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Breastfeeding and motor development: A longitudinal cohort study

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Breastfeeding and Motor Development: A Longitudinal Pregnancy Cohort Study

1. Introduction

Breastfeeding has been linked to a number of positive developmental outcomes including optimal neural (McCroy & Murray, 2013) and early brain development (Herba et al., 2013), improved immunity (Oddy & Rosales, 2010), mental health (Oddy et al., 2010), language ability (Dee, Li, Lee, & Grummer-Strawn, 2007; Whitehouse, Robinson, Li, & Oddy, 2010), cognitive function (Anderson, Johnstone, & Remley, 1999; Oddy et al., 2003) and academic achievement (Oddy, Li, Whitehouse, Zubrick, & Malacova, 2011). In additional breast feeding has been reported to decrease the risk of asthma (Scholtens et al., 2009) and obesity (Chivers et al., 2010; Oddy et al., 2014). While there is a large body of work that has reported outcomes of breastfeeding in these domains fewer have focused on motor development. Previous research , including several international cohort studies (Dee et al., 2007; McCroy & Murray, 2013; W. Oddy et al., 2011; Sacker, Quigley, & Kelly, 2006; Thorsdottir, Gunasdottir, Kvaran, & Gretarsson, 2005; Vestergaard et al., 1999) have reported benefits of breastfeeding on motor development however there remains a paucity of research reporting outcomes beyond early childhood and into adolescence.

Current recommendations for breastfeeding according to the World Health Organization (WHO, 2003) and the National Health and Medical Research Council (National et al., 2012) in Australia are for exclusive breastfeeding until 6 months of age and beyond. Some socio-demographic factors can affect the decision to breastfeed and the duration of breastfeeding, including maternal age, education and socioeconomic status (Scott, Binns, Oddy, & Graham, 2006). Breastfeeding in western populations is reportedly higher in older mothers who have a greater level of education and socioeconomic status (Scott et al., 2006). Researchers who have previously focused on cognitive development suggested improved outcomes among breastfed children may be due to the benefits of having a more favorable home environment and socioeconomic status rather than the breast milk itself (Zhou, Baghurst, Gibson, & Makrides, 2007). In contrast other researchers have reported developmental outcomes to be significantly better in breastfed infants after controlling for confounders such as income, maternal age and sociodemographic information (W. Oddy et al., 2011; Oddy et al., 2003; W. H. Oddy et al., 2011; Vestergaard et al., 1999). What still remains to be explored is whether predominant breastfeeding for at least six months has a long term effect on motor development and how these socio-demographic confounders influence that relationship.

2. Methods

2.1 Participants

Participants were from the Western Australian Pregnancy Cohort (Raine) Study. Pregnant women (N=2900) were recruited during routine antenatal appointments through the main obstetric hospital in Perth, Western Australia, King Edward Memorial Hospital (KEMH) from May 1989 to November 1991 at a rate of approximately 100 per month. Study requirements included a gestation between 16-20 weeks (M=18 weeks), sufficient English speaking skills to understand what the study entailed, expectation to deliver at KEMH and an intention to reside in Perth to facilitate future data collection. There were 2868 live births, with extensive obstetric, health, socioeconomic, demographic and medical data collected during gestation and subsequent follow up phases (Newnham, Evans, Michael, Stanley, & Landau, 1993).

2.2 Measures

2.2.1 Predictor Measure

Duration of breastfeeding was recorded in months and included any breastfeeding, regardless of the introduction of solid food or other milk sources. Breastfeeding data were collected retrospectively during the follow up phases at 1, 2, and 3 years, with each follow up interview within a year of the child's birth date. A binary variable of <6months or ≥6 months was created to compare groups. In addition a categorical variable for breastfeeding, including <3months, 3-5months, 6-11months and ≥12months was created to investigate the effect of breastfeeding over time.

2.2.2 Outcome Measure

Motor Development was measured at 10 (*M* = 10.54, *SD* = 2.27), 14 (*M = 14.02, SD = 2.33)* and 17 (*M = 16.99, SD = 2.97)* years of age using the McCarron Assessment of Neuromuscular Development (MAND) (McCarron, 1997). Participation in motor development testing at 10 (*n* = 1622), 14 (*n* = 1584) and 17 years (*n* = 1221) showed participation rates of 79%, 85% and 69% of the active cohort for each year (Table 1). Nine hundred and eighty nine children completed all three data collection phases, while 533 participated in two of the three phases and 395 completed motor development testing once. The MAND is a ten item battery of tests including fine and gross motor items including a) hand strength b) finger-nose-finger placement c) jumping d) heel-toe walk e) standing on one foot f) beads in a box g) beads on a rod h) finger tapping i) nut and bolt j) rod slide. The Neuromuscular Developmental Index (NDI) was calculated by converting each items' raw score to a scaled score (M=10, SD=3) which was summed and normalized according to age and sex appropriate norms. The NDI (M=100, SD=15) was used as a continuous outcome measure, with a higher score indicating better motor development. A cut-off score of 1SD below the mean (≤85) was used to indicate suboptimal motor functioning (McCarron, 1997). Test-retest reliability coefficients of the MAND are reported at 0.99 overall (McCarron,

1997) and it has been compared favorably to two other motor development tests in detecting motor disability within an Australian population (Tan, Parker, & Larkin, 2001).

2.2.3 Covariates

Potential confounding risk factors experienced during pregnancy, including maternal age (years), smoking, drug and alcohol consumption, maternal stress, hypertensive status and low income were adjusted for in statistical modelling. Maternal smoking was recorded as a categorical variable, with none, <10/day and ≥10/day. Alcohol consumption was recorded as never, once a week or less, several times a week or daily. Due to the small number of individual recreational drugs used by the cohort a binary variable was recorded, reflecting whether or not any recreational drug/s during pregnancy were consumed. Hypertensive status was categorized as normal BP, hypertension (systolic BP >140mmHg and/or diastolic >90mmHg) or preeclampsia (hypertension with the addition of proteinurea >300mg/24hr). Stress was recorded as the total number of stressful events experienced during pregnancy while low income was categorized as <$24000/p.a. according to the Australian government minimum threshold at the time of data collection.

Infant variables included percentage of optimal birth weight (a measure of whether growth potential has been met) (Pereira, Blair, & Lawrence, 2012), mode of delivery, sex, parity, APGAR scores at 1 minute and time to spontaneous respiration. Mode of delivery was recorded as spontaneous vaginal delivery, assisted vaginal delivery, elective caesarean section (decision made prior to spontaneous rupture of membranes, SRM) and non-elective caesarean section (decision made after SRM).

2.3 Data Analysis

Chi square, t-tests and univariate analyses of variance models with bonferroni post hocs were used to identify the maternal and child variables related to motor development outcomes at 10, 14 and 17 years, as measured by the NDI. Maternal and child factors that did not impact on NDI were excluded from the final analyses. No interactions were found between breastfeeding and any of the covariates. To examine the relationship between breastfeeding duration and motor development over time a linear mixed model was created, controlling for covariates related to motor outcome including sex, maternal age, alcohol, socioeconomic status, mode of delivery, gestational stress and hypertensive status.

3. Results

There were differences found in a number of characteristics between breastfeeding groups (Table 2). Mothers who breastfed for ≥6 months were less likely to have been diagnosed with hypertension or preeclampsia during their pregnancy (p = 0.038), experienced less stressful events (p = <0.001) and were older (p = <0.001) than those who breastfed for <6 months. Similar to previous findings (Scott et al., 2006) there were more mothers who breastfed for <6 months that fell under the Australian government threshold for low income (p = <0.001). Maternal risk factors also differed between the groups, with a higher number of mothers in the breastfed <6 month group reporting drinking several times a week (6.6% vs 3.9%), while a higher number in the breastfed ≥6 months group reported drinking on a daily basis (0.9% vs 0.6%). These numbers were small (Table 2) and the majority of women in the cohort reported never drinking (52%) or drinking once a week or less (42%) during their pregnancy. There was a greater percentage of non-smokers in the breastfed ≥6 month group (83.6%) compared to the breastfed <6 month group (67.6%). Infants born to mothers who reported breastfeeding for <6 months had a smaller percentage of optimal birth weight (p =

0.004) and a larger percent were firstborns (p = <0.001). Mode of delivery, infant sex and time to spontaneous respiration did not differ between the groups.

The linear mixed models, adjusted for sex, maternal age, alcohol, socioeconomic status, mode of delivery, gestational stress and hypertensive status revealed breastfeeding ≥ 6 months was associated with a higher NDI (p = 0.019) over time (Table 3). Those who breastfed for <6 months had a lower average NDI (β -1.38) than the ≥6 months group. Males had a higher mean NDI than females (p = <0.001, β-2.38). Increased maternal age (p = 0.013, β 0.13) related to a higher NDI, while increased incidences of gestational stress were negatively related to motor outcome (p = 0.002, β-0.45). Children born from mothers who were diagnosed with preeclampsia (β-6.38) or hypertension (β-0.95) reported lower NDIs than the normal BP groups (p = <0.001). Those who were delivered via elective caesarean section (β-4.10), emergency caesarean (β-1.65) and assisted vaginal birth (β-1.42) had a lower NDI compared to those who had spontaneous vaginal deliveries (p = <0.001).

When breastfeeding was categorized into <3 months, 3-5 months, 6-11 months and ≥12 months results revealed a positive linear trend (p = 0.012, β = 0.61), indicating that increased breastfeeding duration corresponded to improved motor development scores. Post hoc analysis showed an increase in mean adjusted NDI in the 6-11 month group (p = 0.039, β-1.55) compared to the <3 month group. Higher mean NDIs were also revealed in both the 6-11 month (p = 0.013, β-1.97) and ≥12 month (p = 0.021, β-1.85) groups compared to the 3-5 month group.

To investigate the incidence of suboptimal motor functioning between the <6month and ≥6month groups cross sectional univariate analyses was used, and revealed a higher number of those who were breastfed for <6months fell below the recommended cut off score (Table 4). This trend was significant at 10 (p = 0.009), 14 years (p = 0.01) and 17 years (p =

0.05). In addition NDI was also lower at 10 (p = 0.008), 14 (p = <0.001) and 17 (p = 0.035) years in children from mothers who breastfed <6 months (Table 5).

4. Discussion

Breastfeeding for ≥6 months was related to better motor development outcomes at 10, 14 and 17 years of age. Furthermore, when adjusted for maternal age, smoking, stress, delivery mode, hypertensive disease, percentage of optimal birth weight and socioeconomic status a longer duration of breastfeeding remained significantly related to long term motor development. While this is an important finding, it is pertinent to note that overall the group who were breastfed for less than six months had a mean motor development score that still fell within the normal range. However cross sectional univariate analyses investigating the incidence of suboptimal motor functioning revealed a higher number of those who were breastfed <6months fell below the recommended cut off score of the MAND compared to those who were breastfed for more than 6 months (Table 4). This was found at each year, with more cases of suboptimal motor functioning at 10 years (27.1% vs 20.9%), 14 years (25.7% vs 19.6%) and 17 years (31.2% vs 25.6%) in those breastfed for <6 months. These outcomes support previous research findings from other countries such as Ireland (McCroy & Murray, 2013), Britain (Sacker et al., 2006), Denmark (Vestergaard et al., 1999), The United States (Dee et al., 2007), Honduras (Dewey, Cohen, Brown, & Rivera, 2001) and Iceland (Thorsdottir et al., 2005) that identified the long term benefits of breastfeeding on the neurological system.

There are biologically plausible mechanisms that could be responsible for these findings. Underlying processes responsible for motor development, such as motor programming and sensory processing continue to progress well into the first decade of life (Gramsbergen, 2003). Specifically the cerebellar cortex, the layer of neural tissue that comprises the cerebellum, develops later in neural-ontogeny, and is likely to be a key etiological factor in motor programming (Gramsbergen, 2003; Ivry, 2003). Several studies have acknowledged the role of long chain polyunsaturated fatty acids (LC-PUFAs) in human milk, such as docosahexaenoic acid (DHA) and arachidonic acid (AA) as an essential element of neural membranes and a potential mechanism for favorable neurological development (Guxens et al., 2011; Innis, 2000; Uauy & De Andraca, 1995). PUFAs are also noted to provide a neuroprotective effect (Lauritzen et al., 2000). While breast milk contains all the polyunsaturated fatty acids (PUFAs), formulae milk contains only precursors, which could be why the level of DHA in infant brain and erythrocytes is reportedly higher in breast fed infants (Makrides, Neumann, Byard, Simmer, & Gibson, 1994). Research into the levels of DHA in cerebellum gray and white matter of infants reported significantly higher levels in breast fed compared to formulae fed infants (Jamieson et al., 1999). This finding in particular could contribute to the better motor outcomes seen in breast fed infants, as the cerebellum, while not responsible for initiating movement is involved in adjustments to muscle tone, control of movement and posture and the learning of physical tasks and motor skills (Gramsbergen, 2003; Ivry, 2003).

Although no interactions were found between breastfeeding and other covariates mothers who breastfed ≥6 month had less incidence of hypertension or preeclampsia in pregnancy, experienced less stress during pregnancy, were older, more financially stable and less likely to be smokers. It has been previously reported that children from pregnancies involving hypertensive disease (Grace, Bulsara, Pennell, & Hands, 2014), maternal stress (Grace, Robinson, Bulsara, & Hands, 2015; Huizink, Robles de Mina, Mulder, Visser, & Buitelaar, 2003), smoking (Larsson & Montgomery, 2008; Trasti, Vik, Jacobsen, & Bakketeig, 1999) and lower socioeconomic situations (Bobbio, Gabbard, Goncalves, Filho, & Morcillo, 2010) have poorer motor outcomes. While there were no interactions between these variables in the model they may have exerted an accumulative negative effect on motor development. Those in the breastfed for <6 month group may have therefore been disadvantaged through various other lifestyle factors, in addition to a shorter duration of breastfeeding.

The strengths of the study include a large longitudinal cohort and extensive data that enabled a robust statistical analysis of the effects of breastfeeding on children over time. Whilst previous research has primarily focused on infancy and early childhood outcomes, the longitudinal nature of this cohort has allowed for breastfeeding practices to be associated with motor development in later childhood and adolescence. We controlled for factors known to influence breast feeding duration such as family income and maternal age and known risk factors of compromised motor development. In addition the MAND provides a reliable and accurate measure of motor development within an Australian population (Tan et al., 2001).

We acknowledge that there are potential limitations to the study. As the study was not originally designed to be a motor development study early data collection on neurological outcomes was limited. The addition of the MAND as a measure of motor development was not introduced until the 10th year of data collection. The novelty of this study however lies in the longitudinal data and the age of the cohort during MAND testing, which allowed motor development in adolescence to be related back to the antenatal and postnatal periods. This has not been extensively reported previously, however results support the growing body of work that suggests factors during very early life can have long term effects on the developing neurological system.

There are numerous factors that can influence motor development after the antenatal period and infancy, for example childhood movement based programs may help improve motor abilities, whilst other factors such as childhood illness may negatively impact motor outcomes. It is not within the scope of this study to be able to include every variable from childhood in the analyses. While there were extensive socio-demographic, obstetric and medical data available in the cohort controlling for every potential cofounder was not possible.

Retrospective data collection may have led to some inaccuracies in reporting of exact breastfeeding duration, however there has been support for the validity and reliability of maternal recall in breastfeeding data collection (Leeson, 2013). This is particularly evident when the recall is less than 3 years post-breastfeeding and recall in this study was within one year.

5. Conclusion

Our results revealed that early feeding practices have a long term influence on motor development. In particular we showed that breastfeeding for 6 months or longer enhances optimal neuromotor outcome. We found support for breastfeeding initiatives that focus on increasing the proportion of women breastfeeding for 6 months or longer.

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Table 1.
Available Data from each follow up of the Raine Study

Year	**Active**	**MAND**	**Deferred**	**Lost**	**Withdrawn**	**Deceased**	**Total**
Birth	2868		-	-	-	-	2868
10	2047	1622	281	162	348	30	2868
14	1860	1584	357	207	412	32	2868
17	1754	1221	414	184	480	36	2868

MAND = McCarron Assessment of Neurological Development

Table 2. Cohort characteristics of the Western Australian Pregnancy Cohort (Raine) Study by breastfeeding group

Variables	Breastfed <6months		Breastfed ≥6months		Group Difference (p value)
Categorical Variables	N	%	N	%	
Maternal Gest. Hypertension	908		1151		p = 0.038*
Normal BP	651	71.7	873	75.8	
Hypertension	219	24.10	248	21.5	
Preeclampsia	38	4.2	30	2.6	
Maternal Gest. Smoking	907		1149		p = <0.001*
None	613	67.6	960	83.6	
<10/day	164	18.1	116	10.1	
≥10/day	130	14.3	73	6.4	
Maternal Gest. Drinking	905		1148		p = 0.038*
Never	474	52.4	589	51.3	
Once / week or less	391	43.2	473	41.2	
Several times / week	35	3.9	76	6.6	
Daily	5	0.6	10	0.9	
Family Income	843		1107		p = <0.001*
<$24000 p.a.	574	68.1	836	24.5	
≥$24000 p.a.	269	31.9	271	75.5	
Infant Sex	908		1151		p = 0.965
Male	472	52	597	51.9	
Female	436	48	554	48.1	
Parity	905		1146		p = <0.001*
Firstborn	480	53	509	44.4	
Siblings	425	47	637	55.6	
Mode of Delivery	904		1151		p = 0.505
Spontaneous Vaginal	541	59.8	712	61.9	
Assisted Vaginal	175	19.4	214	18.6	
Elective Caesarean	113	12.5	122	10.6	
Non-elective caesarean	75	8.3	103	8.9	
Continuous variables	M	SD	M	SD	
Maternal Age (years)	26.52	5.7	29.46	5.33	p = <0.001*
Percentage Optimal Birth Weight	96.59	15.78	98.36	12.27	p = 0.004*
Time to Spontaneous Respiration	1.88	8.61	1.71	7.83	p = 0.636
Stressful Events During Pregnancy	2.32	2.1	1.92	1.81	p = <0.001*

Table 3 *Linear mixed model results*

Variable	NDI*	CI 95%		Group Difference
Breastfed ≥6 months	95.01	92.96	97.06	p = 0.019
Breastfed <6months	93.62	91.55	95.70	
Delivery Mode				
Spontaneous Vaginal Delivery	96.11	94.10	98.12	p = <0.001
Assisted SVD	94.69	92.49	96.89	
Elective Caesarean	92.01	89.56	94.46	
Non-elective Caesarean	94.46	91.89	97.04	
Maternal Alcohol Intake				
Never	96.65	90.59	102.71	p = 0.027
Once per week or less	93.07	91.68	94.45	
Several times per week	95.39	92.80	97.98	
Daily	92.17	90.86	93.49	
Blood Pressure				
Normal BP	96.76	94.98	98.53	p = <0.001
Hypertension	95.18	93.83	97.80	
Preeclampsia	90.38	86.86	93.90	
Family Income				
Above $24,000p.a	95.84	93.87	97.81	p = <0.001
Below $24,000p.a	92.8	90.60	94.99	
Sex				
Male	96.3	94.28	98.32	p = <0.001
Female	93.92	91.89	95.94	
Maternal Stress (Number of events)				

* Adjusted mean Neuromuscular Development Index

Table 4. Incidences of mild motor disability in the Western Australian Pregnancy Cohort (Raine) Study by breastfeeding group

	Breastfed <6 months				Breastfed ≥6 months				
	<85 NDI		≥85 NDI		<85 NDI		≥85 NDI		Group Difference
Yr 10	149	(27.1%)	401	(72.9%)	164	(20.9%)	621	(79.1%)	p = 0.009
Yr 14	138	(25.7%)	400	(74.3%)	150	(19.6%)	616	(80.4%)	p = 0.010
Yr 17	126	(31.2%)	278	(68.8%)	159	(25.6%)	463	(74.4%)	p = 0.054

* An NDI (Neuromuscular Development Index) of ≤85
indicates a mild motor disability

Table 5. Difference in NDI in the Western Australian Pregnancy Cohort (Raine) Study by breastfeeding group

	Breastfed <6 months	Breastfed ≥6 months	Groups Difference
10	92.96 (13.26)	95.03 (14.41)	p = 0.008
14	96.98 (17.18)	100.84 (18.12)	p = <0.001
17	95.06 (17.14)	97.42 (17.26)	p = 0.035

- NDI Neuromuscular Development Index