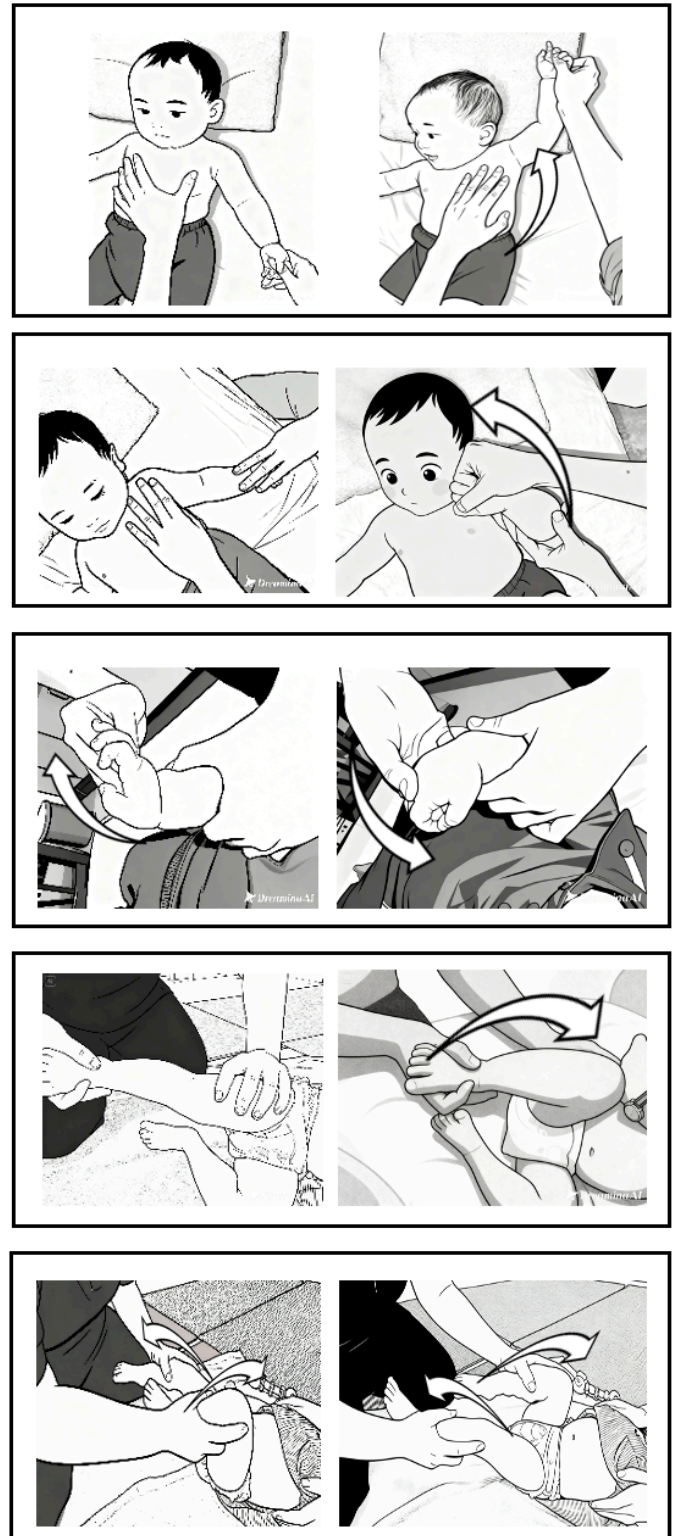
### **Control group (CG)**

The participants in the control group received standardised kinesthetic stimulation (KS) (**Figure 4**) for 15 minutes and were administered three times daily for the duration of the hospital stay. Similarly, KS sessions in the control group were scheduled either before feeding or at least 2 hours after feeding, in accordance with the same safety protocol. The KS protocol used in the control group was identical to the kinesthetic stimulation component delivered within the MT + KS intervention, but without the massage therapy component. All procedures were conducted in the supine position and consisted solely of passive flexion–extension movements of the upper and lower limbs. Each joint was mobilised through passive flexion–extension movements for three repetitions, followed by a 5-second rest interval, consistent with the kinesthetic stimulation component used in the intervention protocol. Unlike the intervention group, the study included no tactile or massage components. All KS sessions were delivered or supervised by trained physiotherapists to maintain procedural consistency and ensure the uniform application of the protocol across all participants.

### **Safety evaluation**

Infants were continuously monitored for desaturation, apnea, bradycardia, vomiting, and respiratory distress during each intervention session (MT + KS or KS-only) and for 30 minutes thereafter. All observations were systematically documented, and upon detection of any abnormal physiological signs, the session was immediately suspended and the attending physician notified. Resumption of the intervention occurred only

after the infant was deemed medically stable; cases requiring ongoing clinical management resulted in permanent discontinuation of treatment.



**Figure 4.** Standardised passive flexion–extension sequence performed in supine, including right and left arm movements, right and left leg movements, and bilateral leg cycling.

## 2.4 Study outcomes

### Primary outcome:

- Average Daily Weight Gain (ADWG) = total weight gain (g) / number of days from intervention initiation until infants reached the 1.8 kg discharge threshold.

### Secondary outcomes:

- Study Weight Gain (StWG) = difference between weight at study enrolment and weight at discharge (or achievement of 1.8 kg), representing growth specifically during the intervention period.
- Length of Stay (LOS): Total number of days from NICU admission until discharge at  $\geq 1.8$  kg.

Baseline variables: Demographic and anthropometric characteristics, including gestational age, sex, ethnicity, birth weight, feeding volume, Apgar score, and thigh circumference.

## 2.5 Statistical analysis

Data were analysed using SPSS version 29. Normality was assessed using the Shapiro–Wilk test. Between-group differences were evaluated using the Mann–Whitney U test, whereas within-group pre-post comparisons were performed using the Wilcoxon Signed-Rank test. Effect sizes ( $r$ ) were calculated using the formula  $r = Z / \sqrt{N}$  to quantify the magnitude of the between-group differences. The magnitude of effect sizes was interpreted according to conventional benchmarks for small, medium, and large effects (Cohen, 1988). Statistical significance was set at  $p < 0.05$  (two-tailed). The minimal clinically important difference (MCID) for ADWG was defined as  $\geq 5$  g/day, based on previous studies (Alvarez et al., 2019; Elmoneim et al., 2021; Jabraeile et al., 2016; Lu et al., 2020; Taheri et al., 2018).

## 2.6 Ethical considerations

The study was approved by the Medical Research and Ethics Committee (MREC) of the Ministry of Health Malaysia (NMRR-ID: 23-00720-4EC). Written informed consent was obtained from parents or legal guardians prior to participation. The trial complied with the Declaration of Helsinki and Malaysian Good Clinical Practice guidelines.

## 3.0 RESULTS AND DISCUSSION

### 3.1 Participant flow and baseline characteristics

A total of 84 preterm infants were randomised equally into two groups: the intervention group receiving combined massage therapy and kinaesthetic stimulation (MT + KS,  $n=42$ ) and the control group receiving

kinaesthetic stimulation alone (KS,  $n=42$ ). All participants completed the intervention and were included in the final analysis, with no attrition or protocol deviation. Baseline demographic and clinical characteristics were comparable between the intervention and control groups, indicating successful randomisation and homogeneity across the samples (Table 1). The mean gestational age was  $32.19 \pm 1.25$  weeks in the intervention group and  $31.93 \pm 1.26$  weeks in the control group ( $p=0.342$ ), representing predominantly late-preterm infants. The gender distribution was balanced, with 59.5% males and 40.5% females in the intervention group versus 45.2% males and 54.8% females in the control group ( $p=0.190$ ). Ethnic composition reflected Sabah's population profile and showed no significant group differences ( $p=0.808$ ). Likewise, birth weight ( $1.59 \pm 0.14$  kg vs.  $1.55 \pm 0.15$  kg;  $p=0.181$ ), feeding regime ( $32.74 \pm 6.30$  ml vs.  $33.76 \pm 4.79$  ml;  $p=0.405$ ), Apgar score at 1 minute ( $9.17 \pm 0.38$  vs.  $9.14 \pm 0.35$ ;  $p=0.766$ ), and thigh circumference ( $0.69 \pm 0.37$  cm vs.  $0.67 \pm 0.24$  cm;  $p=0.725$ ) were statistically similar. These results confirmed that the two groups were homogeneous at baseline, allowing post-intervention outcomes to be interpreted with a minimal risk of confounding.

### 3.2 Growth outcomes

The primary outcome, Average Daily Weight Gain (ADWG), was significantly higher in the MT + KS group ( $27.46 \pm 30.29$  g/day) than in the KS-only group ( $19.72 \pm 6.55$  g/day), as demonstrated by the Mann–Whitney U test ( $p=0.024$ ). Since the data were non-normally distributed, comparisons were based on the Mann–Whitney U test, with higher mean rank values observed in the MT + KS group (Table 2), indicating greater daily weight gain among infants receiving the combined intervention. The between-group improvement of  $+7.7$  g/day exceeded the Minimal Clinically Important Difference (MCID  $\geq 5$  g/day), indicating both statistical and clinical relevance. The corresponding effect size ( $r=0.31$ ) reflects a moderate treatment effect favouring the intervention.

Although Study Weight Gain (StWG) and Length of Stay (LOS) did not reach statistical significance ( $p > 0.05$ ), the observed effect sizes were negligible for StWG ( $r=0.03$ ) and small for LOS ( $r=0.16$ ), indicating limited between-group differences. Within-group analysis using the Wilcoxon signed-rank test demonstrated significant increases in study weight from baseline to discharge in both groups ( $p < 0.001$ ) (Table 2), with the intervention group showing a greater mean-rank improvement over time. Collectively, these findings indicate that the

combined massage and kinesthetic stimulation protocol enhanced daily growth velocity while maintaining clinical stability (Table 2).

3.3 Safety, tolerability, and maternal compliance

All the infants tolerated the intervention well. No adverse physiological events, such as apnoea, bradycardia, oxygen desaturation, or skin irritation, were observed throughout the study period. All participants reached a discharge readiness of ≥1.8 kg.

Session adherence in both groups was verified using maternal diaries and daily physiotherapy observation logs. The mothers demonstrated progressive confidence and technical precision across sessions, reflecting the effectiveness of the physiotherapy-supervised caregiver training model. No withdrawals, missed sessions, or safety events were recorded, indicating that the protocol was well tolerated and feasible to implement in the NICU setting.

Table 1. Baseline demographic and clinical characteristics of preterm infants in the intervention and control groups.

| Characteristics          | Intervention (n=42)<br>Mean ± SD | Control (n=42)<br>Mean ± SD | p-value            |
|--------------------------|----------------------------------|-----------------------------|--------------------|
| Gestational age (weeks)  | 32.19 ± 1.25                     | 31.93 ± 1.26                | 0.342 <sup>a</sup> |
| Gender, n (%)            |                                  |                             |                    |
| Male                     | 25 (59.5%)                       | 19 (45.2%)                  | 0.190 <sup>b</sup> |
| Female                   | 17 (40.5%)                       | 23 (54.8%)                  |                    |
| Ethnicity, n (%)         |                                  |                             | 0.808 <sup>b</sup> |
| Kadazan-Dusun            | 16 (38.1%)                       | 20 (47.6%)                  |                    |
| Bajau                    | 11 (26.2%)                       | 8 (19.1%)                   |                    |
| Malay/Brunei             | 5 (11.9%)                        | 5 (11.9%)                   |                    |
| Others                   | 10 (23.8%)                       | 9 (21.4%)                   |                    |
| Birth Weight (kg)        | 1.59 ± 0.14                      | 1.55 ± 0.15                 | 0.181 <sup>a</sup> |
| Feeding regime (ml)      | 32.74 ± 6.30                     | 33.76 ± 4.79                | 0.405 <sup>a</sup> |
| Apgar Score at 1 minute  | 9.17 ± 0.38                      | 9.14 ± 0.35                 | 0.766 <sup>a</sup> |
| Thigh Circumference (cm) | 0.69 ± 0.37                      | 0.67 ± 02.24                | 0.725 <sup>a</sup> |

All baseline variables were statistically comparable (p > 0.05); <sup>a</sup>: p-value from Mann-Whitney U test; <sup>b</sup>: p-value from Chi-Square test

Table 2. Comparison of growth and hospitalisation outcomes between the intervention (MT + KS) and the control (KS-only) groups.

| Baseline scores | Intervention, n=42<br>(mean ± SD) | Control, n=42<br>(mean ± SD) | p-value | Interpretation             |
|-----------------|-----------------------------------|------------------------------|---------|----------------------------|
| StWG (g)        | 294.045 ± 178.15                  | 285.952 ± 175.40             | 0.795   | Non-significant            |
| ADWG (g)        | 27.457 ± 30.29                    | 19.719 ± 6.55                | 0.024*  | Significant; MICD ≥5 g/day |
| LOS (days)      | 13.286 ± 7.61                     | 14.500 ± 7.36                | 0.519   | Non-significant            |

\*p-value <0.05 (CI of 95%); ADWG: Average daily weight gain; LOS: Length of stay; StWG: Study weight gain.

4.0 DISCUSSION

In this study, we observed that preterm infants in a Malaysian NICU who received a physiotherapy-led sensory–motor stimulation program combining MT and KS showed greater daily weight gain than those receiving kinaesthetic stimulation alone. Infants who received the combined intervention achieved an additional 7.7 g/day in average daily weight gain (ADWG) compared with those receiving kinaesthetic stimulation alone, surpassing the minimal clinically important difference (MCID) threshold of 5 g/day (Elmoneim et al., 2021; Lu et al., 2020). These results support the idea that structured tactile-proprioceptive stimulation can enhance somatic growth and facilitate

neurophysiological adaptation during early postnatal development.

Although differences in study weight gain (StWG) and length of stay (LOS) were not statistically significant, both outcomes demonstrated favourable directional trends in the intervention group. No adverse events or participant withdrawals occurred during the trial, which underscores the safety and tolerability of the intervention.

4.1 Mechanistic interpretation: sensory-motor inputs and neuroplastic growth

The observed improvement in daily weight gain among infants receiving combined (MT + KS) is consistent with

previously described physiological responses to tactile–proprioceptive input. Moderate-pressure massage is known to stimulate cutaneous mechanoreceptors, which may enhance parasympathetic activity through vagal pathways (Diego et al., 2005, 2014; Field et al., 1986). In preterm infants, increased vagal tone has been associated with improved gastric motility, more efficient nutrient absorption, and reduced energy expenditure (Diego et al., 2005, 2014; Elmoneim et al., 2021; Field et al., 1986).

KS further contributes by providing structured proprioceptive input through passive limb movement. This form of stimulation may activate muscle spindle pathways and support early sensorimotor integration, thereby complementing the effects of tactile input (Montaseri et al., 2020; Yoanita et al., 2021; Zhang & Wang, 2023). Rather than acting through a single pathway, the combined intervention likely exerts its effect through multiple, interacting mechanisms that collectively support somatic growth during a vulnerable developmental period (Álvarez et al., 2017; Diego et al., 2005; Elmoneim et al., 2020).

It is unlikely that the observed growth response can be attributed to a single physiological pathway. From a practical standpoint, the combined sensory–motor inputs may support more efficient growth by influencing several regulatory processes simultaneously during a vulnerable developmental period. These interpretations warrant confirmation in future studies incorporating physiological or biochemical markers.

#### 4.2 Comparison with previous literature

Similar improvements in weight gain and physiological stability have been reported in preterm infants receiving tactile–kinaesthetic stimulation across earlier randomised trials and observational studies. Field et al. (1986) first reported enhanced weight gain following three daily sessions of combined stimulation, while subsequent studies confirmed increases in vagal tone, IGF-1 concentration, and behavioural organisation. Elmoneim et al. (2021) further showed that MT + KS improved lean mass and bone mineralisation, suggesting that growth improvements reflect anabolic quality rather than simple fat deposition. Systematic reviews by Mrljak et al. (2022) and Kulkarni et al. (2010) consolidated evidence that massage therapy enhances feeding tolerance, sleep–wake regulation, and mother–infant bonding, with minimal risk when appropriately supervised.

However, most prior protocols were delivered in prone or mixed positions using oil-based massage. These approaches pose potential respiratory and infection risks, particularly for preterm infants with immature airway control and fragile skin integrity. The current trial introduced a supine-only, oil-free, physiotherapy-standardised protocol (Figure 1), eliminating the need for prone handling or oil application while maintaining efficacy. This modification represents a critical shift from traditional techniques to a safer, evidence-based physiotherapy model adaptable to modern NICU environments.

#### 4.3 Physiotherapy and parental empowerment

A central feature of this study was the integration of physiotherapy supervision and maternal participation. In this study, physiotherapists provided hands-on training, supervised daily sessions, and ensured appropriate technique and pacing during sensory–motor stimulation (Álvarez et al., 2017; Montaseri et al., 2020). This approach supported consistent intervention delivery while enabling parents to participate confidently in their infant's care (Yoanita et al., 2021). Empowering mothers to deliver structured sensory input, sustained intervention consistency, and enhanced bonding findings aligned with reports that mother-delivered massage improves infant growth, emotional regulation, and parent–infant interaction (Elmoneim et al., 2021; Zhang & Wang, 2023).

#### 4.4 Clinical implications and relevance to Malaysian NICUs

Adaptation of a structured MT + KS program to the Malaysian NICU context addresses two key challenges: prolonged hospitalisation and limited access to individualised developmental interventions (Elmoneim et al., 2021; Montaseri et al., 2020). By safely accelerating weight gain without adverse events, this physiotherapy-led approach can shorten discharge readiness and improve bed turnover in high-occupancy units, consistent with prior findings of reduced hospital stay following tactile–kinaesthetic stimulation (Álvarez et al., 2017). Its low-technology, caregiver-participatory design enhances its feasibility in resource-limited hospitals, reflecting the scalability reported in similar Southeast Asian trials (Yoanita et al., 2021; Zhang & Wang, 2023). Beyond growth enhancement, the protocol ensures consistent sensory exposure, which may support long-term neurodevelopmental outcomes, underscoring the need for follow-up studies incorporating neurobehavioral and brain imaging measures to explore sustained neuroplastic effects (Elmoneim et al., 2021; Montaseri et al., 2020).

#### 4.5 Strengths and Limitations

This study has several methodological and clinical strengths. First, the randomised controlled trial design minimised selection bias and strengthened the internal validity of the findings. Second, the intervention was delivered using a standardised physiotherapy-led protocol, ensuring consistent implementation and safety within the NICU environment. Third, the integration of maternal participation under physiotherapy supervision enhanced adherence and reflects a realistic model of neonatal care that can be implemented in routine practice. Nevertheless, several limitations should be acknowledged. The study was conducted in a single tertiary neonatal centre, which may limit generalisability to other clinical settings. Although adequately powered for the primary outcome, the sample size remained modest and may have limited the detection of smaller differences in secondary outcomes such as length of hospital stay. In addition, neurophysiological biomarkers such as heart-rate variability or IGF-1 were not measured, and long-term neurodevelopmental outcomes were beyond the scope of the current study.

Key strengths include the randomised design, standardised physiotherapy supervision, comprehensive compliance monitoring, and the use of both statistical and clinical thresholds (Minimal Clinically Important Difference [MCID]  $\geq 5$  g/day) for interpretation. The integration of a supine-only, oil-free massage protocol within a real-world NICU environment demonstrates translational feasibility and safety. Nevertheless, this study had several limitations. First, neurophysiological biomarkers, such as heart-rate variability or IGF-1 concentration, were not directly measured; therefore, mechanistic interpretations are inferential. Second, the outcomes were limited to in-hospital growth and length of hospital stay; long-term neurodevelopmental follow-up was beyond the scope of this study. Finally, although the mothers were trained and supervised, individual variations in technique and frequency could have influenced the magnitude of the response.

#### 5.0 CONCLUSIONS

This randomised controlled trial demonstrates that a physiotherapy-led, supine-only sensory-motor stimulation program combining MT + KS can safely enhance growth in clinically stable preterm infants cared for in a Malaysian neonatal intensive care unit. Infants exposed to the combined MT + KS protocol achieved a clinically meaningful increase in average daily weight gain, exceeding the predefined minimal clinically

important difference, without any adverse physiological events.

From a clinical perspective, the findings suggest that structured tactile and proprioceptive input, when delivered under physiotherapy supervision, can be integrated into routine neonatal care without increasing clinical risk. The use of a supine-only, oil-free protocol aligns with current neonatal safety practices and addresses practical concerns related to respiratory stability and infection control in preterm infants.

Although this study focused on short-term in-hospital growth outcomes, the observed improvement in growth velocity may reflect enhanced physiological regulation associated with repeated sensory-motor stimulation, as suggested in previous studies reporting improvements in vagal activity and gastrointestinal motility following massage-based interventions in preterm infants. Previous studies have suggested similar mechanisms, with improvements in autonomic activity and metabolic markers following massage-based interventions, including enhanced vagal activity and gastrointestinal motility, associated with improved weight gain in preterm infants ([Diego et al., 2005, 2014](#)). However, the present study evaluated clinical growth outcomes rather than direct neurophysiological or biochemical measures.

Future studies should incorporate objective neurophysiological or biochemical markers, such as heart-rate variability and insulin-like growth factor-1 levels, to directly examine underlying mechanisms. Longitudinal follow-up is also warranted to determine whether early growth benefits translate into sustained neurodevelopmental advantages after discharge.

**Data Availability:** All anonymised datasets, intervention manuals, and monitoring templates are available from the corresponding author upon reasonable request.

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reviewed, edited, and provided critical feedback regarding the manuscript. All authors read and approved the final version of the manuscript for submission. All authors agree to be accountable for all aspects of this study.

**Conflicts of Interest:** The authors declare no conflict of interest.

## References

- Álvarez, M. J., Rodríguez-González, D., Rosón, M., Lapeña, S., Gómez-Salgado, J., & Fernández-García, D. (2019). Effects of massage therapy and kinesitherapy to develop hospitalized preterm infant's anthropometry: A quasi-experimental study. *Journal of Pediatric Nursing*, 46, e86-e91. <https://doi.org/10.1016/j.pedn.2019.03.015>
- Arora, J., Kumar, A., & Ramji, S. (2005). Effect of oil massage on growth and neurobehavior in very low birth weight preterm neonates. *Indian Pediatrics*, 42(11), 1092.
- Cohen, J. (1988). *Statistical power analysis for the behavioral sciences* (2nd ed.). Lawrence Erlbaum Associates.
- Diego, M. A., Field, T., & Hernandez-Reif, M. (2005). Vagal activity, gastrointestinal motility, and growth in massaged preterm infants. *The Journal of Pediatrics*, 147(1), 50–55. <https://doi.org/10.1016/j.jpeds.2005.02.023>
- Diego, M. A., Field, T., & Hernandez-Reif, M. (2014). Preterm infant weight gain is increased by massage therapy and exercise via different underlying mechanisms. *Early Human Development*, 90(3), 137-140. <https://doi.org/10.1016/j.earlhumdev.2014.01.009>
- Dupont, W. D., & Plummer, W. D., Jr. (1990). Power and sample size calculations: A review and computer program. *Controlled Clinical Trials*, 11(2), 116–128. [https://doi.org/10.1016/0197-2456\(90\)90005-M](https://doi.org/10.1016/0197-2456(90)90005-M)
- Elmoneim, M. A., Mohamed, H. A., Awad, A., El-Hawary, A., Salem, N., El Helaly, R., Nasef, N. & Abdel-Hady, H. (2021). Effect of tactile/kinesthetic massage therapy on growth and body composition of preterm infants. *European Journal of Pediatrics*, 180(1), 207-215. <https://doi.org/10.1007/s00431-020-03738-w>
- Fenton, T. R., & Kim, J. H. (2013). A systematic review and meta-analysis to revise the Fenton growth chart for preterm infants. *BMC Pediatrics*, 13, 59. <https://doi.org/10.1186/1471-2431-13-59>
- Field, T., Diego, M., & Hernandez-Reif, M. (2010). Preterm infant massage therapy research: A review. *Infant Behavior and Development*, 33(2), 115-124. <https://doi.org/10.1016/j.infbeh.2009.12.004>
- Field, T. M., Schanberg, S. M., Scafidi, F., Bauer, C. R., Vega-Lahr, N., Garcia, R., Nystrom, J. & Kuhn, C. M. (1986). Tactile/kinesthetic stimulation effects on preterm neonates. *Pediatrics*, 77(5), 654-658. <https://doi.org/10.1542/peds.77.5.654>
- Jabraeile, M., Rasooly, A. S., Farshi, M. R., & Malakouti, J. (2016). Effect of olive oil massage on weight gain in preterm infants: A randomized controlled clinical trial. *Nigerian Medical Journal*, 57(3), 160–163. <https://doi.org/10.4103/0300-1652.184060>
- Kulkarni, A., Kaushik, J. S., Gupta, P., Sharma, H., & Agrawal, R. K. (2010). Massage and touch therapy in neonates: the current evidence. *Indian Pediatrics*, 47(9), 771-776.
- Lockridge, T. (2018). Neonatal neuroprotection: Bringing best practice to the bedside in the NICU. *The American Journal of Maternal/Child Nursing*, 43(2), 66-76. <https://doi.org/10.1097/NMC.0000000000000411>
- Lu, L.-C., Lan, S.-H., Hsieh, Y.-P., Lin, L.-Y., Chen, J.-C., & Lan, S.-J. (2020). Massage therapy for weight gain in preterm neonates: A systematic review and meta-analysis of randomized controlled trials. *Complementary Therapies in Clinical Practice*, 39, 101168. <https://doi.org/10.1016/j.ctcp.2020.101168>
- Montaseri, S., Barati, R., Edraki, M., & Hemmati, F. (2020). The effects of massage therapy with or without physical exercises on the weight of premature infants admitted to the neonatal intensive care unit: A randomized clinical trial. *Shiraz E-Medical Journal*, 21(2), e91033. <https://doi.org/10.5812/semj.91033>
- Mrljak, R., Arnsteg Danielsson, A., Hedov, G., & Garmy, P. (2022). Effects of infant massage: a systematic review. *International Journal of Environmental Research and Public Health*, 19(11), 6378. <https://doi.org/10.3390/ijerph19116378>
- Prescott, M. G., Geist, M., Olsson, E., Fiander, M., Soll, R. F., & Bruschettini, M. (2024). Infant positioning for promoting development and preventing morbidity in preterm infants. *The Cochrane Database of Systematic Reviews*, 2024(12), CD016029. <https://doi.org/10.1002/14651858.CD016029>
- Scafidi, F. A., Field, T. M., Schanberg, S. M., Bauer, C. R., Vega-Lahr, N., Garcia, R., Poirier, J., Nystrom, G. & Kuhn, C. M. (1986). Effects of tactile/kinesthetic stimulation on the clinical course and sleep/wake behavior of preterm neonates. *Infant Behavior and Development*, 9(1), 91-105. [https://doi.org/10.1016/0163-6383\(86\)90041-X](https://doi.org/10.1016/0163-6383(86)90041-X)
- Taheri, P. A., Goudarzi, Z., Shariat, M., Nariman, S., & Matin, E. N. (2018). The effect of a short course of moderate-pressure sunflower oil massage on the weight gain velocity and length of NICU stay in preterm infants. *Infant Behavior and Development*, 50, 22–27. <https://doi.org/10.1016/j.infbeh.2017.11.002>
- Yoanita, R., Gunardi, H., Rohsiswatmo, R., & Setyanto, D. B. (2021). Effect of tactile–kinesthetic stimulation on growth, neurobehavior and development among preterm neonates. *Journal of Bodywork and Movement Therapies*, 28, 180-186. <https://doi.org/10.1016/j.jbmt.2021.06.02>

Zhang, Y., Duan, C., Cheng, L., & Li, H. (2023). Effects of massage therapy on preterm infants and their mothers: A systematic review and meta-analysis of randomized controlled trials. *Frontiers in Pediatrics*, 11, 1198730.  
<https://doi.org/10.3389/fped.2023.1198730>