UCD GEARY INSTITUTE DISCUSSION PAPER SERIES

"Breast is Best, But for How Long?

Testing Breastfeeding Guidelines for Optimal Cognitive Ability

Dr. Orla Doyle
UCD Geary Institute & UCD School of Public Health and Population Science,
University College Dublin, Belfield, Dublin 4, Ireland
E-mail: orla.doyle@ucd.ie

Lori Timmins
Department of Economics, University of British Columbia, Vancouver, Canada

Acknowledgements: Permission to use the Millennium Cohort Study given by the ESRC Data Archive at Essex is gratefully acknowledged. Thanks to Kevin Denny and participants at the Royal College of Physicians of Ireland, Faculty of Public Health Medicine Winter Scientific Meeting and the UCD Geary Institute Symposium on Health and Behaviour for comments and suggestions.

Abstract

Objectives: To investigate the relationship between breastfeeding duration and cognitive development using longitudinal survey data. The World Health Organisation (WHO) and the American Academy of Pediatrics (AAP) recommend exclusive breastfeeding until six months post-partum and a combination of complementary foods and breast milk thereafter. This study estimates non-parametric regression models to test whether these recommendations also hold for cognitive ability.

Design: Longitudinal cohort study with two waves of 18,819 children who were born in the UK between 2000-2002. We estimate several generalised additive regression models to examine the impact of exclusive and non-exclusive breastfeeding duration on cognitive ability, while controlling for a range of confounding family characteristics.

Setting and Participants: Participants of the UK Millennium Cohort Study (MCS).

Main outcome measures: Cognitive development at age three as measured by the Bracken School Readiness Assessment.

Results: The models identify a non-linear relationship between exclusive and non-exclusive breastfeeding and cognitive ability. There are high initial positive returns to exclusive breastfeeding which peak at six months, with the returns to non-exclusive breastfeeding continuing to increase until 10/12 months. These results suggest that the WHO/AAP guidelines recommending exclusive breastfeeding for the first 6 months of life also hold for optimal cognitive ability. The models also show that the optimal switching point from exclusive to non-exclusive breastfeeding occurs at six months, and that a combination of breast milk and solids should continue until thereafter, peaking at 10 months.

Conclusion: While breastfeeding recommendations primarily target physical growth and development, our study confirms that such recommendations are also optimal for cognitive development. These results provide further evidence that recent UK policy initiatives to extend paid maternity leave is appropriate for the maximal development of the child's cognitive ability. While this study controls for a range of confounding factors, there may still exist unobserved family characteristics which mediate this relationship.

I. INTRODUCTION

The World Health Organisation (WHO)[1] and the American Academy of Pediatrics (AAP)[2] recommend exclusive breastfeeding for the first six months of life, with the introduction of complementary foods thereafter. These guidelines implicitly suggest that the benefits to breastfeeding are non-linear, such that some defined point exists at which the returns to exclusive breastfeeding either levels off or diminishes. These recommendations are primarily based on the physical health and development of children rather than their optimal cognitive development.[3] Yet in developed countries, gains in cognitive skills are considered a key benefit of breastfeeding, as the reliance on breast milk for protection against infections and infant mortality plays a less critical role than in developing countries.[4]

Comparable guidelines on the optimal duration of breastfeeding for maximising cognitive development is lacking, despite the large literature linking breastfeeding to neurodevelopment which can be traced back the 1920's.[5] Much of this literature is concerned with identifying the causal links between breastfeeding and later cognitive outcomes, with several studies demonstrating that the link is significantly reduced when one controls for potential confounding factors such as maternal IQ and the quality of the home environment.[6] Yet the question of the optimal duration of breastfeeding has received less attention. In general, evidence shows that the incidence of breastfeeding and longer periods of breastfeeding are associated with higher cognitive scores,[7] yet there are few studies which explicitly test the impact of exclusive and non-exclusive breastfeeding duration on cognitive development.[8]

Typically breastfeeding studies use binary measures comparing breast fed and formula fed children, with some studies using categorical variables representing differential lengths of breastfeeding. Yet such a simple categorisation, based on broadly defined time periods, cannot capture the point at which the marginal benefits, or the returns, to cognitive skills are optimised. If the relationship between breastfeeding and cognitive ability is causal,

then using the quantity of breast milk is the most appropriate tool for testing this relationship.[9] This is best quantified using a continuous measure of breastfeeding duration which distinguishes between exclusive and non-exclusive breastfeeding. Studies using such continuous measures of breastfeeding duration, defined in weeks or months, are less common due to data collection constraints. That measures of breastfeeding duration are somewhat arbitrarily defined may help explain why the evidence in this field is inconsistent. In addition, where continuous measures are used, they are often treated linearly i.e. they assume that a longer period of breastfeeding (for example one week) is associated with the same cognitive gain. Yet treating breastfeeding as a categorical factor or assuming a linear relationship is not consistent with the WHO/AAP guideline recommendations in terms of physical health which assumes that the benefits diminish after some point. These methods fail to capture any non-linearity that may exist between the breastfeeding and cognitive ability relationship.

This study provides the first known test of the WHO/AAP guidelines for cognitive development. Using a large-scale longitudinal cohort survey this study applies semi-parametric techniques to test the linearity of the association between exclusive and non-exclusive breastfeeding duration and cognitive ability at age three, while controlling for a range of potentially confounding factors. This has particularly important policy consequences in the UK where the incidence of breastfeeding is substantially below the recommended guidelines. The UK Infant Feeding Survey for 2005 showed that while 76% of women initiated breastfeeding, only 35% exclusively breastfed at one week and this fell to 3% at five months.[10] At the WHO recommended duration of 6 months, less than 1% of UK children were exclusively breastfed, and 25% were non-exclusively breastfed. Recent policy initiatives to promote the incidence and duration of breastfeeding, such as extending the period of paid maternity leave, have been adopted.[11] Given these initiatives, it is important to test whether these guidelines on the optimal length of breastfeeding, not only for healthy physical development, but also importantly for elevated cognitive development.

II. DATA AND METHODS

The Millennium Cohort Study (MCS) is a longitudinal study of 18,819 children who were born in the UK between 2000-2002. The sample was clustered geographically by electoral wards and was constructed to over-represent areas of disadvantage, communities with high concentrations of ethnic minorities (England only), and the three smaller countries of the UK. The sample was identified through Child Benefit records provided by the Department of Social Security. The overall response rate was 72%.[12] This study utilises the first two waves of the survey. Wave 1, which was conducted when the children were nine months old, interviewed mothers and their partners on questions relating to the pregnancy and the delivery, breastfeeding practices, the child's health and development, childcare and parenting practices, and their participation in employment and education. The second wave was conducted over two years later, and contains information on the parental situation, child's health, childcare, employment and income, as well as the nature of parenting activities. The children's cognitive and social-emotional development were assessed in addition to measures of their health. Details of the MCS are published elsewhere.[13] A number of studies to date have used the MCS data to examine ethnic[14] and social class[15] differences among breastfeeding practices, the impact of breastfeeding on gross and fine motor skills,[16] and the impact of maternal employment on breastfeeding initiation[17] and duration[18], yet none to date have examined the issue of breastfeeding duration and cognitive ability.

Outcome measure

The primary outcome measure is cognitive ability at age 3 as measured Bracken Basic Concept Scale-Revised (BBCS-R) School Readiness Assessment. Six of the eleven sub-tests of the BBCS-R were used to assess the children's knowledge of colours, letter identification, numbers/counting, sizes, comparisons and shape recognition.[19] In total, 88 concepts were tested to determine the children's basic concept development. The normed standardised composite score is used which represents the percentage of children in the sample who ranked

at or below the child's score. The Bracken scale has been validated and correlates well with other standard measures of cognitive ability, such as the PPVT-R (r=0.74 to 0.88). It has also been used to predict future academic achievement.[20]

Breastfeeding definition

Exclusive breastfeeding is defined as the number of weeks the child was exclusively fed breast milk from birth. Non-exclusive breastfeeding is defined as the number of weeks the child was fed both breast milk and some other form of supplementary formula or solids. While this data were collected retrospectively at nine months post partum, the reliability and validity of breastfeeding recall has been demonstrated in other studies.[21]

Non-exclusive breastfeeding was initiated for 73% of the estimation sample of 12,254 children, while 27% never experienced nay breastfeeding. Our estimation sample only includes those present in wave 1 and 2 with full information on our variables of interest. Within the sample, 12% were non-exclusively breastfed for one week or less, 25% continued to be breastfed until 4 months, 10% were breastfed for a further two months and a further 25% were non-exclusively breastfed beyond six months. In terms of exclusivity, 36% of the total sample were never exclusively breastfed. 12% were exclusively breastfed for at least one week, a further 35% of the sample were exclusively breastfed for between one week and four months, 16% of the sample were exclusively breastfed for between four and six months, while just 1% of the sample were exclusively breastfed beyond six months.

Figure 1 shows the distribution of the duration of exclusive breastfeeding (in completed weeks) for mothers who ever initiated breastfeeding. It identifies two main peaks, the first at one week postpartum, with 21% of mother who ever initiated breastfeeding stopping exclusive breastfeeding at that point, and the second at week 17, with a further 21% stopping. This is consistent with previous studies which identify a relationship between the timing of maternal return to employment and breastfeeding duration.[22] In 2000, at the time of the cohort's birth, UK maternity leave policy provided mother with 18 weeks of paid

maternity leave[23] and the UK government recommended breastfeeding for at least four months. We therefore find that many mothers stop exclusively breastfeeding their child in the week prior to the end of their paid maternity leave.

Confounders

Potential confounding variables include a range of child, maternal and family factors. Child characteristics include gender, age in months, birth weight in kilograms, ethnicity, and number of siblings. Maternal characteristics include age at the time of the child's birth; age at the birth of her first child; marital status at the time of birth; an indicator of employment at the time of the first interview; an indicator of low maternal education, measured by leaving school at age 16 or before and obtaining no educational qualifications. Other maternal characteristics include: maternal stress as measured by the Malaise Inventory questionnaire[24]; maternal attachment as measured by a short-form Condon Maternal Attachment Scale[25]; and an indicator of whether the mother smoked during pregnancy. Family characteristics include a measure of the quality of the home environment as measured by the Home Observation for Measurement of the Environment (HOME).[26]

Statistical methods

All semi-parametric analyses were conducted using R[27] with sampling weights to adjust for over sampling of disadvantaged wards and to obtain robust standard errors. A key feature of this study is to move beyond the standard logistic and linear regression models which typify this field. Most studies assume that the relationship between breastfeeding duration and cognitive ability is linear. For example, cognitive ability increases/decreases by the same factor with each additional week of breastfeeding, for all weeks of breastfeeding regardless of the actual duration i.e. for all values of the explanatory variable. However, as suggested by the WHO and AAP recommendations, the relationship between breastfeeding and cognitive development may not be the same for all durations of breastfeeding.

The aim of this study is to capture any non-linearity within the breastfeeding/cognitive ability relationship using a generalised additive model (GAM). Generalised additive models do not impose linearity on the relationship of interest; rather it allows one to fit one or more explanatory variables i.e. breastfeeding duration, with non-parametric (non-linear) functional forms. The GAM replaces the linear form with a sum of smooth functions which are estimated using a smoothing spline function and backfitting.[28] The advantage of GAM is that it provides a better fit to the data by allowing the relationship between breastfeeding duration and cognitive ability to vary across the whole distribution. Another feature of GAM is that it does not produce a set of regression coefficients as in a standard linear model as it estimates the impact of each individual week of breastfeeding on ability. Therefore graphical methods are used to interpret the non-parametric components of the models. Overall a GAM matches the flexibility of a non-parametric model, with the ease of interpretation associated with linear models.[29]

We estimate four generalized additive models examining the impact of exclusive and non-exclusive breastfeeding on cognitive development, both including and excluding cofounding factors. These are considered semi-parametric models, as breastfeeding duration is allowed to enter the model non-parametrically, while the confounding variables are treated linearly – that is conventional regression coefficients are estimated for these variables.

III. RESULTS

Figures 2 and 3 provide the graphical representation of the GAM results for the non-parametric components. Figure 2 represents the relationship between length of exclusive breastfeeding and child cognitive development measured at age 3. The model on the right-hand side controls for all the potential confounding factors listed above, while the model on the left-hand side excludes them. The solid line is the fitted smooth function, and the dotted

lines indicate the 95% confidence bands. The marginal benefits to breastfeeding are referred to as the returns to breastfeeding, which are represented by the slope of the line.

Figure 2a shows that there are high initial returns to exclusive breastfeeding up to 5 weeks postpartum as indicated by the steep initial curve. The returns then continue to increase steadily, albeit at a lower rate, peaking at 23 weeks, and then declining after this point. However, note that the confidence intervals widen at the decline reflecting the fact that there are relatively few observations in this range. Figure 2b estimates the same model of exclusive breastfeeding but controls for a range of confounding factors, as outlined previously. The overall curve is shifted downwards and flattened, indicating that the returns to breastfeeding are reduced once one controls for confounders, regardless of the breastfeeding duration. Yet there are still high initial returns to breastfeeding until 6 weeks, with the returns then levelling off and remaining constant until 16 weeks before continuing to rise until it peaks at 28 weeks (approximately 6.5 months).

Figure 3 examines the relationship between length of non-exclusive breastfeeding and cognitive development. Figure 3a shows increasing returns to non-exclusive breastfeeding which peaks at 26 weeks and then levels off. The returns are therefore constant between 6 and 10 months postpartum. The confidence bands in this model, apart from durations of 45 weeks or more, are narrow indicating greater precision. Figure 3b shows that the curve shifts downwards when confounders are included. In this model, after high increasing returns until 12 weeks, the returns steadily rise until 45-50 weeks, with the confident bands widening at this point.

Finally, we find that all the additional confounders have a statistical significant effect on cognitive ability in both the exclusive and non-exclusive models. [1]

[1] Due to space constraints, these are not presented but are available from the authors on request.

IV. DISCUSSION

The GAM models estimated here identify a non-linear relationship between breastfeeding duration and cognitive ability. The optimal length of exclusive breastfeeding is approximately 28 weeks, which corresponds to the WHO/AAP guidelines of six months. While higher returns are associated with exclusive breastfeeding until six months, we also find a non-linearity in shorter durations of breastfeeding with the returns to exclusive breastfeeding being almost identical for those who stop exclusively breastfeeding between 6 and 16 weeks. The optimal duration of non-exclusive breastfeeding peaks at approximately at 10-11 months, again confirming the current guidelines indicating that the benefits of exclusive breastfeeding level off sooner than non-exclusive breastfeeding. Importantly, given a specific duration of breastfeeding, exclusive breastfeeding leads of higher levels of cognitive ability than non-exclusive breastfeeding.

This study confirms that the current WHO/AAP guidelines hold for cognitive development. However the results represent an association between breastfeeding and cognitive ability, rather than necessarily identifying a causal relationship. The dominant methodological debate throughout this literature concerns the causal nature of this relationship.[30] Recent work posits that this link may be driven by selection bias, whereby the type of mother who chooses to breastfed is also the type of mother who provides a cognitively stimulating environment for their child. Studies show that the link between breastfeeding and cognitive development is significantly reduced when one controls for potential confounding factors such as maternal IQ and the quality of the home environment, which may both influence the decision to breastfeed, while having an independent effect on the child's ability.[31] In this study we control for a wide range of confounders, including a measure of the quality of the home environment, and several maternal characteristics such as depression and attachment to the child to account for this. Nonetheless the benefits to breastfeeding remain significant. However caution should be applied when interpreting our results as causal. Further

work identifying the causal nature of this relationship is needed using either sibling difference models[32] or two stage least squares[33].

The current emphasis on identifying the underlying relationship between breastfeeding and ability has been conducted in isolation from other pressing methodological issue in the area - the dosage effect. Yet, distinguishing between exclusive and non-exclusive breastfeeding and using methods that enable the test of the optimal duration of breastfeeding in a flexible non-parametric manner, may help further the causality debate. For example, one of the primary explanations for the relationship between breastfeeding and ability is that several components of breast milk, such as long chain polyunsaturated fatty acids,[34] growth factors,[35] and cholesterol choline, and fat soluble vitamins[36], can influence neurodevelopment. The findings in this study indicate that children who received longer durations of exclusive breastfeeding up until six months have greater cognitive scores than children who were exclusively breastfed for shorter periods. This suggests that the quantity of breast milk may matter for cognitive ability. This is consistent with the explanation that breastfeeding has a direct effect on ability i.e. is causal, rather than being a correlate.

V. CONCLUSION

There is an extensive literature identifying a link between breastfeeding and neurodevelopment, such as cognitive ability, visual development, and neuromotor development. For a detailed review see Petryk, Harris and Jongbloed (2007).[37] Our analysis extends this literature by addressing the current need to include an appropriate dose-type classification of breastfeeding which distinguishes between exclusive and partially breastfed children. A limited number of studies have identified a positive dose-response, with longer durations of breastfeeding being associated with higher cognitive scores.[38,39,40] Yet the methods employed in many of the previous studies impose unnecessary assumptions of linearity on the data and preclude the analysis of the optimal duration of breastfeeding.

Estimating the point at which the returns to breastfeeding is optimised is important, as assuming that more is always better, as a linear model might demonstrate, can have serious consequences for employment policies and maternal well-being. For example, during the collection of the first wave of the MCS data, the UK recommendations were based on four months exclusive breastfeeding,[41] which corresponded with the existing maternity leave policies at that time. Subsequently, for the women in our sample who did initiate breastfeeding, a large proportion of them stopped exclusively breastfeeding at four months. In addition, previous work has found that women who return to work within four months after birth are less likely to initiate breastfeeding.[42] Rates of breastfeeding in the UK are among the lowest in Europe[43] and recent initiatives have been introduced to increase both breastfeeding initiation and length of duration by ~2% per annum.[44] UK maternal leave policy has been amended several times within the last decade, including the extension of statutory maternity payments to 26 weeks in 2003[45] and 39 weeks in 2007[46]. Given this current policy change and the evidence that women breastfeeding decisions are directly affected by these policies, determining the optimal duration of exclusive and non-exclusive breastfeeding using sound statistical methods is an important exercise. The results in this study imply that the 2003 extension to six months paid leave was, in fact, sufficient for promoting the optimal amount of exclusive breastfeeding, yet the 2007 extension to nine months may help improve the incidence of non-exclusive breastfeeding.

It should be noted that this study only examines the consequences for cognitive development, rather than the overall physical health of the child, which the guidelines were original developed to address.

Figure 1 Distribution of Exclusive Breastfeeding

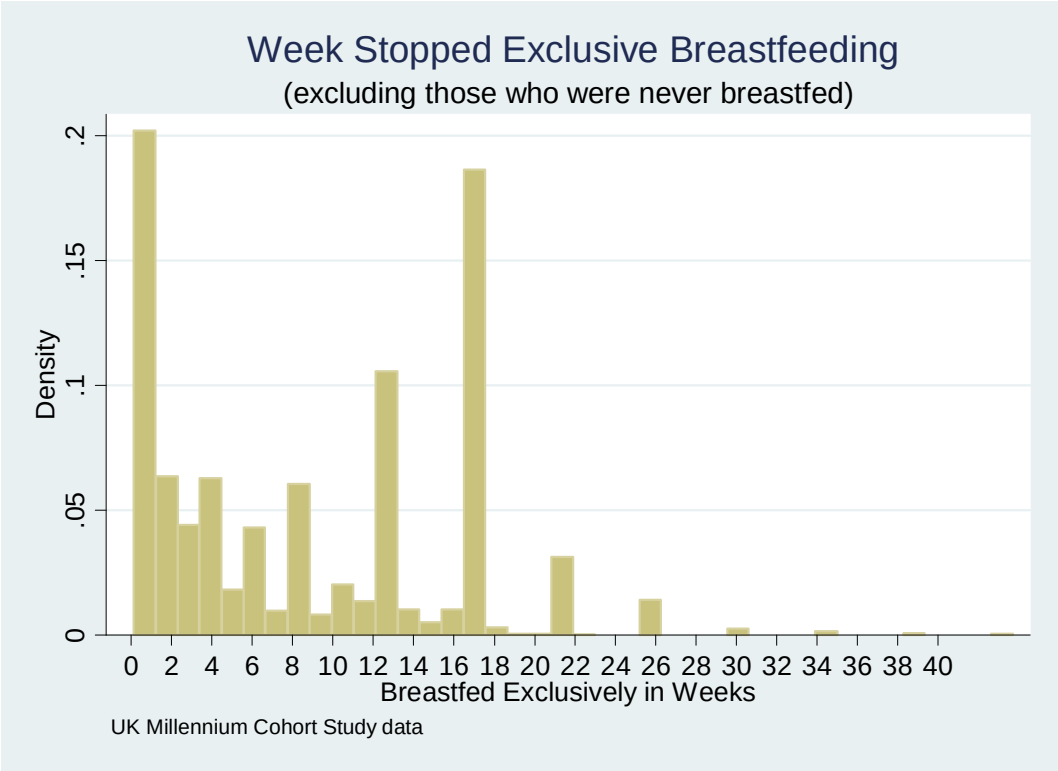


Figure 2 Cognitive Ability & Exclusive Breastfeeding

Figure 2a

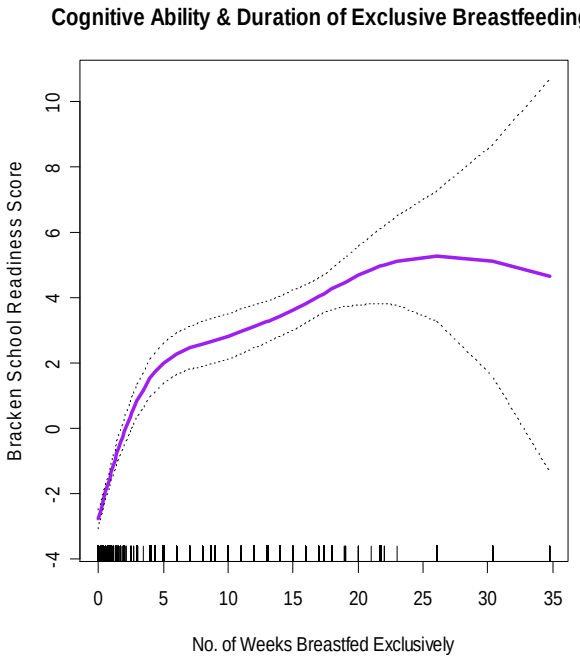


Figure 2b

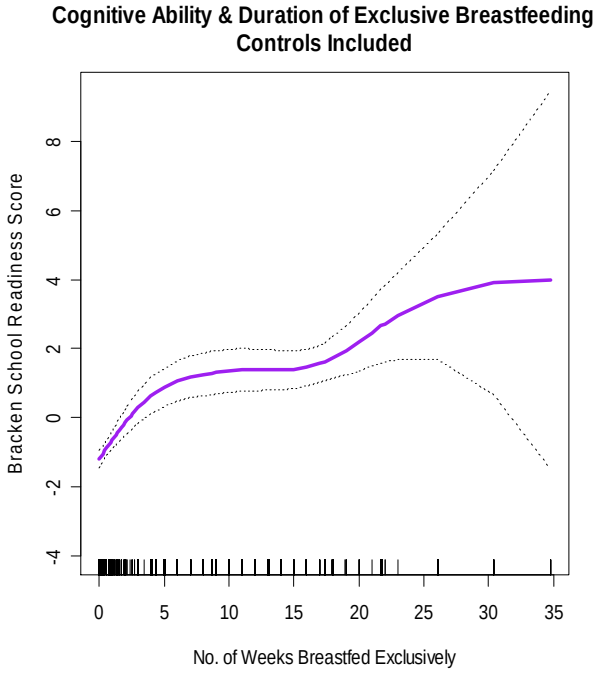


Figure 3 Cognitive Ability & Non-Exclusive Breastfeeding

Figure 3a

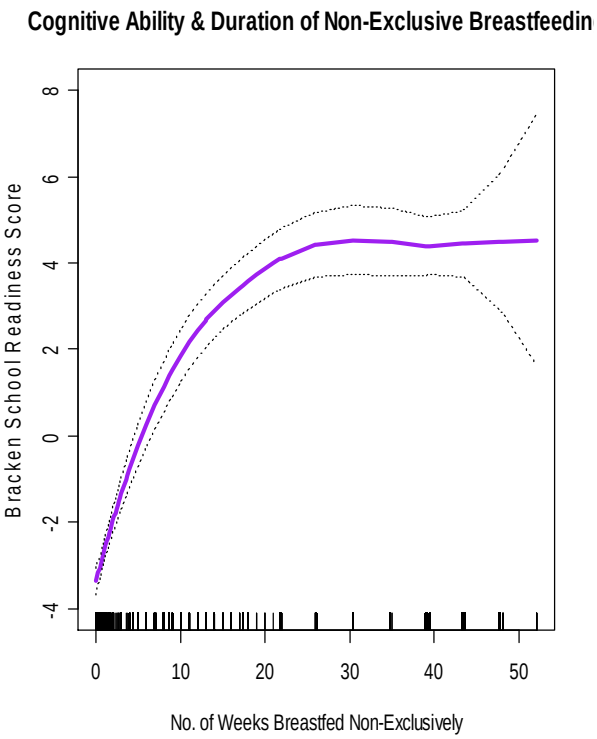
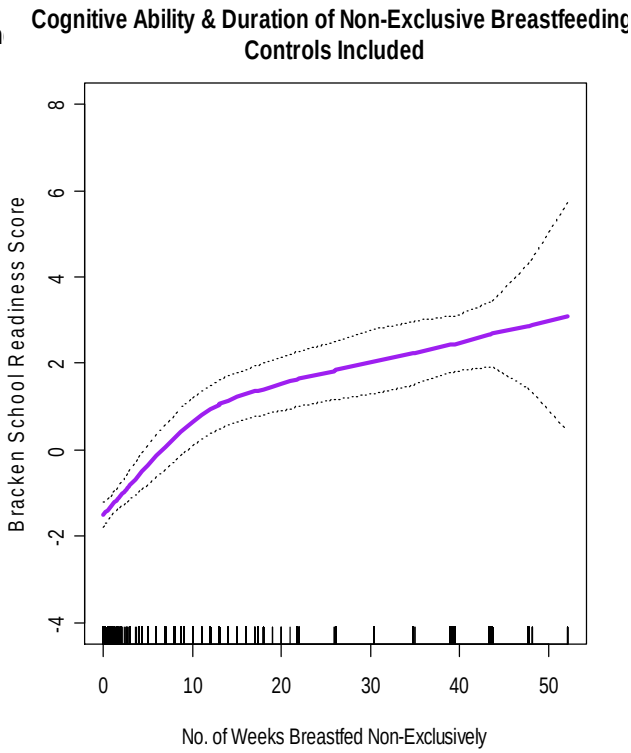


Figure 3b



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