

Soothing Effect of an Edible Teether: A Pilot Study in Children during Primary Dentition Age

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ABSTRACT

Background: Irritability and discomfort are common symptoms during teething periods in infants and toddlers. Non-pharmacological remedies to relieve teething symptoms include teethers and food for chewing. However, the efficacy of such remedies for their soothing effect has been poorly investigated.

Materials and methods: In this home-based pilot study, the soothing effect of a novel edible teether with a slowly dissolvable texture was investigated in 12 children aged 5 to 19 months old during primary dentition age. After parents observed their child getting irritable, the child received the edible teether for an exposure duration of 15 to 20 minutes. Parental ratings of children's mood states (crankiness, stress, happiness, and calmness) were collected using visual analog scales, and child cardiac measurements (heart rate and heart rate variability) were assessed using a wearable device. The soothing effect was quantified via mood ratings and physiological calming responses as a before-after comparison using Wilcoxon signed-rank tests.

Results: Parents perceived their child as significantly calmer and happier, less stressed, and marginally less cranky after edible teether exposure than before. The child cardiac variables showed no significant changes; however, exposure to the teether induced a marginal increase in HR within normal ranges, potentially indicating a stimulation effect.

Conclusion: The pilot study provides the first insight on the soothing effect of a novel edible teether on parent-reported mood states in young children during primary dentition age. Further research is needed to understand the relative contribution of the different components of an edible teether to the observed effects, such as texture and exposure duration, and to demonstrate its efficacy against a control product.

Trial registration: Swiss registry of clinical trial: CER-VD 2019-02155.

Keywords: Children, Edible teether, Soothing, Teething.

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BACKGROUND

The human primary dentition is a developmental process spanning from prenatal to preadolescent years. Primary teeth start developing *in utero* at gestational age (calcification; the basic substance of the tooth forms and the hard tissue that surrounds the teeth is formed), and they usually start erupting into the oral cavity from about 6 months of life (central incisors) to approximately 30 months of life (second molars). The formation is completed between 18 months and 24 months (central incisors) and 36 months (second molars), while exfoliation continues up to 13 years of life.¹ When the first teeth protrude through the gum, 70.5% of children from 0 to 36 months of age show signs and symptoms of teething, with gingival irritation (86.81%), irritability (68.19%), and drooling (55.72%) being the most frequent symptoms as reported by a meta-analysis including 16 studies.² Irritability of children suffering from discomfort and pain during teething periods is a parent pain point.³ Pharmacological and nonpharmacological methods do exist to distress children during their tooth eruption. Medications including analgesics would reduce the pain associated with teething but parents are not always comfortable with therapeutic approaches that could threaten their child's health.⁴ Non-pharmacological methods used by parents for soothing their distressed children with teething symptoms include remedies with mechanical actions on the gums such as biting on objects or foods and massaging the gums.⁵ Parental perceived efficacy of five different nonpharmacological interventions for teething management was evaluated in a clinical study involving 270 children aged 8–36 months.⁴ According to the parents, the most efficacious methods

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for reducing irritability were food for chewing (45.7%) and teething rings (42.1%) followed by cuddle therapy (17.1%), rubbing gums (15.8%), and cooling gums with a piece of ice (10.9%). Scientific evidence based on appropriate methodologies is still needed to demonstrate the efficacy of remedies with mechanical actions on the gums for their acute soothing and calming effect.

Acute calming responses can be quantified in young children via physiological measures. Heart rate (HR), heart rate variability (HRV), and skin conductance are autonomic parameters broadly used in psychophysiology research as they typically reflect the balance of the sympathetic and parasympathetic systems.⁶ The parasympathetic branch of the autonomic nervous system (ANS) mediates the calming response allowing the body to re-balance through modulations of vital functions, typically resulting in an acute increase of HRV and decrease of HR.⁶ Several studies have successfully monitored cardiac

parameters to assess the calming response to nonpharmacological interventions in preterm infants and in infants aged up to 12-month-old during distress situations.^{7–16} Crying reduction or cessation induced by parental soothing was typically accompanied by a decrease in HR and or an increase in HRV as shown in groups of 69 infants aged 0–6 months,¹⁶ of 53 infants aged 4–12 months,¹⁷ and 12 infants aged 1–6 months.¹¹ Similarly, reduction of the stress response after painful medical procedures at the hospital in young populations was reflected by the modulation of cardiac parameters induced by interventions such as music,^{7,18} kangaroo care,^{9,19,20} or sucrose intake.²¹ Another study in preterm infants successfully showed stress reduction due to skin-to-skin contact during diaper change through lowered skin conductance level.²² Altogether, these studies suggest that manifestations of soothing and calming responses in infants induced by parental and nonpharmacological interventions are reflected both behaviorally and physiologically through modulation of cardiac parameters monitored under laboratory conditions. The physiological measures are of interest in a young population due to their noninvasive, language-, and cognitive ability independent nature. They further allow for acute measurements due to their moment-to-moment variability.

MATERIALS AND METHODS

Aim and Design of the Study

This pilot study aimed to investigate the soothing and calming effect of an edible teether in children during the primary dentition age range, using a longitudinal (before and after exposure to the edible teether) design. The soothing effect was assessed through subjective parental ratings of children's mood and the calming effect was quantified in children on the physiological level using a wearable device equipped with sensors for cardiac measurements. The study also explored the feasibility of home-based assessments of stress responses under ecological conditions. We assumed that the irritability state of the children caused by tooth eruption symptoms would generate a physiological stress similar to previous studies that resulted in crying. From this, we hypothesized that exposure to the edible teether would result in a physiological calming response with a reduction in HR and increased HRV. At the behavioral level, we expected parents to perceive an improvement of their child's mood state, from irritability/stress to calmness/happiness.

The research protocol was approved by the Human Ethics Review Committee of the Vaud University Hospital Center in Lausanne, Switzerland (Swissethics). The volunteer participation was performed according to the guidelines of the Declaration of Helsinki 2000.

Participants

The final study sample comprised 12 healthy children (mean age = 12.4 months, standard error = 4.98, range = 5–19 months) with teething symptoms (mean number of teeth = 5.75, standard error = 4.90, range = 0–17), and recruited from the staff of Nestlé Research in Lausanne (Switzerland) and from a local recruiting agency. Children were accompanied by at least one of their parents who were informed about the aims of the study. Both parents gave written informed consent and received financial compensation for participating in the study. The screening was performed by a medical doctor and a research nurse with at least one of the parents in the presence of the child. All participants were reported by the parents to be in good health, free of food allergies or intolerance, with no sensory impairment and no condition that could affect functions of the ANS including cardiovascular disease and major neurodevelopmental delays. The social-emotional development status of participants was measured by the Ages and Stages Questionnaires: Social-Emotional, second edition (ASQ®:SE-2).²³

Procedure

Parents accompanied by their child attended the first visit to receive the study material (product, instruction manual, Everion wearable device, and tablet) and training for the home-based assessments. The study product was a 15 g edible teether, similar to a cereal-based biscuit composed of corn, wheat, rice flour, and lactose (Gerber Soothe'N'Chew™, USA). Key characteristics are a cylindrical tube shape with a spongy texture that slowly dissolves in the mouth.

The home-based assessments were performed on two different study days at the parents' convenience and the child's irritability. In this context, assessments were performed twice to maximize the chances of obtaining viable data. On the assessment days, parents were asked to avoid applying teething gels on their children to avoid any interference with possible soothing effects from the study product. Parents were instructed to perform the assessments only on "normal" days with no major deviation of the child's lifestyle (i.e., same eating, sleeping, and activities patterns in the previous 24 hours) when their child had finished napping, was not hungry, or needed a diaper change. Compliance with the assessment procedures was verified with a checklist completed by the parent.

The procedure for home-based assessments is described in Figure 1. In the preparation phase, parents had to first verify child study compliance before attaching a wearable device to the child's upper arm and setting up a tablet for data recording. A buffer time was then allocated with a minimum of 30 minutes for the calibration of the wearable device and with a maximum of 180 minutes for observing irritability to avoid a change in the child's state (e.g.,

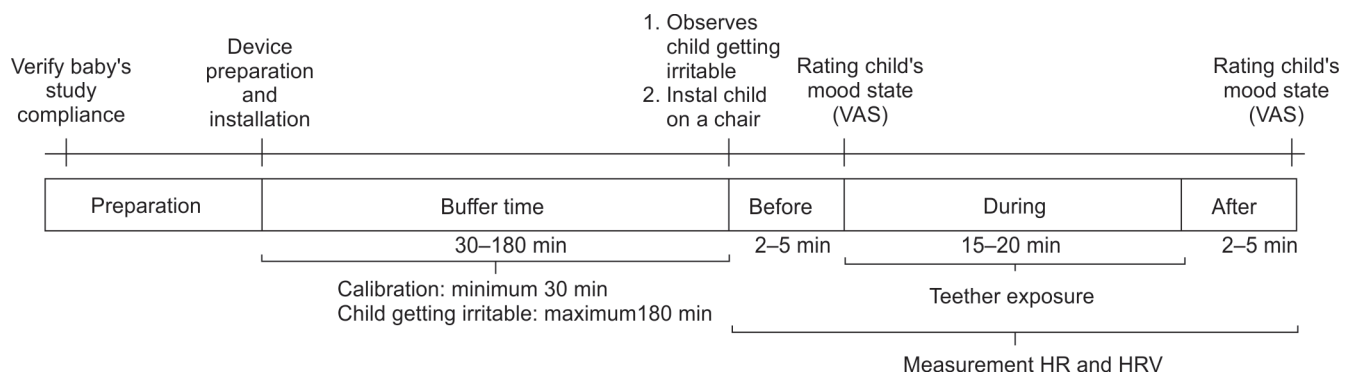


Fig. 1: Procedure for home-based assessments. HR, heart rate; HRV, heart rate variability; VAS, visual analog scale

hunger, fatigue). The assessment phase started when the parents observed their child becoming irritable and after installing her/him on a highchair. After a baseline period of 2 to 5 minutes (before), parents gave the edible teether to their child for an exposure of 15 to 20 minutes (during) and waited again for another 2 to 5 minutes period (after) before removing the wearable device from their child. Flexibility in the period durations with minima and maxima has been set to allow the parents to adapt to their child and behave smoothly. Parents rated their child's mood state before and after exposure to the teether, and cardiac parameters were recorded from the child throughout the assessment. After successful completion of two assessments, the parents returned by postal mail or in person the study material to the research center (unused products if applicable, filled questionnaires, and the wearable device for HR and HRV measurements).

Parental Ratings of Child Mood States

Parents had to rate how they perceived their child was feeling "right now" using 100-mm visual analog scales (VAS) anchored from "not at all" to "extremely" for two positive (happiness, calmness) and two negative (stress, crankiness) mood dimensions. Parental ratings were obtained before and after teether exposure.

Child Cardiac Measurements

Cardiac variables were collected in the children with the Everion medical-grade and wireless armband (Biovotion AG, Zürich, Switzerland) connected via Bluetooth to the Biovotion RnD app installed on a tablet. The Everion device is equipped with a photoplethysmograph (PPG) sensor for measurements of cardiac parameters. It is also equipped with built-in sensors of temperature, accelerometer, impedance, and barometer. The PPG sensor of the device can record a wide range of HR (30–240 bpm), which encompasses the elevated HRs of children (~110–160 bpm).^{12,24} Heart rate recordings extracted from the PPG sensor are highly comparable with those of the Holter which is the medical device for cardiac assessments at rest or during intense physical exercise.^{25–27} This is permitted by an accelerometer-based detection algorithm that reduces the impact of motion on HR,

which can occur unintentionally during home-based studies. The Everion device is designed for use in adults but it is also suitable for use in children thanks to its light biocompatible materials and armband made of soft and flexible material (polyethersulfone, lycra). The wristband is available in different sizes allowing the parents to choose the most comfortable and the most adapted one for their child.

Heart rate (bpm) and HRV (ms) signals were extracted from the PPG sensor data and calculated by the Biovotion RnD app at a frequency of 1 Hz. Heart rate variability was calculated as the root mean square of successive differences (RMSSD) using a sliding window of 5 minutes and the calculation was repeated every second. Data acquired on the tablet in a comma-separated values format were extracted for visualization, manual removal of artifacts, and processing. Heart rate and HRV data measured in the current population from the upper arm were of acceptable quality within expected ranges. Periods containing artifacts were identified in HR data as abrupt drops with values <80 bpm (likely due to skin contact inconsistency) and removed. Datapoints obtained for HR and HRV were averaged across three time periods (before, during, and after teether exposure) for statistical analysis.

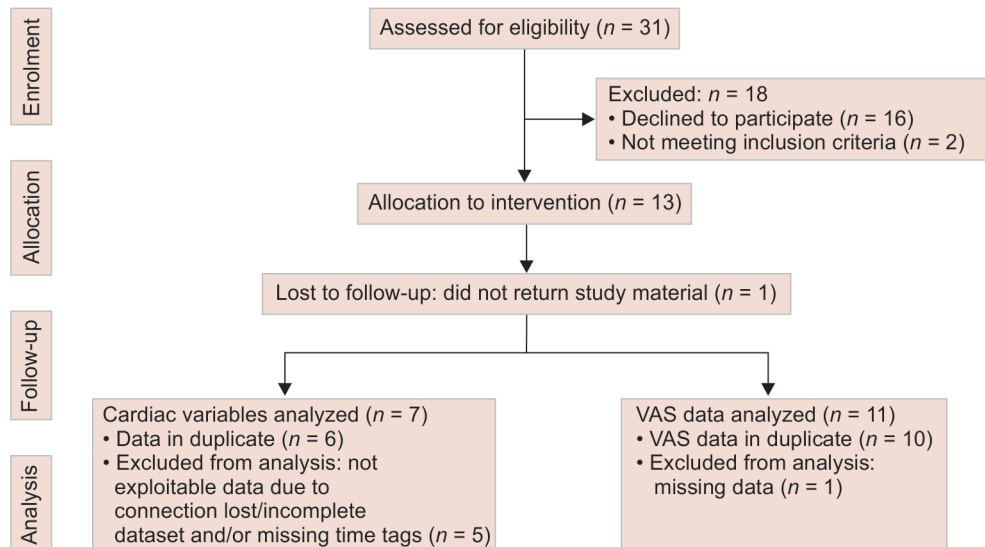
Statistical Analysis

Wilcoxon signed-rank tests were performed to examine the difference in parental ratings (before vs after) for each mood dimension, and the difference in HR and HRV values (before vs during, before vs after, during vs after). Where possible, individual data available for the two assessments were pooled together as the mean value to account for potential intra-variability. The data were analyzed using R software version 3.5.0 (R Foundation for Statistical Computing, Vienna, Austria), and the threshold for statistical significance was set at $p < 0.05$.

RESULTS

Parental ratings of child mood state (VAS data) were analyzed in eleven participants and child cardiac variables in seven participants (Flowchart 1).

Flowchart 1: Consort diagram of participants. VAS, visual analog scale



Parental Ratings of Child Mood States

Changes in parental ratings of child mood state are displayed as the mean scores obtained before and after teether exposure in Figure 2. Results show a general increase in positive moods and a decrease in negative moods. Children were perceived by their parents as significantly calmer ($p = 0.014$) and happier ($p = 0.010$) after product exposure compared to before. The increase in calmness and in happiness scores were approximately 58.8% and 48.2%, respectively. Parents also rated their children as less stressed ($p = 0.032$) and marginally less cranky ($p = 0.08$) after exposure to the teether compared with before. The decrease in stress and crankiness scores were approximately 30.5% and 31.1%, respectively.

Child Cardiac Variables

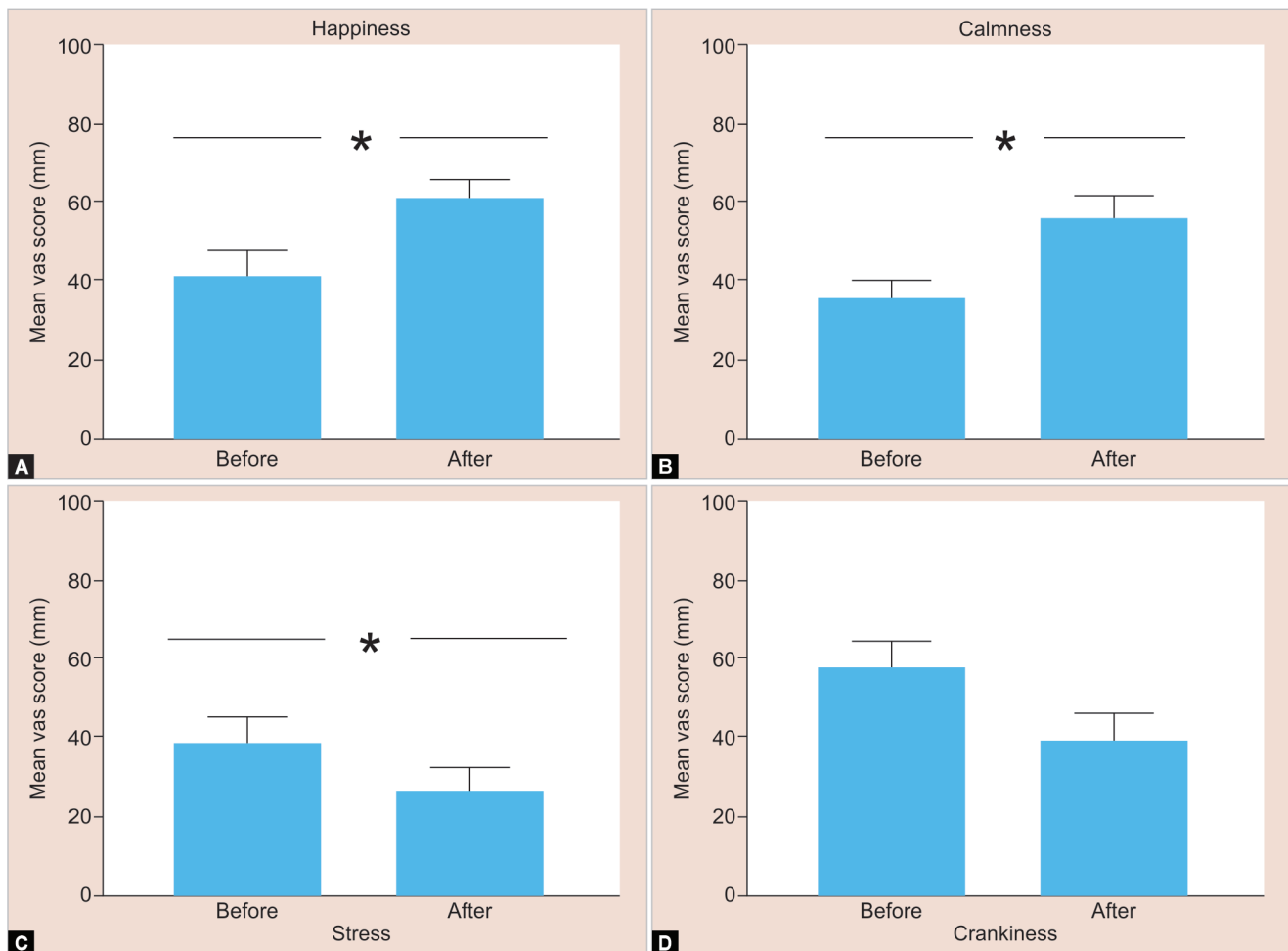
Changes in cardiac variables are displayed as their mean values over time in Figure 3. Results show a general increase in HR of approximately 6% and a decrease in HRV of approximately 7.5% from before to after exposure to the teether. Paired comparisons revealed no significant differences across the different time periods for any of these measures. Heart rate marginally increased from before to during product exposure ($p < 0.1$). This marginal increase was maintained after product exposure as measured during 2 to 5 minutes.

DISCUSSION

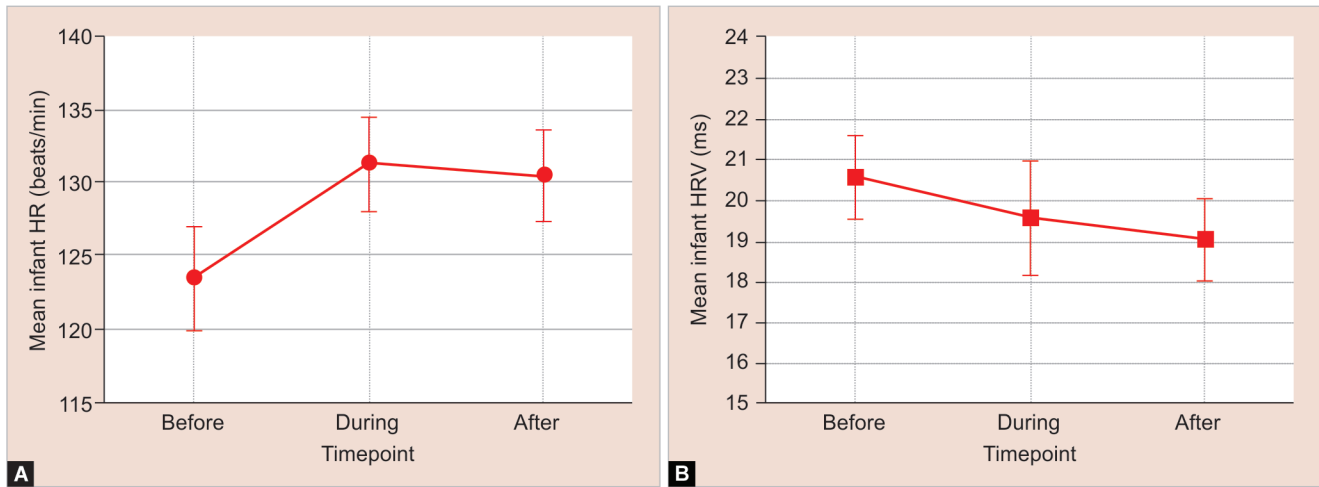
This pilot study in young children at primary dentition age demonstrated the first positive effects of an edible teether on parent-rated mood states in children as well as a trend in increased HR within normal ranges, suggesting potential positive stimulation during chewing or exposure to the edible teether.

Heart rate values collected at the different timepoints, from before to after exposure to the teether, were in the normal range for such a population, with norms reported to be between 127 bpm and 145 bpm in children under 1 year of age.^{28,29} The baseline value of 123 bpm obtained here is close to the lower limit and could be associated with a calming state. It could be that the irritability state observed by the parents was not associated with physiological stress as we were assuming.

From this basal state, the exposure to the teether coincided with a 6% increase in HR that was maintained 2–5 minutes after exposure and still within the normative range.^{28,29} Similarly, HRV values obtained in the current study can be considered within the normal range³⁰ and displayed a 7% decrease over time. Although not significant, such a pattern of cardiac changes (i.e., increased HR and decreased HRV) is consistent with an activation of the sympathetic nervous system involved in stimulation and arousal rather than in relaxation and function restoration.³¹ The circumplex model of emotion originally developed by Russell³²



Figs 2A to D: Parental ratings of child mood states for the four different dimensions. Data from 11 children (10 with averaged data from 2 assessment days); Bar \pm SE; (* $p < 0.05$); Wilcoxon signed-rank test. VAS, visual analog scale



Figs 3A and B: Changes in cardiac parameters measured in children before (2–5 minutes), during (15–20 minutes), and after (2–5 minutes) teether exposure. $N = 6$, bars \pm SE [Left: mean children heart rate (beats/minute). Right: Mean children heart rate variability (ms). HR, heart rate; HRV, heart rate variability]

is composed of a two-dimensional circular space, containing arousal (stimulation–deactivation) and valence (positive–negative) dimensions. Considering this model in combination with the positive effects shown in the parental ratings, it is possible that the modulation of the cardiac parameters observed in response to the edible teether corresponds to a “positive stimulation” with a positive state of excitement or pleasure.^{33,34} The soft and spongy texture of the teether is likely to be the main driver of the soothing effect due to its massaging properties as evidenced by the study of nonpharmacological interventions for teething management.⁴ The flavor of the edible teether might also be accompanied by positive effects, with positive mood effects having been observed in response to the smell of vanilla,³⁵ the smell of lavender,³⁶ and sweet taste.¹⁸ The long-lasting duration of the present edible teether relative to a classical food and its appropriate shape for holding and self-feeding could also contribute to a pleasurable and stimulating experience.

Limited data are available on the topic of the physiological correlates of mood state in a children population >6-month-old. Indeed, the majority of past studies on autonomic parameters affected by the stress response in children were performed in preterm infants or those <6 months.^{7–16,37} Further research is needed to test the new hypotheses raised above and to compare the efficacy of different teething management methods. In the ecological home-based set-up employed here, there was a high loss of data collected from the wearable device of approximately 40%. Reasons were mostly related to misuse of the equipment by the parents despite the on-site training and detailed manual at their disposal. This should be considered for the sample size estimate of future similar studies. Other considerations are the measurement of cardiac parameters at “rest” to quantify the effect of the irritability state, and the use of a control group to compare the intervention effect.

Overall, the current work provides novel insight on the effect of an edible teether on soothing in children at primary dentition age. As a pilot study, the preliminary findings and approach have laid the ground for important contributions to the scientific evaluation of nutritional approaches for teething management. This study focused on a simple before–after design. Future studies should

include a control group to control for placebo effects and allow for the comparison of alternative solutions and confirm the findings presented here.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

The research protocol was submitted and approved by the Human Ethics Review Committee of the Vaud University Hospital Center in Lausanne, Switzerland (Swissethics). The volunteer participation was performed according to the guidelines of the Declaration of Helsinki 2000.

CONSENT FOR PUBLICATION

All participants signed a Volunteer’s Written Informed Consent for participation in a research project. This document contains the following statement:

“I hereby declare that I have been informed that the data deriving from the trial will be used for scientific research. These data could result, where applicable, in publications and marketable products and services. In that case, I will not be able to ask for any financial compensation. When the results of the trial are published, data will be treated in the strictest confidentiality and my identity will never be disclosed.”

COMPETING INTERESTS AND FUNDING SOURCE

All authors are employees of Société des Produits Nestlé SA, (SPN). All of them were involved in the preparation of the article, in study design; in the collection, analysis, and interpretation of data; in the writing of the report; and in the decision to submit the manuscript for publication. This does not alter our adherence to all journal policies on sharing data and materials. Once shared, the data must be kept confidential.

AUTHORS’ CONTRIBUTIONS

Nora Schneider and Julie Hudry conceived the study and designed research; Clara Lerond, Selima Zahar, and Aidan Makwana conducted research and analyzed data; Clara Lerond and Julie

Hudry wrote the paper. Clara Lerond, Selima Zahar, Nora Schneider, and Julie Hudry interpreted the data. Nora Schneider and Selima Zahar revised the draft critically for intellectual content. All authors read and approved the final manuscript.

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