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## Eight-year outcome of implementation of abusive head trauma prevention

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## ABSTRACT

Low incidence rates and economic recession have hampered interpretation of educational prevention efforts to reduce abusive head trauma (AHT). Our objective was to determine whether the British Columbia experience implementing a province-wide prevention program reduced AHT hospitalization rates. A 3-dose primary, universal education program (the *Period of PURPLE Crying*) was implemented through maternal and public health units and assessed by retrospective-prospective surveillance. With parents of all newborn infants born between January 2009 and December 2016 ( $n = 354,477$ ), nurses discussed crying and shaking while delivering a booklet and DVD during maternity admission (dose 1). Public health nurses reinforced Talking Points by telephone and/or home visits post-discharge (dose 2) and community education was instituted annually (dose 3). During admission, program delivery occurred for 90% of mothers. Fathers were present 74.4% of the time. By 2–4 months, 70.9% of mothers and 50.5% of fathers watched the DVD and/or read the booklet. AHT admissions decreased for < 12-month-olds from 10.6 (95% CI: 8.3–13.5) to 7.1 (95% CI: 4.8–10.5) or, for < 24-month-olds, from 6.7 (95% CI: 5.4–8.3) to 4.4 (95% CI: 3.1–6.2) cases per 100,000 person-years. Relative risk of admission was 0.67 (95% CI: 0.42–1.07,  $P = 0.090$ ) and 0.65 (95% CI: 0.43–0.99,  $P = 0.048$ ) respectively. We conclude that the intervention was associated with a 35% reduction in infant AHT admissions that was significant for < 24-month-olds. The results are encouraging that, despite a low initial incidence and economic recession, reductions in AHT may be achievable with a system-wide implementation of a comprehensive parental education prevention program.

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## 1. Introduction

Abusive head trauma (AHT) [or shaken baby syndrome (SBS)] is a devastating form of infant abuse (Barr, 2012; Christian, Block, & Neglect, 2009) with significant mortality and morbidity (Duhaime, Christian, Moss, & Seidl, 1996; Keenan et al., 2003; Keenan, Hooper, Wetherington, Nocera, & Runyan, 2007; King, MacKay, & Sirnick, 2003), medical costs (Miller et al., 2017; Peterson et al., 2014), the destruction of families and society's failure to protect its most vulnerable citizens. Evaluation studies of the effectiveness of prevention efforts are mixed, and interpretation of these studies is challenging. Because crying is a significant trigger (Barr, Trent, & Cross, 2006; Barr, 2012; Lee, Barr, Catherine, & Wicks, 2007; Talvik, Alexander, & Talvik, 2008), prevention has targeted parents with education about crying and shaking. Randomized controlled trials (RCTs) of maternal education have demonstrated improved crying knowledge (Barr, Barr et al., 2009; Barr, Rivara et al., 2009; Bechtel et al., 2011; Fujiwara, Yamada et al., 2012), sharing of learned information with other caregivers (Barr, Barr et al., 2009; Barr, Rivara et al., 2009; Fujiwara, Yamada et al., 2012) and changed crying response behaviors (Barr, Barr et al., 2009; Fujiwara, Yamada et al., 2012). In observational studies, education of new mothers changed behaviors by reducing calls to a nurse advice line (Zolotor et al., 2015) and visits to emergency rooms for crying complaints (Barr, Rajabali, Aragon, Colbourne, & Brant, 2015). Economic influences may have confounded studies of the effectiveness of prevention through educating parents about crying and shaking. Early studies reported 47% and 78% reductions in AHT admissions pre- to post-implementation (Altman et al., 2011; Dias et al., 2005), but later studies reported an increase (Dias, Rottmund, & Cappos, 2017) or no reduction of cases (Zolotor et al., 2015). The later implementations coincided with the economic recession (December 2007–June 2009) associated elsewhere with substantial increases in AHT admissions (Berger et al., 2011; Huang et al., 2011; Klevens, Luo, Xu, Peterson, & Latzman, 2016; Wood et al., 2016; Xiang et al., 2013) that persisted post-recession (Wood et al., 2016), potentially confounding interpretation of the results.

This paper describes the eight-year outcome of AHT admissions in British Columbia (BC) following implementation of a primary, universal prevention program, the *Period of PURPLE Crying* ([www.dontshake.org/purplecrying](http://www.dontshake.org/purplecrying); National Center on Shaken Baby Syndrome [NCSBS], Farmington, UT). The intervention included three “doses:” education of parents of all newborns during maternity admission or home births; post-partum reinforcement of Talking Points by public health nurses (PHNs); and an annual public education campaign. The intervention had two aims: (1) improving understanding of early increased crying by parents, and (2) reducing AHT incidence. Aim 1 was evaluated by measuring visits for crying complaints to the BC Children's Hospital (BCH) emergency previously reported (Barr et al., 2015). Aim 2 is being evaluated by retrospective-prospective surveillance of AHT hospital admissions.

Implementation began in January 2008. At that time, AHT incidence in the USA and Britain clustered around 30 per 100,000 person-years for < 12-month-olds (Barlow & Minns, 2000; Ellingson, Leventhal, & Weiss, 2008; Fujiwara, Barr, Brant, Rajabali, & Pike, 2012; Keenan et al., 2003). Subsequently, Fujiwara, Barr et al. (2012) and others in Canada (Bennett et al., 2011)—consistent with reports in New Zealand (Kelly & Farrant, 2008) and Britain (Hobbs, Childs, Wynne, Livingston, & Seal, 2005)—reported incidences around 15 per 100,000 person-years. In BC, there were an estimated 10 admissions per 100,000 person-years using the same data and methodology (unpublished). With that incidence, assuming a 14-year baseline and a birthrate of 45,000/year in BC, power to detect a 50% reduction as previously reported by Dias et al. (2005) required 9 years and detecting a statistically significant 30% reduction was not possible. Consequently, achieving statistically significant reductions with highly variable but low annual incidences approached infeasibility. Nevertheless, because of mixed and potentially confounded reports on prevention effectiveness, we elected to report our experience after 8 years of follow-up.

## 2. Patients and methods

### 2.1. Intervention

The *Period of PURPLE Crying* program development began in 2002. The strategic approach and materials centered on parental interest in their infants' normal development, especially crying, and the dangers of shaking when frustrated with crying. It utilized 40 years of empirical evidence supporting a developmental interpretation of early increased crying (Barr, 2000, 2012; Brazelton, 1962; St.James-Roberts et al., 1991) and clinical and epidemiological evidence that crying was the most common stimulus for AHT (Barr et al., 2006; Brewster, Nelson, & Hymel, 1998; Kempe, 1971; Lee et al., 2007; Reijneveld, van der Wal, Brugman, Sing, & Verloove-Vanhorick, 2004; Talvik et al., 2008). AHT was conceptualized as a failure of normal, common, iterative infant-caregiver interactions, rather than only of abnormal behavior, at-risk caregivers or their interaction (Barr, 2012; Jenny, 2008).

Dose 1 included scripted interactions between a maternity nurse (or midwife) and mother with father present if possible, protocolized use of the 10-page educational booklet where the nurses reviewed the booklet as the stimulus for the discussion, viewing an educational film on a DVD when possible, emphasis on key program messages (Talking Points: see Fig. 1), and providing the materials to the parents to take home with them. In 2012, another film (*Crying, Soothing and Coping*) was added to the DVD emphasizing parental coping when soothing failed. Unique to the *PURPLE* program, parents received their own booklet and DVD (available in 10 languages) to share with fathers and other caregivers, and review later when crying increases (Barr, 2000; Brazelton, 1962). Two features emphasized non-maternal caregivers. First, because fathers are the most common perpetrators (Barr, 2012; Starling, Holden, & Jenny, 1995), nurses were encouraged to teach with fathers present. Second, Talking Point #4 emphasized sharing information with anyone caring for the infant (e.g. grandparents, sitters).

In Dose 2, to assure consistent and accurate messaging from multiple sources (Willinger, Ko, Hoffman, Kessler, & Corwin, 2000), the Talking Points were reinforced within 2 weeks during routine post-natal telephone contact or, occasionally, during home visits

## The Period of PURPLE Crying Program: Talking Points

### FOR NURSES

I strongly recommend you read and watch these materials when you get home because **it is very important information.**

**Let me go over some important points with you:**

1. Infant crying is normal, especially in the first 4-5 months of life.
  - Remember, crying increases at about 2 weeks, peaks at 2-3 months, declines by 5 months.
  - Some babies cry as long as 5 hours a day or more, others cry for only 20 mins or less each day. This is still normal -- this early crying time is what we call the *Period of PURPLE Crying*.
2. If you are concerned, always have your doctor examine your baby. However, if your baby is growing, is not sick or has no fever or other symptoms, then they are very likely going through the *Period of PURPLE Crying*.
3. Some parents say they get so frustrated with the crying they could just shake the baby.
  - Remember, shaking is the most dangerous thing anyone can do to a baby.
  - Even mild shaking can cause brain damage and hard shaking can be deadly.
4. Make sure you tell others about the *Period of PURPLE Crying* and the dangers of shaking a baby.
  - Do not leave your baby with someone who gets frustrated easily.
  - Show everyone the booklet and DVD before they care for your baby.
  - Don't be embarrassed to tell them. It can save your baby's life.

Fig. 1. Talking Points delivered by maternity and public health nurses.

from PHNs. Other potential sources of contact for new parents in the postpartum period (“reinforcement” groups) were also trained, including pediatricians, family physicians, adoptive/foster parent support, crisis lines, Aboriginal support, Health-Link BC (phone-in service), pregnancy outreach, infant development and early childhood education staff. In contrast to the maternity and public health nurses, the role of these professionals was not to disseminate the program, but rather (1) to be aware of the existence and purpose of the program so that both parents and professionals were talking about the *Period of PURPLE Crying* program; and (2) to assure that parents received consistent messages about crying, its normality, its importance and the dangers of responding violently to it. Other than tracking the numbers of professionals trained, we did not track fidelity parameters on them.

Nurses in 49 maternity units (n = 2014) and 112 public health offices (n = 959) were trained by 2 full-time educators (January 2008—January 2009) that included 30-minute in-person sessions, on-line training, webinars, and certificates for successful completion. In each maternity, at least eighty percent of nurses were trained before implementation. Updates and new nurse training occurred annually. By December 2015, over 5400 maternity nurses and PHNs and 4800 reinforcement group practitioners had completed training.

Dose 3 (public education) began in 2010. The campaign was *CLICK for Babies* ([www.CLICKforBabies.org](http://www.CLICKforBabies.org)), originally “PURPLE Caps.” First developed in North Carolina, the campaign asked volunteers to knit purple caps for Prevent SBS BC. Over 4000 caps distributed to hospitals were provided as gifts to each newborn during November. Because of its success and cost effectiveness, the campaign was repeated annually.

The study was approved by the UBC Behavioural Research Ethics Board in 2007 and re-approved annually.

### 2.2. Participation rates

The program targeted parents of all newborn infants born between January 2009 and December 2016 (n = 354,477). Four tracking methods were utilized to estimate the percentage of newborn families receiving and using the program: (1) public health

(PH) evaluation forms; (2) public health nurse (PHN) surveys; (3) parent surveys; and (4) maternity nurse surveys (for father and other caregiver exposures).

PH evaluation forms (January 2009–September 2011) were used to track an estimated 79% of all parents targeted to receive the intervention. PH monitoring could not track 21% of parents that included First Nations births on reserve or in rural areas (followed separately by First Nations Health Authority nurses), home births (followed by midwives), self-paid and out-of-province births or those with significant language barriers. PH unit nurses called parents within two weeks of discharge and reviewed the Talking Points reinforcing the *PURPLE Crying* messages. If parents had been missed in maternity, the program was delivered by home visitor or by mail. By prior agreement, PH evaluation forms were discontinued in September 2011.

From October 2012–December 2016, participation rates were estimated with a randomized, stratified sample of PHN surveys (3 min;  $n = 910$ ). From 2010, parent telephone surveys occurred in three waves of approximately two years each (2010–2011, 2012–2013, 2014–2016) of randomized, stratified samples of mothers of 2–4-month-old infants (5 min; total  $n = 2572$ ).

Each survey (PHN or parent) asked whether parents received the program, how it was provided (maternity, midwife, public health, other) and, if received, had they reviewed the DVD and/or booklet. To reduce recall bias, the PHN survey requested nurses to answer the questions based on the last mother they contacted regarding the new baby follow-up. The PH evaluation also determined where parents reviewed the DVD and/or booklet (at home, hospital, or elsewhere). The parent surveys included five knowledge questions to insure receipt of program messages.

### 2.3. Fathers and other caregivers

Father and other caregiver exposures were tracked with randomized, stratified sample surveys of maternity nurses (3 min;  $n = 841$ ; September 2009–November 2013). Two questions asked whether someone else (fathers, grandparents, “others”) was in the room during teaching. In the 2012 and 2014 parent surveys, mothers were asked whether fathers and other caregivers had watched the DVD and/or read the booklet. In 2010, 2012 and 2014 parent surveys, mothers were asked whether they had talked about crying and shaking with other caregivers.

### 2.4. Hospitalization rates

A retroactive review of all Child Protection Service (CPS) case charts (1995–2003) was undertaken in 2004 by two child abuse physicians (J.H. and M.C.) and re-reviewed in 2013 with the additional years 2004–2006 for definite cases only. Prospectively from January 2007, AHT admissions were tracked through two systems: the CPS and the Inflicted Head Injury Surveillance program. All serious child abuse assessments and child neurosurgery cases are referred to British Columbia Children's Hospital (BCCH), the only pediatric hospital in BC. All CPS referrals with physical abuse as a primary or secondary referral and/or diagnosis were reviewed quarterly with a protocolized process by CPS (physicians and social workers) and investigation teams. To assure consistency in defining cases, throughout the years of prospective reviews this committee was chaired by one or other of the child abuse physicians who carried out the retrospective reviews. To define a case, reviewers followed the Canadian Pediatric Society and American Academy of Pediatrics recommendations that have remained the same throughout; namely, that AHT is a medical diagnosis made when an infant or child presents with physical injury to the head due to violent shaking, impact or a combination of the two, and may involve intracranial hemorrhage, retinal hemorrhage, brain injury, skull fracture and rib or long bone fractures. Cases did not have to have all of these but were required to have clear clinical documentation of intracranial pathology. Using an adaptation of certainty from Feldman et al. (Feldman, Bethel, Shugerman, Grady, & Ellenbogen, 2001), cases were classified as definite, probable, possible, unknown and definitely not. Independently, the Inflicted Head Injury Surveillance program actively monitored all neurosurgery cases biweekly. Cases were compared quarterly to assure no missed cases in the CPS reviews. With five child abuse and neglect teams in other hospitals throughout BC, teleconferences reviewed all physical abuse cases < 24-months-old. No missed AHT cases were discovered.

To calculate incidence per person-year annually, the estimated population by age (accounting for immigration and out-migration) produced by Statistics Canada 2017 ([www.bcstats.gov.bc.ca/apps/PopulationEstimates.aspx](http://www.bcstats.gov.bc.ca/apps/PopulationEstimates.aspx)) was used. Hospitalization rates per 100,000 person-years by date of birth were calculated for < 12 and < 24-month-olds through 2016. Follow-up for hospitalization was available only to 2017 so children born in 2016 had an average 1.5 years of follow-up to their second birthday. The person-years denominator was adjusted accordingly in corresponding rate calculations. Rates were first examined for serial correlation by applying the Durbin-Watson test to a linear regression model for the square root (variance stabilizing) transformation of rates. Poisson regression was then applied to model the change in rates by including an indicator term characterizing observations from 2009 forward. Analyses were calculated with R, version 3.3.3 (Team, 2017).

## 3. Results

### 3.1. Participation rates

By September 2011, 89,885 PH administration forms had been returned of which 82,992 were complete, for a return rate of 74.5% of registered births (82,992/111,351). Since an estimated 21% of registered births are not followed by public health, the completed forms provided responses for 94.3% (82,992/87,967) of registered births followed by public health. That parents received the materials was recorded for 91.2% (75,662/82,992), or at least 86.0% (75,662/87,967) of births followed by public health. Of

parents receiving materials, 83% received them during maternity, 7% from public health, 1% from “other;” for 9% this information was missing.

Through December 2016, PHNs reported that 89.8% of their patients confirmed receiving the materials. Of those, 93.1% received them from maternity, 3.1% from public health, 0.6% from midwives, and 3.2% from “others.”

On parent surveys, receiving materials was confirmed by 92.7% of participants consistently through the years (2010:93.8%; 2012:91.3%; 2014:93.0%). Of those, 83.2% received the materials in maternity, and this remained stable or increased slightly in later years (2010:82.7%; 2012:81.2%; 2014:85.0%).

### 3.2. Reading and viewing materials

On PH administration forms (through September 2011), 20.1% of mothers reported viewing the DVD (77.6% at home; 17.7% in hospital; 4.6% elsewhere) and 17.7% read the booklet (81.0% at home; 15.9% in hospital; 3.1% elsewhere). Combined, 23.3% watched the DVD and/or read the booklet. On PHN surveys (2012–2016), nurses reported that 24.8% of mothers viewed the DVD and 19.6% read the booklet; combined, 31.8% watched the DVD and/or read the booklet. The PHN surveys did not inquire about where the materials were watched or read.

By parent surveys at 2–4 months, 53.0% of mothers reported watching the DVD and 60.1% read the booklet. Combined, 70.9% watched the DVD and/or read the booklet. Watching/reading tended to increase over time (2010:67.9%; 2012:71.9%; 2014:72.1%).

### 3.3. Fathers and other caregivers

Maternity nurse surveys indicated someone other than mother was present during teaching 80.3% of the time, consisting of fathers (74.4%); grandparents (9.3%); and “others” (5.6%).

On the 2012 and 2014 parent surveys, 37.7% of fathers watched the DVD and 38.7% read the booklet; combined, 50.5% watched the DVD and/or read the booklet. In addition, 8.7% of other caregivers watched the DVD and 7.6% read the booklet; combined, 11.3% watched the DVD and/or read the booklet.

On the 2010, 2012 and 2014 surveys, 31.5% of mothers reported talking with other caregivers about crying and shaking.

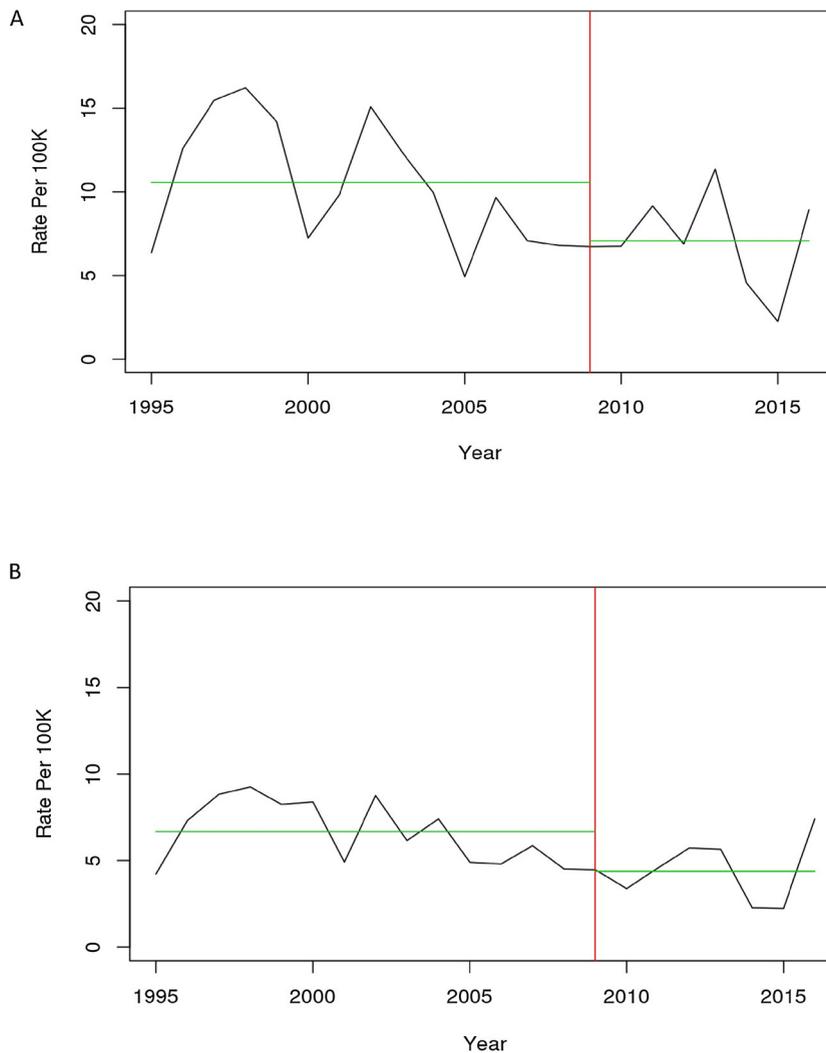
### 3.4. Hospitalization rates

Estimated AHT admission rates per 100,000 person-years by date of birth pre- and post-implementation are illustrated in Fig. 2 A (< 12-month-olds) and B (< 24-month-olds) through 2016. The Table 1 shows estimated rates with confidence intervals, relative risk for admission post-implementation, and absolute risk reduction post-implementation. As anticipated (Bennett et al., 2011; Fujiwara, Barr et al., 2012), admission rates by CPS retrospective-prospective assessment for < 12-month-olds prior to implementation averaged 10.6 per 100,000 person-years. Following implementation, admission rates decreased for < 12-month-olds to 7.1 per 100,000 person-years, a reduction of 33% ( $P = 0.090$ ). For < 24-month-olds, admission rates decreased from 6.7 to 4.4 per 100,000 person-years, a 35% reduction ( $P = 0.048$ ). This represents an absolute annual reduction of 3.5 and 2.3 cases for < 12 and < 24-month-olds per 100,000 person-years respectively.

## 4. Discussion

The BC experience implementing a 3-dose primary, universal educational prevention program was associated with a 35% decrease in AHT admissions that was statistically significant for < 24-month-olds, and a similar though non-statistically significant 33% decrease for < 12-month-olds. Although less than the 47% and 75% reductions reported in New York (Altman et al., 2011; Dias et al., 2005), this is better than the more recently reported increase in Pennsylvania (Dias et al., 2017) or no change in North Carolina (Zolotor et al., 2015). Unfortunately, those implementations coincided with the Great Recession, itself associated with substantial increases in at least 11 other states or regions (Berger et al., 2011; Huang et al., 2011; Klevens et al., 2016; Wood et al., 2016; Xiang et al., 2013) that persisted post-recession (Wood et al., 2016) in some. Consequently, the North Carolina program may have prevented a rise despite no reduction in rates, although comparing rates from some states without systematic prevention programs did not show differences from North Carolina (Zolotor et al., 2015). In Canada, the recession also coincided with the implementation. Nevertheless, hospitalization rates declined in sharp contrast with neighboring Washington State that experienced a doubling of AHT admissions (Berger et al., 2011; Wood et al., 2016). The lower pre-implementation BC admission rate made it more challenging to achieve a statistically significant reduction. Also, there may have been less room for an educational intervention—compared to more intensive and/or targeted social support interventions (Olds, 2006; Sanders, Markie-Dadds, & Turner, 2012)—to achieve further reductions. Consequently, the BC experience provides a contrasting and encouraging finding for educational prevention efforts that differs from recent reports.

A number of program features may have contributed to the favorable results. First, all tracking systems indicated that approximately 90% of parents received the intervention. Second, participation remained high indicating no “fatigue” over time. Third, since materials were available in 10 languages, most participants received the education in their preferred language in the diversified population of BC. Fourth, PHNs provided materials to 7% of parents who would have been “missed” during the first two years. Fifth, parents receiving materials from the maternity nurse increased slightly between 2010 (82.7%) and 2014 (85.0%). Similarly, parents receiving materials from public health decreased to 3.1% from the earlier 7% rate. These indices imply that the program became



**Fig. 2.** AHT Hospital Admissions per 100,000 Person-Years by Date of Birth for (A) < 12-month-olds and (B) < 24-month-olds. Vertical lines represent January 2009 date of implementation. Horizontal lines represent mean rates pre- and post-implementation by date of birth.

**Table 1**  
AHT Admission Rates and Comparative Risks (2009 and later versus Pre-2009).

	Age < 12 Months		Age < 24 Months	
	Admission Rate <sup>a</sup>	95% C.I.	Rate <sup>a</sup>	95% C.I.
Pre-2009	10.6	8.3 to 13.5	6.7	5.4 to 8.3
2009 and later	7.1	4.8 to 10.5	4.4	3.1 to 6.2
Comparative Risks post-2009				
	<b>Relative Risk</b>	95% C.I.	P-value	
Age < 12 months	0.67	0.42 to 1.07	0.090	
Age < 24 months	0.65	0.43 to 0.99	0.048	
	<b>Absolute Risk Difference<sup>a</sup></b>	95% C.I.		
Age < 12 months	-3.5	-7.3 to -0.3		
Age < 24 months	-2.3	-4.5 to -0.2		

<sup>a</sup> per 100,000 person-years.

more “embedded” in maternity nurse practice.

Importantly, actual use of materials (viewing and/or reading) increased over time post-discharge, supporting the program principle that parents receive their own DVD and booklet to take home. PH administration forms and PHN surveys captured viewing/

reading rates within days after discharge. Those rates increased from 23% to 32% over 7 years. Of mothers who reviewed the materials early, about four-fifths reviewed them at home. Both the DVD and booklet were important, since roughly 50% reported reviewing each. More importantly, however, later parent surveys captured viewing/reading 2–4 months after discharge. These measures are particularly important for two reasons. First, they demonstrate use later in infancy when the normative increase in crying and likely caregiver frustration would have occurred (Barr, 2000, Barr, 2012; Brazelton, 1962; St. James-Roberts & Halil, 1991). Second, previous neonatal maternal education programs to prevent SIDS (sudden infant death syndrome) showed that approximately 20% of caregivers reported changing from the safer non-prone position they were taught at birth to the less safe prone position in the 2nd and 3rd months of life (Lesko et al., 1998; Willinger et al., 2000). In the current prevention program, reviews of the materials more than doubled to 71% of mothers by 2 to 4 months of life. Since not all parents were likely to be stressed by their infant's crying, these rates suggest that having the materials at home was supportive weeks later when faced with increased crying.

Two important program principles involved fathers and sharing information with other caregivers. All current studies cite related males as the most common perpetrators (Barr, 2012; Starling et al., 1995). For prevention purposes, there is no clear public health access to all fathers. Emphasizing the importance of having fathers present resulted in accessing a creditable 74% of fathers. Furthermore, providing the materials to take home was associated with approximately 50% of fathers having viewed and/or read the materials after discharge. Emphasizing sharing of information with other caregivers resulted in grandparents and "others" being present during maternity teaching 9% and 6% of the time respectively, materials being viewed and/or read by other caregivers 11% of the time, and verbal message transfer occurring in 31% of families. We do not know how often other caregivers are utilized but communicating crying and shaking messages appears to be enhanced with mothers as "teachers" of other caregivers.

Following the disappointing Pennsylvania (Dias et al., 2017) and North Carolina (Zolotor et al., 2015) results, Leventhal and colleagues (Leventhal, Asnes, & Bechtel, 2017) proposed five modifications to strengthen postpartum maternal education efforts: (1) receiving the education from "multiple, diverse sources;" (2) focusing parents on their own frustration and anger, rather than their infant's behavior; (3) combining prevention with other forms of parental support, such as paid parental leave (available in BC); (4) home visiting; and (5) actively including male caregivers. Wholly or partially, this *Period of PURPLE Crying* implementation included all five strategies.

Interpreting the AHT reduction as due to this program implementation must be treated with caution. Other unmeasured influences may have been contributory. AHT cases are relatively rare and highly variable year-to-year, only two reasons why a randomized, controlled trial would have been infeasible. Had the province been larger, a time series design with implementation delayed in different regions might have resulted in a more robust demonstration of time-dependent program effects. Interpretation is further limited by the unavailability of similar comparison data from adjacent provinces and states. However, a doubling of rates was documented in adjacent Washington State (Berger et al., 2011; Wood et al., 2016) as were significant increases in 7 states (Klevens et al., 2016) and 4 regions (Berger et al., 2011; Huang et al., 2011; Wood et al., 2016; Xiang et al., 2013). Canada-USA differences in health care systems could have contributed to the lower initial admission rate and/or the reduction following implementation. For example, Klevens et al. (2016) reported that the introduction of paid family leave in California prevented rises in AHT admissions associated with the recession, a program already in place in BC. The potential synergies between supportive family programs such as paid family leave and the *Period of PURPLE Crying* might have facilitated the latter's effectiveness. Finally, our study excluded fatal AHT cases not admitted to hospital resulting in a slight underestimate of overall incidence.

## 5. Conclusion

Our study found an association of the *Period of PURPLE Crying* program implementation province-wide in BC with a 35% decrease in AHT hospitalizations. This reduction occurred despite low pre-implementation rates and contrasted positively with reports of increasing rates or no changes following prevention implementations concurrent with the economic recession (Dias et al., 2017; Zolotor et al., 2015). This result converges with a reduction of 29.5% in emergency visits for crying complaints related to the same program (Barr et al., 2015), implying that the messages were received and effective in reducing parental concern about normal increased postnatal crying (Barr, 2012). A report of lifetime costs of AHT cases in the USA (Miller et al., 2017) estimated that, if existing prevention programs reduced AHT by as much as 2%, there would be a net saving to society and government. Because of the tragic individual, family and societal costs, consideration of parental education programs as a component of AHT prevention may be appropriate.

## Declaration of interest

The National Center on Shaken Baby Syndrome (NCSBS) and RG Barr jointly registered the trademark for the *Period of PURPLE Crying*. Graham Consulting ULC consults and provides grants for child abuse prevention and child development programs. It owns the royalties that are a minor share of the net profits from the sale of the *Period of PURPLE Crying* program. RG Barr and M Barr sit as two members of the uncompensated Board of Directors. M Barr was the former Executive Director of the NCSBS, a 501(c)3 non-profit organization. Both are uncompensated members of the International Advisory Board of the NCSBS. The other authors have no conflict of interest or financial interests relevant to this article to disclose.

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