Early weight gain in infants with cleft lip and palate treated with and without Nasoalveolar Molding: A Retrospective Study

Shannon Woods, DMD

A thesis submitted in partial fulfillment
of the requirement for the degree of
Master of Science in Orthodontics

Oregon Health & Science University
Portland, OR

November 2016

Acknowledgments

Thank you to my thesis mentor Dr. Judah Garfinkle for his advice throughout all the stages of this project.

Thank you to my thesis committee members: Dr. David Covell, Dr. Larry Doyle, and Dr. Lauren Busch for their feedback and support of the project.

Thank you Mansen Wang for statistical analysis.

Thank you to Sydney Stoker for her help with data collection.

Thank you to Maureen Oliverio RN, CPNP for all her assistance in acquiring a patient base.

Thank you to Jose Rodriguez for help in acquiring the control subjects.

Thank you to my family, especially Chris and Sloan, for all their love and support.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

Early weight gain in infants with cleft lip and palate treated with and without Nasoalveolar Molding: A Retrospective Study

Shannon M. Woods, DMD*
Judah S. Garfinkle, DMD, MS*[b]
Larry M. Doyle, DDS*
David A. Covell Jr. PhD, DDS*
Lauren S. Busch, DDS

*Department of Orthodontics, Oregon Health & Science University, Portland, OR
[b]Craniofacial and Cleft Palate Clinic, Doernbecher Children's Hospital, Portland, OR

Corresponding Author:
Shannon Woods, DMD
E-mail: shannonwoodsdmd@gmail.com
Phone: 541-280-1401

DECLARATION OF INTERESTS

None of the authors have any interest, financial or otherwise, in any of the parameters involved in this study.

ABSTRACT

Objective: To assess the impact of Nasoalveolar Molding (NAM) on weight change in infants born with cleft lip and/or cleft palate (CL/P) until age of 6 years.

Design: A retrospective chart review was conducted of infants with CL/P to compare longitudinal weight change of infants treated with NAM (+NAM) or not treated with NAM (-NAM) prior to the primary lip surgery. In addition, a healthy non-cleft control sample (C) was collected.

Setting: Doernbecher Children's Hospital, Oregon Health & Science University, Portland, Oregon

Patients, Participants: From the craniofacial clinic database, consecutively presenting infants with more than 5 longitudinal weight records born with a non-syndromic CL/P were evaluated, beginning in 2008, until a sample size of 40 treated infants, and 40 untreated infants was met. From the Doernbecher pediatric department database a non-cleft control group of 40 infants was selected from consecutive births.

Interventions: Weight measurements were obtained from the charts of CL/P and control subjects.

Main Outcome Measures: The weight gain observed in each population group was compared to determine if +NAM subjects demonstrated differences in weight gain compared to -NAM subjects, using a C group as a baseline.

Results: The weight gain observed was greatest in the C Group, followed by both the +NAM and -NAM group. There was no statistically significant difference in weight gain or weight gain percentage between the +NAM and -NAM groups. Additionally the +NAM and -NAM infants demonstrated greater weight rebound up to 9 months of age when compared to the control group.

Conclusions: There is no statistically significant difference in weight gain between +NAM patients and -NAM patients, indicating NAM therapy has no effect on weight gain. Control patients demonstrate the greatest overall weight gain.

Key Words: Cleft Lip and/or Cleft Palate (CL/P), Unilateral Cleft Lip and/or Palate (UCL/P), Bilateral Cleft Lip and/or Palate (BCL/P), Nasoalveolar Molding (NAM). Pre-surgical infant orthopedics (PSIO)

Introduction

One of the earliest observed co-morbidities in infants with a unilateral cleft lip and/or palate (UCL/P) or bilateral cleft lip and/or palate (BCL/P) is a low birth weight and delayed weight gain. [1, 2, 3, 4, 5, 6, 7] Nyarko et al concluded infants born with a CL/P have twice the risk for low birth weight compared to non-cleft infants. [8] In normal non-cleft infants, sucking is achieved though negative intraoral pressure accomplished by sealing the lips and velopharynx and expanding the intraoral cavity, either with contraction of the tongue or movement of the mandible, whereas infants with CL/P are unable to seal their lips and therefore cannot provide the necessary negative intraoral pressure needed to suck milk into the oral cavity. [9, 10, 11, 1, 12, 13, 4, 5] The loss of negative pressure is due to air exchange between the nasal and oral cavities resulting in prolonged feeding times, nasal regurgitation, increased risk of choking and aspiration, and an infant that fatigues before a full feeding due to increased effort and energy expenditure resulting in delayed weight gain. [5, 4, 13, 1, 11 10, 7, 14]

The introduction of presurgical infant orthopedics (PSIO) was thought initially to counteract the delayed weight gain by facilitating feeding. [15] These postulations have since been refuted. Both Prahl et al. and Masarei et al. concluded both passive and active appliances had no effect on feeding or consequent nutritional status in patients with UCLP. [15] One PSIO in particular, the nasoalveolar molding device (NAM), was introduced with the sole purpose of improving the esthetic outcome of the cheiloplasty and palatoplasty by reducing the initial cleft deformity. Opponents of the NAM state that the treatment is expensive and may have an adverse effect on maxillary growth. [15] Because the NAM appliance is being increasingly used clinically, it is important to determine that the approach poses no burden on weight gain in cleft infants.

The primary objectives of NAM are to restore symmetry to the nasal cartilages, achieve projection of the nasal tip, non-surgical elongation of the columella, align the alveolar ridges and reduce the intersegmental distance. [16] The reduced intersegmental distance allows for an improved esthetic and surgical prognosis that may be less likely to require secondary revisions. [Grayson, Grayson-Garfinkle] With regard to impact on feeding, the Dutchcleft study examined the efficacy of alveolar molding, which unlike the NAM device lacks the nasal stent, in achieving weight gain. The study which found no positive effect concluded that “infant orthopedics with the aim of improving feeding and consequent nutritional status in infants with unilateral cleft lip and palate can be abandoned”.[17] To date there is no study evaluating the impact of NAM (with a nasal stent) on infant weight change.

At the Doernbecher Craniofacial Clinic, on average, the NAM appliance is delivered at 4 weeks, and adjusted weekly until the infant reaches 5 months of age. Once the subject has reached 4-5 months of age, primary cheiloplasty surgery is performed, followed by palatoplasty at 12 months of age. This study examines the infant weight gain from birth to 9 months to evaluate any changes observed while the NAM appliance was in place, from primary lip surgery, and from birth to 6.3 years to evaluate for any long term differences in weight gain. The null hypothesis will be tested, that the presence of the NAM device does not affect weight gain when compared to cleft infants that did not receive NAM therapy.

MATERIALS AND METHODS

This research was performed with the approval of the Institutional Review Board (IRB) of Oregon Health & Science University (OHSU). Records of infants with CL/P were collected from the Doernbecher Children's Hospital (DCH) Craniofacial Clinic database in Portland, Oregon. Records from control subjects were collected from the Pediatric Medicine Clinic at OHSU DCH. For the data collected, subjects were de-identified and given anonymous identification numbers. Patient consents were obtained at the first visit, and patients were given the option to opt out of any research.

Sample size was based on a power calculation using the average initial weight difference between C and –NAM of 0.20 kg, with a standard deviation of 0.3. In order to achieve an α level of 0.5, and a power of 0.8, each group required at least 38 subjects. Inclusion criteria were comprised of non-syndromic infants with an isolated cleft palate, isolated cleft lip, or cleft lip and palate that exclusively fed orally. All +NAM subjects completed NAM therapy, while all –NAM patients did not initiate therapy. Exclusion criteria eliminated patients that demonstrated syndromic cleft lip and/or palate (e.g., Robin Sequence), infants receiving food through a G (gastrointestinal) tube, incomplete anthropomorphic weight measurements, and subjects who initiated NAM therapy but did not complete treatment. Subjects were selected consecutively between 2008 and 2014 until 40 +NAM, 40 -NAM, and 40 C subjects were selected.

The +NAM and -NAM subjects were further divided into complete cleft lip and palatal involvement (CL/P), cleft lip (CL), or cleft palate (CP). All +NAM subjects were treated by a single provider (JG) at the craniofacial clinic at DCH. For subjects with a cleft, periodic weight measurements (Scale-Tronix Pediatric Scale 4800 Welch Alynn, Skaneateles Falls, NY) were made in kilograms and age was recorded in days at each appointment with the craniofacial team. All C patients received weight measurements at each periodic pediatric checkup appointment (Scale-Tronix 4800). A minimum of 5 data collection measurements were reported for each patient, although due to missed appointments or scheduling challenges, there was variability in the number of observations for the length of the data collection period. If multiple weights were documented on the same day, the first weight measurement was used in this study.

Weight data was compared among the three groups. Statistical analysis was completed with the SAS 9.3 software (SAS Institute Inc., Cary, NC). All data with a power $P<0.05$ were considered as statistically significant. The statistical test performed was a generalized linear regression (GLM) with repeated measurements, as all subjects had longitudinal data with multiple measurements at different time points. A Post-hoc pairwise comparison was used with a Tukey adjustment.

RESULTS

Three of the 120 subjects were removed from the study, two –NAM subjects and one +NAM subject, as following data collection, it was determined that they received supplemental feeding through a G tube. All +NAM subjects were diagnosed with cleft lip and palate. All –NAM subjects were diagnosed with cleft lip and palate except for 4 who were diagnosed with isolated cleft palate, and one subject diagnosed with isolated cleft lip (the 5 were included in the study). Age ranged from day 1 to day 3037, where the average data collection widow was 1502 days or 4 years for all 3 subject groups.

Weight measurements for the 3 groups (1,983 measurements) are plotted in Figure I where a line of best fit was applied to each group. When using weight as an outcome, the C group demonstrated a statistically significant greater weight gain than the –NAM group ($p = 0.0185$; Table I). The +NAM group fell between the C and –NAM groups regarding weight gain where no statistical differences were found between the C and +NAM, and the +NAM and –NAM groups.

When age was compared to percent weight gain (Table II), group C had significantly less weight gain than the +NAM and –NAM groups ($p = 0.0001$ and $p = 0.0041$ respectively). There was no statistically significant difference in infant weight gain or percentage of weight gain between the +NAM and –NAM groups.

DISCUSSION

This study examined weight gain between two cleft populations from birth to 6.3 years, evaluating the NAM device as an intervention. While there are multiple clinical and esthetic benefits of NAM use reported in the literature, it is important to rule out that NAM could have a negative impact on weight gain. Pre-operative weight gain is important as surgeons use a Rule of Tens to evaluate if an infant is healthy enough for primary cheiloplasty. [18] The Rule of Tens requires an infant to be 10 lb in weight, have 10 mg/dL hemoglobin count, and is at least 10 weeks of age. [18] For this reason it is crucial to determine that the introduction of the NAM plate does not hinder weight gain in infants.

Our finding of no statistical difference in weight between –NAM and +NAM groups confirms that the presence of the NAM plate does not hinder weight gain, although both groups showed lower weight than that of control infants. These outcomes are similar to the majority of investigations on growth of children with clefts where deficiencies in weight and height are found, especially during the first year of life before primary palatoplasty has occurred at 12 months. [19] From infancy to 2 years, delayed weight gain can be attributed to environmental factors such as difficulty feeding and recurrent infectious diseases. [19] After the first 2 years of life, poor weight gain is usually due to biologic factors such as reduced growth hormone production. [19] When comparing weight to age from birth to 6.3 years, we found the –NAM group had less increase in weight compared to the C group, confirming that infants with a CL/P start with a lower birthweight and continue to weigh less than unaffected infants. These findings are consistent with Kay et al. who report that throughout the first 2 years of life, there was an overall trend toward lower average weights for infants with clefts compared to unaffected infants. [13]

When using the percentage of weight gain as an outcome from birth to 6 years, we found a significant increase in weight percentage in the +NAM and -NAM groups relative to the C group. This finding confirms the cleft subjects are experiencing an increased rate of weight gain, or "rebound". There was no statistical difference between +NAM and -NAM in percentage of weight gain, confirming that intervention with the NAM appliance does not affect the weight gain rebound. Miranda et al. report similar results where growth impairment was found in children who had cleft palate with or without cleft lip but only in early infancy. [1] After the age of 5 months, the cleft children presented with catch-up growth. [1.]

Because the NAM device is present for an average of 5 months, we evaluating a 9 month treatment window both for overall weight and the percentage of weight gain. Our results showed that during this window, the control group gained more weight than the +NAM and –NAM groups, and there was no difference between +NAM and -NAM weight gain. Further examination of percentage of weight gain indicates that the infants with a cleft demonstrated increased rebound over the control infants. In other words, this confirms that infants with a cleft demonstrated greater weight rebound than did the control population, both in the birth to 9 months and birth to 6.3 year treatment windows. This finding is consistent with the literature that feeding challenges cause problems with weight gain resulting in a slower growth for the infant with a cleft (when compared to C) until the lip and palate is surgically closed. [18]

All of the above comparisons demonstrate there is no statistically significant difference between the +NAM group and -NAM groups. This finding suggests there is neither a benefit nor a disadvantage to NAM use in regard to weight gain, confirming the null hypothesis that the use of NAM does not impact weight gain. The data from this study corroborate findings from prior literature showing that infants with a cleft experience a weight rebound when compared to control infants.

This study draws similar conclusions made by Cunningham et al. that infants with CL/P displayed an intrinsic growth pattern that was below the mean for the general population. [21] Authors Lee and Zarate report a weight gain rebound after palatoplasty, which is consistent with the findings in this present study. Lee et al. report that despite significant growth faltering for CL/P infants, rapid recovery takes place following surgical repair and appears to have resulted in no residual growth deficit. [6] Zarate et al. agree that despite the initial lag in weight gain there typically is an eventual recovery of the weight gain between 6 months and 3 years.[12] A third study by Miranda et al. document that children with CL/P had median BMI growth curves below the growth curves for typical children but showed spontaneous recovery starting at 5 months.[1] Weight recovery was statistically significant in the cleft groups when compared to the control groups in this study, both for the 9 month and 6 year treatment window.

The present study confirms that from birth to 9 months, there is a notable decrease in weight gain observed in the cleft population when compared to unaffected infants, and that the cleft population demonstrate an increase in percentage of weight gain. Other authors quote the weight gain was significantly limited in the first 2 months of life, and by 3 months of age patients began to catch up to unaffected infants. The patients generally stayed below normal until 6 months of age.[2]

There are limitations with the current study. As a retrospective study, there was no control over additional factors that can contribute to weight gain. Examples of such factors include the source of milk (breast or formula), composition of formula (if formula fed), type of feeding method, when introduction to solid foods occurred, access to lactation consultants, socioeconomic status, medications such as antacids, and any additional health complications the infant may have faced during growth such as ear infections. While it is presumed that surgical repair occurred for each cleft patient, that information was not recorded for this study. A total of 3 –NAM infants were diagnosed with CP only and therefore did not receive cheiloplasty surgery. One –NAM subject had CL only, and did not receive palatoplasty. Moreover, the +NAM and –NAM subjects may have had varied exposure to supportive care from the craniofacial team. Furthermore, there was no way to assess compliance in each NAM patient to ensure 24 hours use. Lastly, while JG was the sole practitioner for each +NAM and -NAM patient, the C population was under the care of multiple pediatricians.

CONCLUSIONS

There was no statistically significant difference in the weight gain observed between the +NAM group and -NAM groups, confirming that presence of the NAM appliance does not affect weight gain. Additionally, infants in both groups demonstrated a similar pattern of weight rebound when compared to control infants as described in prior literature. Therefore when NAM is indicated for clinical or esthetic correction of the pre-surgical cleft deformity, practitioners and caretakers can feel comfortable that NAM will not affect infant weight gain.

REFRENCES

1. Miranda GS, Marques IL, deBarros SP, Arena EP, deSouza L. Weight, length, and body mass index growth of children under 2 years of age with cleft lip and palate. *The Cleft Palate-Craniofacial Journal.* 2014; 0: 0
2. Avedian L, Ruberg R. Impaired Weight Gain In Cleft Palate Infants. *Cleft Palate Journal*. 1980; 17: 1.
3. Bessell A, Hooper L, Shaw WC, Reilly S, Reid J, Glenny A-M. Feeding interventions for growth and development in infants with cleft lip, cleft palate or cleft lip and palate*. The Cochrane Collaboration*. 2011; 1
4. Choi BH, Kleinheinz J, Joos U, Komposch G. Sucking efficacy of early orthopaedic plate and teats in infants with cleft lip and palate. *International Journal of Oral and Maxillofacial Surgery*. 1991; 20:167-169.
5. Brine EA, Rickard KA, Brady MS, Liechty EA, Manatunga A, Sadove M, Bull MJ. Effectiveness of two feeding methods in improving energy intake and growth in infants with cleft palate: a randomized study. *Journal of the American Dietetic Association*. 1994;94:722-738.
6. Lee J, Nu-NAM J, Wright C. Height and weight achievements in cleft lip and palate. *Archives of Disease in Childhood*. 1997;76:70-72.
7. Gopinath VK, Muda WA. Assessment of growth and feeding in children with cleft lip and palate. *The Southeast Asian Journal of Tropical Medicine and Public Health*. 2005; 36: 254-258.
8. Nyarko KA, Lopez-Camelo J, Castilla EE, Wehby GL. Does the relationship between prenatal care and birth weight vary by oral clefts? Evidence using South American and United States samples. *The Journal of Pediatrics*. 2013; 162: 42-49.
9. Clarren SK, Naderson B, Wolf LS. Feeding infants with cleft lip, cleft palate, or cleft lip and palate. *Cleft Palate Journal*. 1987; 24:244-249.

10. Masarei AG, Sell D, Habel A, Mars M, Sommerland BC, Wade A, The nature of feeding in infants with unrepaired cleft lip and/or palate compared with healthy noncleft infants. *Cleft Palate Craniofacial Journal*. 2007; 44: 321-328.
11. Miller CK. Feeding issues and interventions in infants and children with clefts and craniofacial syndromes. *Seminars in Speech and Language*. 2011; 32: 115-126.
12. Zarate YA, Martin LJ, Hopkin RJ, Bender PL, Zhang X, Saal H. Evaluation of growth in patients with isolated cleft lip and/or cleft palate. *The Journal of Pediatrics*. 2010; 125:e543-e549.
13. Kaye A, Thaete K, Snell A, Chesser C, Goldak C, Huff H. Initial Nutritional Assessment of Infants with Cleft Lip and/or Palate: Interventions and Return to Birth Weight. *The Cleft Palate-Craniofacial Journal*. 2016: 00(00).
14. Jones WB. Weight gain and feeding in the neonate with cleft: a three center study. *Cleft Palate Journal.* 1988; 25: 379-384.
15. Uzel A, Alparslan N. Long-term effects of presurgical infant orthopedics in patients with cleft lip and palate: a systematic review*. Cleft Palate-Craniofacial Journal*. 2011; 48: 587.
16. Grayson BH, Garfinkle JS. Early cleft management: The case for nasoalveolar molding. *American Journal of Orthodontics* 2014; 145: 134.
17. Prahl C, Kuijpers-Jagtman AM, Van 'T Hof M, Prahl-Andersen B. Infant Orthopedics in UCLP: Effect on Feeding, Weight, and Length: A Randomized Clinical Trial (Dutchcleft). *The Cleft Palate-Craniofacial Journal*. 2005; 42: 171-177.
18. Hansen PA, Cook NB, Ahmad O. Fabrication of a Feeding Obturator for Infants. *The Cleft Palate-Craniofacial Journal*. 2015; 0;0
19. Marques IL, Nackashi JA, Borgo HC, Martinelli AP, Pegoraro-Krook MI, Williams WN, et al. Longitudinal study of growth of children with unilateral cleft-lip palate from birth to two years of age. *Cleft Palate Craniofacial Journal*. 2009; 46: 603-609.

20. Ball JV, Dibiase DD, Sommerlad BC. Transverse maxillary arch changes with the use of preoperative orthopedics in unilateral cleft palate infants. *Cleft Palate Craniofacial Journal*. 1995; 32: 483.
21. Cunningham ML, Jerome JT. Linear growth characteristics of children with cleft lip and palate. *The Journal of Pediatrics*. 1997; 131: 707-711.
22. Becker M, Svennson H, Kallen B. Birth weight, body length, and cranial circumference in newborns with cleft lip or palate. *Cleft Palate Craniofacial Journal*. 1998; 35: 255-261.
23. Britton KF, McDonald SH, Welbury RR. An Investigation into infant feeding in children born with a cleft lip and/or palate in the West of Scotland. *European archives of paediatric dentistry : official journal of the European Academy of Paediatric Dentistry*. 2011; 12:250-255.
24. Brophy TW: Cleft Lip and Cleft Palate. *Journal of the American Dental Association*. 1927; 14: 1108.
25. Felix-Schollaart B, Hoeksma JB, Prahl-Andersen B. Growth comparisons between children with cleft lip and/or palate and controls. *Cleft Palate Craniofacial Journal*. 1992; 29:475-480.
26. Glenny AM, Hooper L, Shaw WC, Reilly S, Kasem S, Reid J. Feeding interventions for growth and development in infants with cleft lip, cleft palate or cleft lip and palate. *Cochrane Database Systematic Review*. 2004; (3):CD003315.
27. Grayson BH, Maull D: Nasoalveolar molding for infants born with clefts of the lip, alveolus, and palate. *Clinics in Plastic Surgery*. 2004; 31: 149.
28. Grayson BH, Santiago PE, Brecht LE, et al: Presurgical nasoalveolar molding in infants with cleft lip and palate. *Cleft Palate Craniofacial Journal.* 1999; 36: 486.
29. Haschke F, Van't Hof MA. Euro-growth references for length, weight, and body circumferences. Euro-growth study group. *Journal of Pediatric Gastroenterology and Nutrition*. 2000;31 (suppl 1): S14-S38.

30. Hotz M, Gnoinski WM. Comprehensive care of cleft lip and palate children at Zurich University: a preliminary report. *American Journal of Orthodontics* 1976; 70: 481-504.

31. Hotz MM, Gnoinski WM: Effects of early maxillary orthopaedics in coordination with delayed surgery for cleft lip and palate. *Journal of Maxillofacial and Oral Surgery*. 1979; 7: 201.

32. Kozelj V. Changes produced by presurgical orthopedic treatment before cheiloplasty in cleft lip and palate patients. *Cleft Palate Craniofacial Journal*. 1999; 36: 515.

33. Maas C, Poets CF. Initial treatment and early weight gain of children with Robin Sequence in Germany: a prospective epidemiological study. *Archives of Disease in childhood. Fetal and Neonatal Edition*. 2014;99: 491-494.

34. Matsuo K. Hirose T. Preoperative non-surgical over-correction of cleft lip nasal deformity. *British Journal of Plastic Surgery* (1991); 44: 5-11.

35. McNeil CK. Orthodontic procedures in the treatment of congenital cleft palate. *Dental Record; a monthly journal of dental science art and literature* 1950; 70: 126.

36. Montagnoli LC, Barbieri MA, Bettiol H, Marques IL, Souza L. Growth impairment of children with different types of lip and palate clefts in the first 2 years of life: a cross-sectional study. *The Journal of Pediatrics (Rio J)*. 2005; 81: 461-465.

37. Persson M, Sandy JR, Wayken A, Wills AK, Al-Ghatam R, Ireland AJ, Hall AJ, Hollingsworth W, Jones T, Peters TJ, Preston R, Sell D, Smallridge J, Worthington H, Ness AR. A cross-sectional survey of 5-year-old children with non-syndromic unilateral cleft lip and palate: the Cleft Care UK study. Part 1: background and methodology. *Orthodontics and Craniofacial Research*. 2015; 18: 1-13.

38. Rudman D, Davis T, Priest JH, Patterson JH, Kutner MH, Heymfiels SB, Bethel RA. Prevalence of growth hormone deficiency in children with cleft lip or palate. *The Journal of Pediatrics*. 1978; 93: 378-382.

39. Seth AK, McWilliam BJ. Weight gain in children with cleft palate from birth to two years. *The Cleft Palate Journal*. 1988; 25:146-150.

40. Shaw WC, Bannister RP, Robert CT. Assisted feeding is more reliable for infants with clefts- a randomized trial. *The Cleft Palate Craniofacial Journal*. 1999;36:262-268.

41. Shetty V, Thakral A, Sreekumar C. Comparison of early onset nasoalveolar molding with patients who presented for molding up to 1 year of age. *Journal of Oral and Maxillofacial Surgery*. 2015; 1-17.

42. Shetty V, Vyas HJ, Sharma SM, Sailer HF. A comparison of results using nasoalveolar moulding in cleft infants treated within 1 month of life versus those treated after this period: development of a new protocol. *International Journal of Oral and Maxillofacial Surgery*. 2012; 41:28-36.

Figure Legends:

Figure I: Weight (kg) vs Age (days) for all treatment groups

Figure II: Weight (kg) vs Age (days) for the –NAM group individual measurements

Figure III: Weight (kg) vs Age (days) for the –NAM group individual measurements with a line of best fit

Figure IV: Weight (kg) vs Age (days) for the C group individual measurements

Figure V: Weight (kg) vs Age (days) for the C group individual measurements with a line of best fit

Figure VI: Weight (kg) vs Age (days) for the +NAM group individual measurements

Figure VII: Weight (kg) vs Age (days) for the +NAM group individual measurements with a line of best fit

Figure VIII: Line of best fit for C, -NAM, and +NAM groups

Figure IX: Percent change from initial weight measurement (kg) compared to age (days) for C, -NAM, and +NAM groups

Table I: Weight vs Age comparison for all three treatment groups birth to 6.3 years

Comparison	Difference	Standard Error	DF	t Value	Adj P value
C vs +NAM	0.3768	0.2477	113	1.52	0.2831
C vs -NAM	0.6856	0.2506	116	2.74	0.0185*
+NAM vs -NAM	0.3088	0.2457	112	1.26	0.4212

*Statistically significant

Table II: Percentage of weight gain vs age for all three treatment groups from birth to 6.3 years

Comparison	Difference	Standard Error	DF	t Value	Adj P value
C vs +NAM	-0.5121	0.1017	107	-5.04	<.0001*
C vs -NAM	-0.3303	0.1024	110	-3.23	0.0041*
+NAM vs -NAM	0.1817	0.101	106	1.8	0.1722

*Statistically significant

Table III: Weight vs Age from Birth to 9 months

Comparison	Difference	Standard Error	DF	t Value	Adj P value
C vs +NAM	0.5483	0.147	114	3.73	0.0009*
C vs -NAM	0.5716	0.1479	116	3.87	0.0005*
+NAM vs -NAM	0.02333	0.1484	117	0.16	0.9865

*Statistically significant

Table IV: Percent of weight gain vs age from birth to 9 months

Comparison	Difference	Standard Error	DF	t Value	Adj P value
C vs +NAM	-0.1877	0.04307	104	-4.36	<.0001*
C vs -NAM	-0.1281	0.04327	105	-2.96	0.0101*
+NAM vs -NAM	0.05967	0.04337	106	1.38	0.3564

*Statistically significant

Figure I: Weight as Outcome for all 3 groups

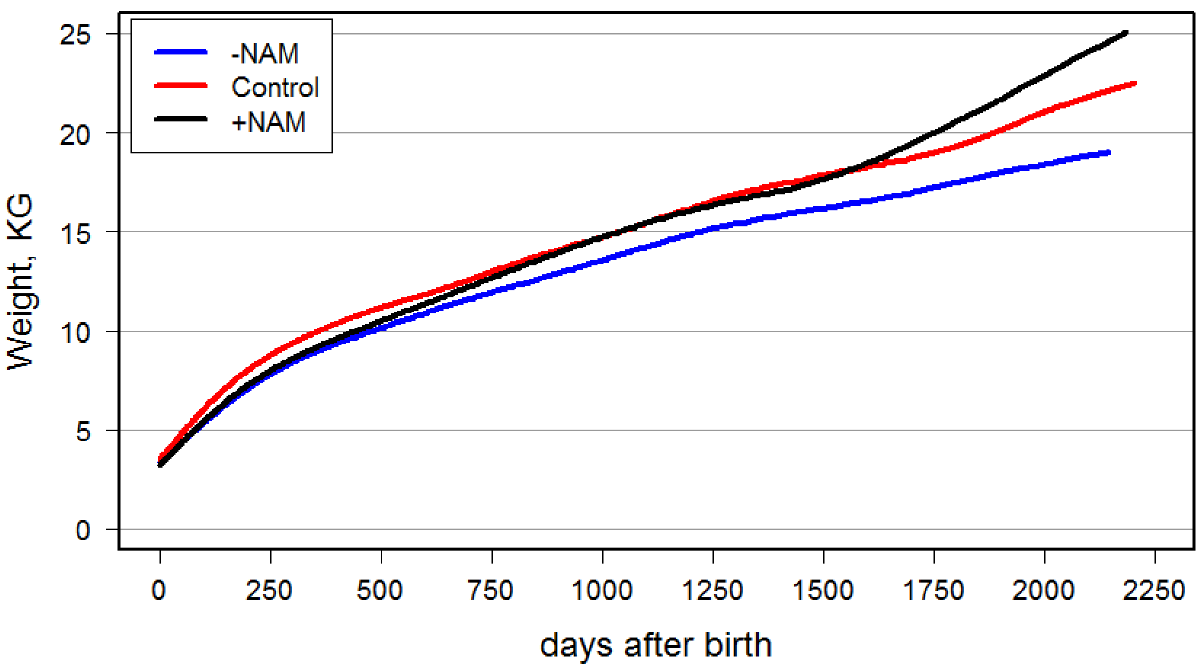


Figure II: -NAM Scatter Plot

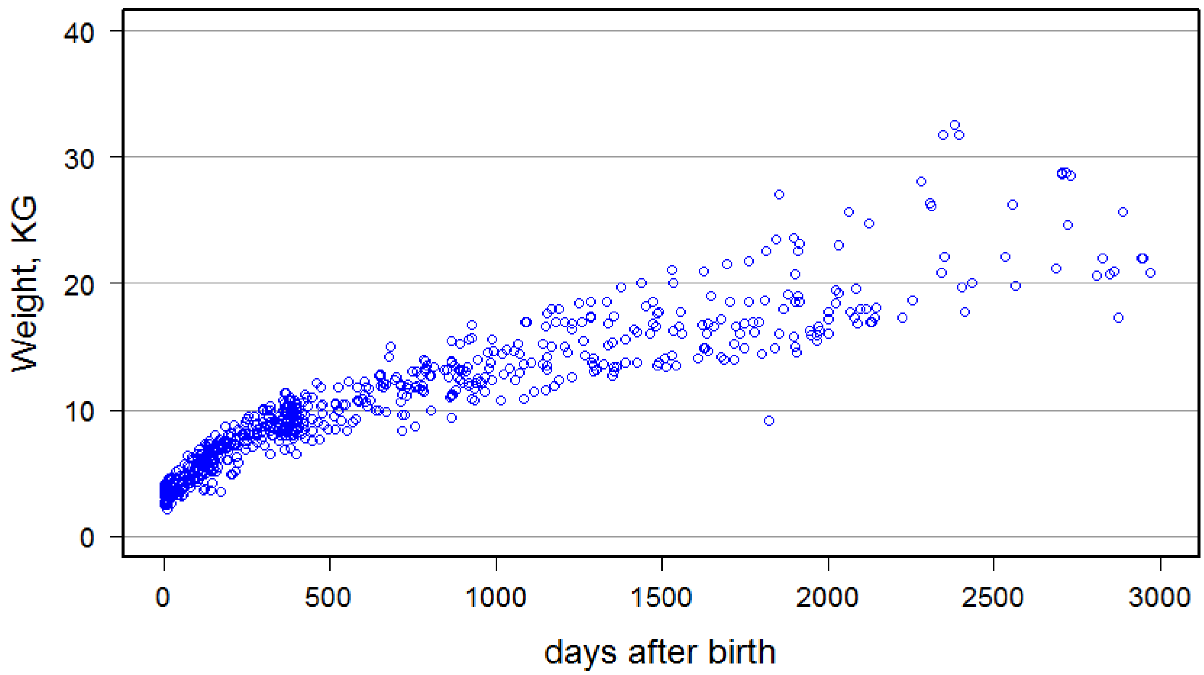


Figure III: C Scatter Plot

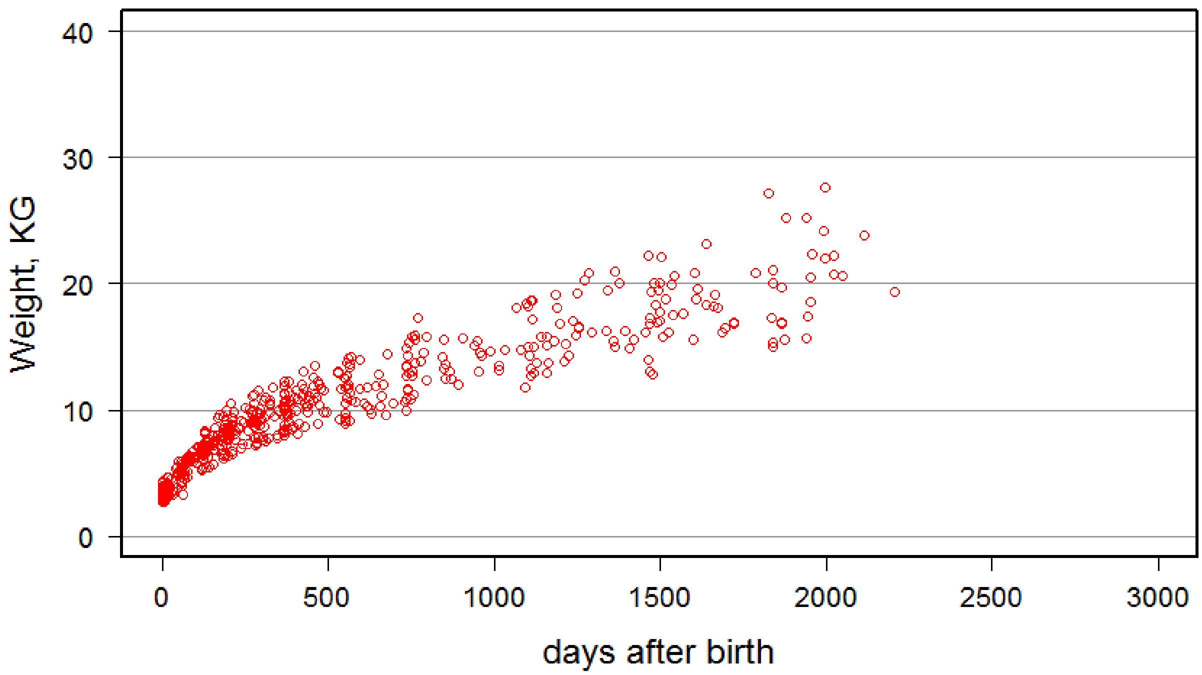


Figure IV: +NAM Scatter Plot

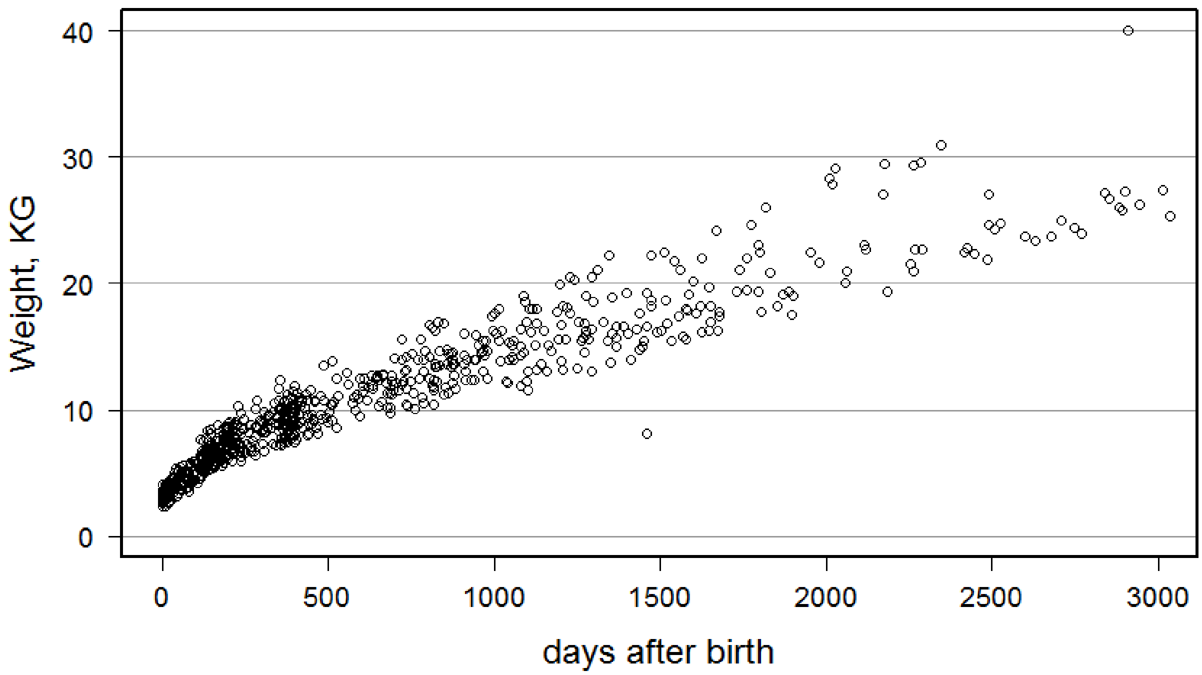


Figure V: Percent change from first measurement as outcome for all 3 treatment groups

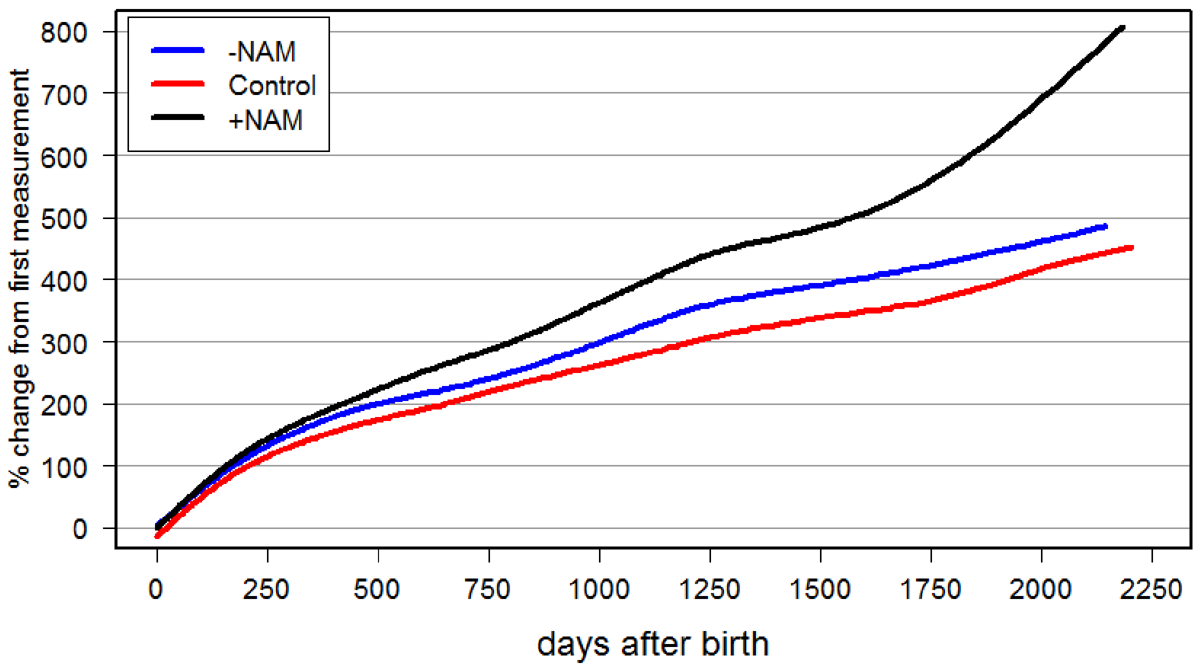


Figure VI: Weight vs Age from 0-9 Months

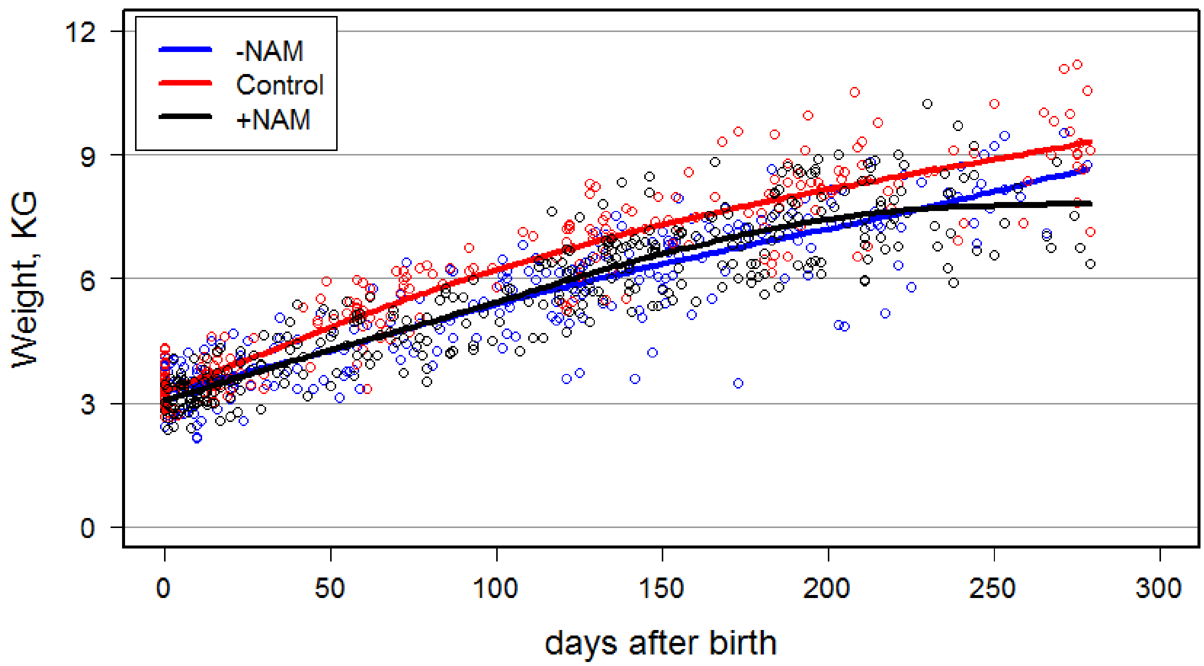


Figure VII: Weight vs Age Line of Best fit 0-9 Months

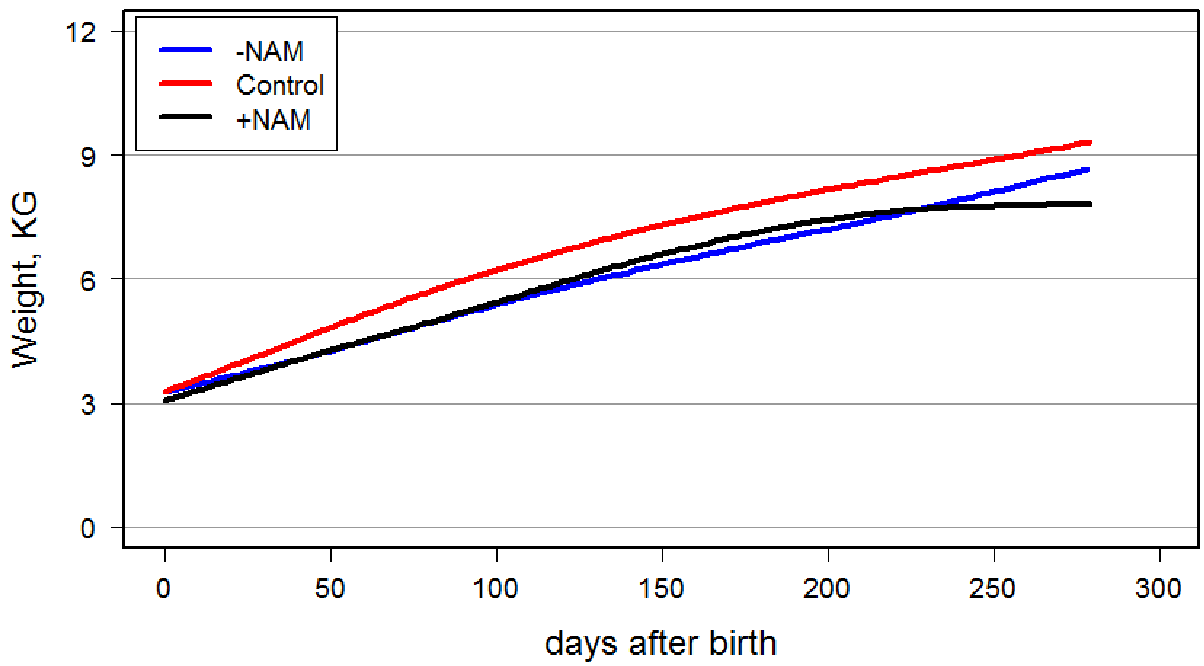


Figure VIII: Percent of Weight vs Age 0-9 months

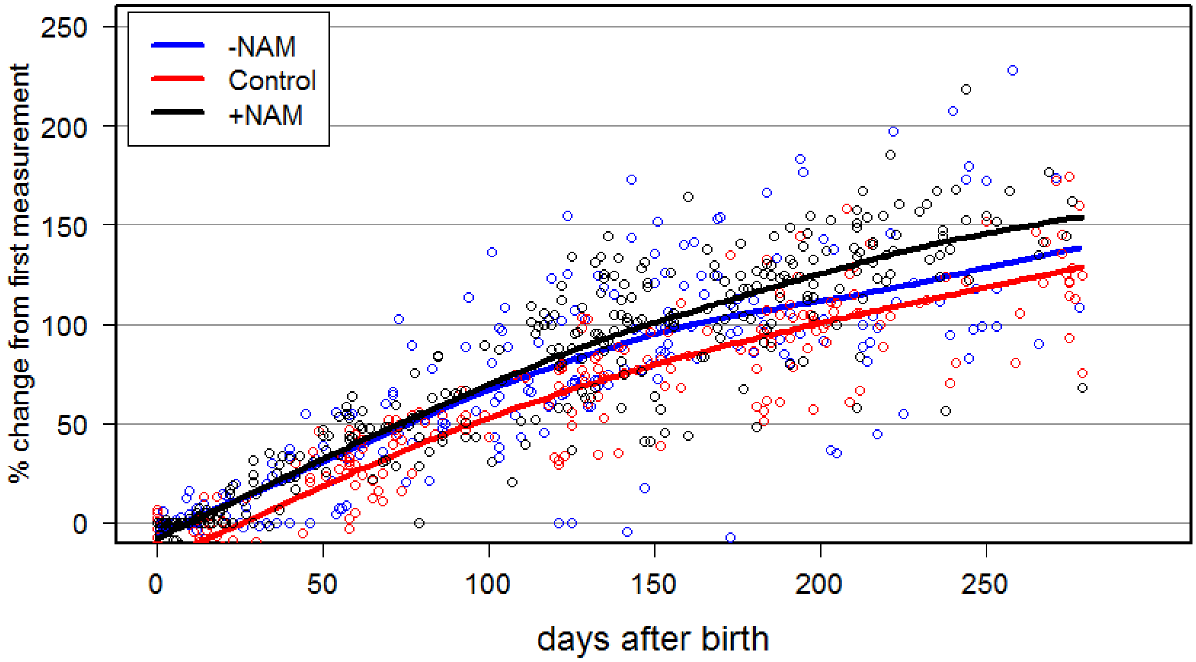
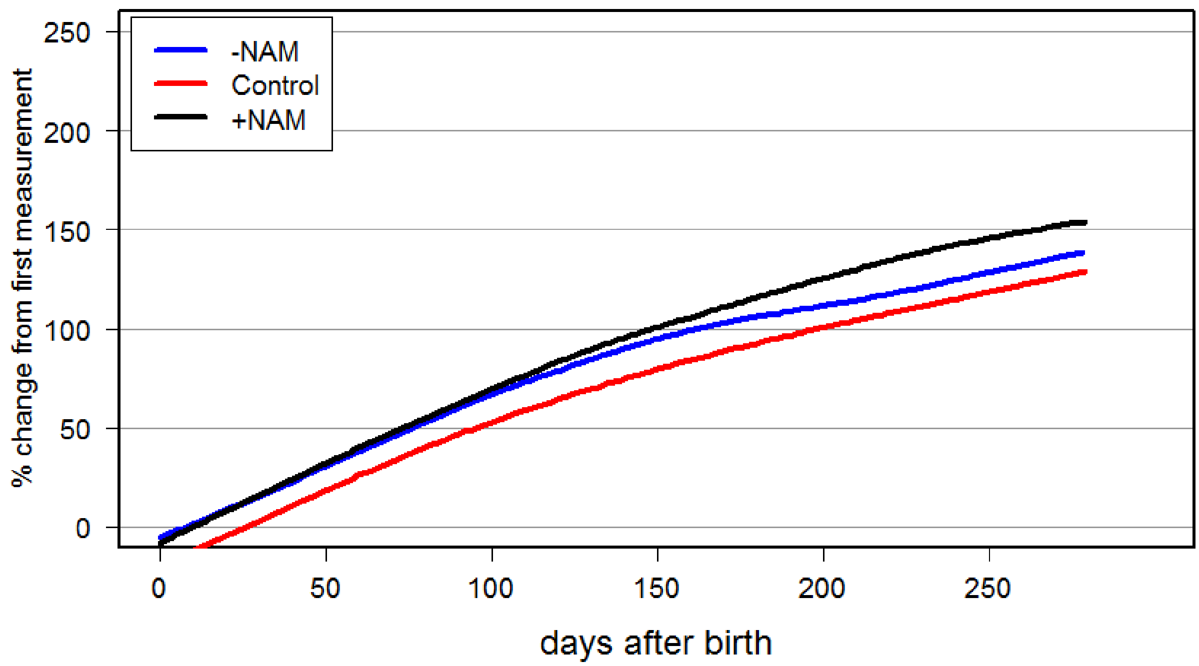


Figure IX: Percent of Weight gain vs Age 0-9 Months



LITERATURE REVIEW

Etiology, Incidence, and Diagnosis of Cleft lip and Palate

It is well documented that cleft lip and palate is the most common congenital anomaly affecting the face. The incidence of cleft lip, cleft palate, or both varies by gender, race, nationality, and the type of deformity. According to Cunningham et al incidence of CL/P among black patients is approximately 1:2500, in Caucasian patients 1:1000, and in Japanese patients 1:500 live births. [21] Clefting is currently known to occur in more than 250 syndromes. [21] Clefts can be present on one side (UCL/P), or both sides (BCL/P). The cleft can involve any one, or a combination of the lip, palate, soft palate and uvula. Some clefts are complete, where the oral cavity is in open communication with the nasal cavity or incomplete, where there is only a partial communication between the two cavities.

While variable, the unilateral cleft lip and/or palate (UCL/P) deformity is usually characterized by asymmetry and a wide nostril base and separated lip segments. The affected nasal cartilage is displaced laterally and inferiorly, which results in a depressed nasal dome. The asymmetric nostrils, deviated septum and distorted maxillary arch prove to be the primary reconstructive challenges. [16] The bilateral cleft presents with a rotated premaxilla anteriorly. The width of the alar base from nostril to nostril, and therefore the lip segments, are markedly wider. The nasal tip is usually flat and attached to the displaced prolabium, with a deficient or completely absent columella. [27.] The deficient columella and ectopic premaxilla are the predominant challenges faced in bilateral cleft lip and palate correction. [16]

Co-morbidities associated with clefting

Children and adults affected with a UCL/P or BCL/P may experience a wide range of associated co-morbidities. In addition to physical presentation of the cleft noted above, the psychosocial implications become apparent as children feel dissatisfied with their facial appearance and speech.[8] As the child grows into adulthood, the presence of CL/P is associated with reduced level of education, lower marriage rates, poorer economic performance, increased inpatient mental-health admissions, and higher mortality and suicide rates. [8]As a result, The American Cleft Palate Association Team Standards for cleft management should at a minimum include the involvement of surgeons, speech pathologists, and orthodontists to address the physical aspects, while access to other specialists, like social work, audiology, and genetics are also required standards. [13]

One of the earliest observed co-morbidities is a low birth weight and concomitant delayed weight gain. [1, 2, 3, 4, 5, 6. 7] Nyarko et al in the Journal of Pediatrics concluded infants born with a CL/P have twice the risk for low birth weight compared to non-cleft infants. On average, infants with a cleft are 100-600 grams lighter at birth, experience increased feeding problems and ear infections, require more surgical interventions, and increased hospitalizations when compared to non-cleft infants.

Feeding difficulties associated with clefts

Ineffective sucking, swallowing, and delayed weight gain are common co-morbidities resulting from the CL/P.[1, 2, 3, 4, 5, 6. 7] As many as 63% of infants born with non-syndromic unrepaired CL/P experience feeding difficulties, preventing the necessary negative intraoral pressure to draw milk into the oral cavity. [10] Studies have confirmed a cause and effect relationship between this feeding problem and poor weight gain in the first 2 years of life and illustrated a trend toward lower average weights for infants with CL/P compared to the non-cleft infants. [39, 1, 2,17, 3, 22, 7] Rudman noted a correlation between the presence of CL/P and a decrease in height in infants with CL/P. [38, 21] In some cases, severe feeding and swallowing issues have the potential to result in nutritional and/or respiratory compromise, as well as to create significant stress for families and caretakers. [11, 1, 13, 14, 7] Studies from Scotland, report as many as 29% of infants with CL/P demonstrated poor weight gain that required a naso-gastric tube (NGT) to assist in feeding while in the hospital or shortly after discharge to maintain sufficient nutrition. [23] Additionally Felix-Shollaart et al. agreed that feeding difficulties and intestinal disorders, in addition to airway infections, had a negative influence on growth, measured by weight and height. [25]

In the normal non-cleft infant feeding pattern, sucking is achieved though the combined tasks of generating negative intraoral pressure and making effective intraoral muscular movements. Negative intraoral pressure is accomplished by sealing the lips and velopharynx and expanding the intraoral cavity, either with contraction of the tongue or movement of the mandible. Infants with CL/P are unable to seal their lips or the velopharynx and therefore cannot provide the necessary negative intraoral pressure needed suck milk into the oral cavity. [9, 10, 11,1, 12,13, 4, 5]

The loss of negative pressure is due to air exchange between the nasal and oral cavities. This often results in prolonged feeding times, nasal regurgitation, increased risk of choking and aspiration, and an infant that fatigues before a full feeding due to increased effort and energy expenditure. This inadequate nutritional intake during a critical growth period can result in growth failure, impaired immune function, decreased major organ function, and delayed surgical healing and changes in behavior. [5] Many studies report that the Habermann nipple feeder (also termed the Medela Special Needs Feeder) or the Pigeon Nipple, provides a specialized anti-chamber that helps the infant draw the milk into the posterior of the oral cavity for sucking and swallowing. [13] Additional resources include a squeezable plastic feeding container equipped with a long narrow nipple that permits formula to be squeezed into the pharynx without sucking. [5] Lastly, a caretaker can squeeze milk into the oral cavity if an adequate feeder cannot be identified.

Prior literature on surgical correction

The prognosis for correction of the physical deformities depends on the severity of the cleft, access to multidisciplinary care, finances, and family compliance. Historically early lip repair surgery without orthopedic alveolar intervention lead to a poorer surgical prognosis. Currently, the treatment protocol at several cleft centers around the world involves primary lip repair at 3-4 months of age, which may or may not be followed with alveolar alignment or alveolar bone grafting. [41] C Kerr McNeil, in 1995, pioneered a study examining orthodontic procedures associated with surgical correction of CL/P. McNeil concluded that following surgical closure of the lip cleft, the resultant pressure of the soft tissues of the upper lip upon the malformed maxilla may produce unfavorable lateral collapse of the arch, this collapse can be exacerbated by tension on the palatal tissues from surgical closure. [35] Since this study, it is well established in the literature that surgical repair alone cannot solve the multiple deformities that arise from clefts of the lip and palate. [42, 41, 30]

Pre-surgical management of the cleft was first documented by McNeil in 1954 and later modified by Burstone in 1958.[20] Since 1950, many early goals of pre-surgical orthopedics were to facilitate proper infant feeding, maintain the appropriate position of the palatal shelves and induce narrowing of the cleft width, which in turn would improve the prognosis of the surgical repair. [41, 30, 20] Since then these goals have not been confirmed controversy still exists as to the unrealistic claims of the early proponents. [41] Many outdated early orthopedic devices utilized head straps, orthodontic elastics, surgical tape and a series of wires to re-approximate the lip and palate, but did not address the deficient columella or depressed nasal cartilages. [41]

History of the NAM appliance

In an effort to address the deficient columella and concave nasal cartilages, in 1993, Dr. Grayson introduced the technique of Nasoalveolar Molding (NAM). Unlike prior presurgical infant orthopedic techniques, NAM was the first to directly address the nasal deformity. The NAM appliance consists of a removable acrylic alveolar plate with an acrylic bulb at the end of a 0.036 inch stainless steel wire that extends from the plate into the nostril. [16], [41] Matsuo tested the efficacy of molding nostril cartilage in very young infants. [27] Mustuo recognized that cartilage in the newborn was soft and lacked elasticity. [27] He postulated the elevated levels of maternal estrogen and hyaluronic acid observed shortly after birth in the infant could act to inhibit cartilage intercellular matrix crosslink formation. These increased levels are thought to facilitate the relaxation of ligaments as the fetus passes through the birth canal. However, these levels are short-lived and begin to decline to normal 6 weeks after birth. According to Matsuo, birth to 6 weeks is therefore the optimal window to perform NAM therapy, as the nasal cartilage is still capable of plastic deformation. [27] While the optimal time for initiation and termination of NAM therapy has been much discussed, Shetty et al concluded that subjects who received the NAM device within the first month of life displayed the greatest improvement in intersegment distance, nasal height, nasal dome height and columella height when compared to control subjects. [41]

Objectives of NAM therapy

Grayson outlines that the principal objective of NAM therapy is to reduce the severity of the initial cleft deformity. This enables the surgeon to benefit from the repair of an infant that presents with a minimal cleft deformity at the time of surgery. Additional objectives of NAM therapy include restoring symmetry to severely deformed nasal cartilages, achieve projection of the flattened nasal tip, nonsurgical elongation of the columella, alignment of the alveolar ridges and reduction the overall distance between the lip segments. [16]. In prior studies, the average decrease in the alveolar intersegment distance has been reported to be 8.4 to 12.1mm. [42, 41] Surgical tapes actively bring the lip segments together in conjunction with the molding plate. Taping the lips together helps to upright the inclined columella along the mid-sagittal plane. In addition to columella retraction, the stent can help to correct the depressed concave nostril shape. As reduction of the alveolar gap width is accomplished, the base of the nose and lip segments align. [27] The alar rim, which was initially stretched over a wide alveolar cleft deformity, shows laxity and elevates the cartilage into a symmetrical and convex form.[27] The nasal tip on the cleft side is over-corrected in its forward projection, which is accomplished via the nasal stent, the molding plate and surgical taping.[27] In the infant with bilateral clefts of the lip alveolus and palate, the objective of presurgical NAM therapy includes the nonsurgical elongation of the columella, centering the premaxilla to achieve continuity with the posterior alveolar cleft segments. [27]

The timing of CL/P corrective surgery is important as the cleft team must be careful not to hinder hard or soft tissue growth when possible. Hotz claims pre-surgical orthopedics is critical in order to meet functional requirements while surgical intervention is postponed to allow the maxillary segments to grow to their full potential. From a 10 year Zurich growth study, Hotz states the single stage palatal closure (also referred to as the "Combined French-German technique") involved lip closure at age 3 to 6 months and palatal closure at age 2 to 2 ½ with mucoperiosteal flaps. At the 8-year mark, most patients with single stage palatal closure at age already displayed a strong tendency towards maxillary retrognathism, whereas the group with delayed closure of the hard palate cleft, the viscerocranium was well proportioned. [30, 20] Additionally, preoperative orthopedics with a delayed surgery allows time to remove the action of the tongue from the cleft area, thereby freeing the palatal shelves and removing any potential constraint on the cleft, perhaps closing additional space prior to surgical correction. [20, 32, 30] The delay of surgery helps minimize the palatal scar tissue and results in a higher overall palatal vault. [30] Additionally, avoiding radical primary surgery can prevent the maxillary growth restrictions seen a result of extensive scar tissue. [20] For optimal nasal alar correction, the surgery should be delayed as long as possible to prevent scar tissue around the alar cartilage. [34] As mentioned earlier, the anatomical defects suffered by children with CL/P are known to cause early difficulties with weight gain. However Lee et al confirm that while cleft palate was associated with significant growth faltering in early infancy, rapid recovery took place following surgical repair and resulted in no residual growth deficiency. [6]

Conclusions from the literature

Not all authors agree that pre-operative orthopedics influence weight gain. The Dutchcleft study examined the efficacy of *alveolar molding appliances* (which unlike the NAM device was lacking the nasal stent) in weight gain. The study concluded that "infant orthopedics with the aim of improving feeding and consequent nutritional stats in infants with unilateral cleft lip and palate can be abandoned".[17] The author concludes that the presence of the orthopedic plate made no difference in the ability of infants with a cleft to generate the necessary negative pressure in the mouth. [17]The average weight-for-age and weight-for-length measurements were not statistically different between the treatment group and the control group. However, overall the infants with cleft lip and palate demonstrated significantly lower weight-for-age during the first 14 months when fed with a passive maxillary plate, which coincides with prior literature. [17] To date, there is not a study comparing NAM therapy and infant weight gain.

Appendix A: Recommendations for future research

There are many factors that can influence weight gain in a growing infant. This study attempted to control as many factors as possible within a respective study, however there are many factors that could be evaluated. It would be ideal to identify if the UCL/P children had different weight gain pattern than the BCL/P children. In addition, there may be variations in weight gain between males and females (which is reflected in the literature).

While it is impossible to evaluate if socioeconomic status had an effect on weight gain, it would be valuable to track the frequency of each patients appointments and access to care, such as access to lactation consultants and ENT for ear infection management. All of these factors can affect weight gain and would add to the body of literature on NAM therapy.