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Peer-reviewed scientific studies demonstrating health benefits of unprocessed milk, 2001-2018

This summary of peer-reviewed research has been compiled to address and refute Province of British Columbia policy statements such as:

- **"... there is no credible or scientific evidence that unpasteurized milk produces any measurable health benefits over pasteurized dairy products."** [43]
- **"Regarding the purported 'healthiness' of raw milk, there is no credible or scientific evidence that consumption of raw milk produces any measurable health benefits**." [44]

"The protective effects of raw cow's milk on infections were comparable to those of breastfeeding, suggesting similar anti-infective properties of bovine and human milk…" [22]	*"If efforts were taken by dairy farmers, milk industries, microbiologists, and health protection agencies to create such a minimally processed and safe cow's milk, a novel basic food might emerge with an enormous public health value. A prevention strategy based on a well-accepted food of everyday nutrition might succeed without profound changes in lifestyle."* [22]

Main Findings:

- Significant and reproducible evidence from large multi-country cross-sectional and cohort studies for a protective effect of raw farm milk consumption in childhood against the development of asthma and allergic diseases.
- Evidence from cross-sectional studies for a significant protective effect of raw farm milk consumption against rhinitis, respiratory tract infection, otitis and fever.
- Consumption of raw farm milk is a major independent factor in the "farm effect" by which children exposed to farm environments have a lower incidence of asthma and allergic diseases than non-exposed children.
- Protective effect against asthma and allergy is most pronounced when exposure to raw farm milk begins *in utero*, followed by consumption prior to one year of age.
- Children fed boiled farm milk more likely than controls to show signs of milk allergy at age 1, while consumption of raw farm milk is protective against developing milk allergy.
- Childhood consumption of raw farm milk correlates with higher pulmonary function and lower incidence of allergic diseases in adults.
- Many cellular signalling pathways are activated by consumption of raw farm milk, notably the promotion of regulatory T cell maturation and the epigenetic control of gene expression.
- Biological mechanisms are being further investigated with mouse models of asthma and gastrointestinal allergy and with molecular and genomic studies of human intestinal cell lines.
- Raw farm milk is a complex substance containing many bioactive components, including whey proteins, transcription factors, immunoglobulins, omega-3 fats and microRNAs.
- Commercial processing of milk, including pasteurization, homogenization and centrifugation, denatures bioactive proteins and RNA molecules and alters bioavailability of fat-soluble components.

Table 1: Summary of studies of raw milk with health outcomes, 2001-2018

Authors	Study population	Countries	Exposure	Main results
Cross-sectional studies				
Riedler et al. [1]	Rural farm and non-farm children (n = 812) aged 6–12 years, (ALEX Study)	Austria, Germany, Switzerland	Milk directly produced or purchased on a farm	Consumption of farm milk during first year of life significantly inversely associated with asthma, hay fever, and atopy, independent of other farm exposures
Barnes et al. [2]	Rural farm and non-farm and urban children aged 11–19 years (n = 929)	Greece	Unpasteurized milk products	Adj. OR and (95% CI) of atopy and unpasteurized farm milk consumption with and without simultaneous farm animal contact: 0.32 (0.13–0.78) and 0.58 (0.34–0.98), respectively
Wickens et al. [3]	Children living on farms or in small towns, aged 7–10 years (n = 293)	New Zealand	Unpasteurized milk ever, yogurt at least weekly before age 2 years	Adj. OR and (95% CI) for early yogurt consumption and hay fever 0.30 (0.1–0.7); any unpasteurized milk and atopic eczema: 0.2 (0.1–0.8). No significant association between unpasteurized milk consumption and asthma or atopy
Remes et al. [4]	Rural farm and non-farm children aged 6–15 years (n = 710)	Finland	Farm milk in infancy	Farm milk consumption not associated with atopy. No other allergic health outcomes reported
Radon et al. [5]	Rural farm and non-farm young adults aged 18-44 years (n = 321)	Germany	Raw, unboiled farm milk	Raw milk consumption and atopy adj. OR and (95% CI): 0.65 (0.36–1.18). In those visiting animal houses before age 7 years raw milk consumption and atopy: 0.35 (0.17–0.74)
Perkin and Strachan [6]	Rural farm and non-farm children (n = 4767), subsample (n = 879) with skin prick test	England	Unpasteurized milk (based on food-frequency questionnaire)	Current unpasteurized milk consumption associated with less eczema adj. OR and (95% CI): 0.59 (0.40–0.87) and atopy: 0.42 (0.10–0.53), and higher production of whole blood stimulated IFN-g. Effect independent of farming status. No effect on asthma
Waser et al. [7]	Rural farm and non-farm, Steiner Schools', and peri-urban children (n = 14 893) aged 5–13 years, (PARSIFAL Study)	Sweden, the Netherlands, Austria, Germany, Switzerland	Milk directly produced or purchased on a farm	Adj. OR and (95% CI) of farm milk consumption ever in life and asthma: 0.47 (0.61–0.88), rhinoconjunctivitis: 0.56 (0.43–0.73), sensitization to pollen: 0.67 (0.47–0.96), and food mix: 0.42 (0.19–0.92). Association observed in all subgroups, independent of farm-related co-exposures
Ege et al. [8]	Rural farm and reference children aged 5-13 years (n = 8263) (PARSIFAL Study)	Sweden, the Netherlands, Austria, Germany, Switzerland	Regular or rare farm milk consumption	Adj. OR and (95% CI) of regular farm milk consumption and asthma ever: 0.77 (0.60-0.99); current wheeze: 0.74 (0.58-0.96); not significant effect on atopic sensitization. When contolling for atopy status, effect of regular farm milk consumption on atopic asthma: 0.56 (0.31-1.01); no effect on non-atopic asthma
Bieli et al. [9]	ALEX (n = 576) and PARSIFAL (n = 1478) children with available DNA samples	Sweden, the Netherlands, Austria, Germany, Switzerland	Milk directly produced or purchased on a farm	Association between farm milk and asthma varied between genotypes of CD14/-1721. Adj. OR (95%CI) AA: 0.81 (0.07–0.47); AG: 0.47 (0.26–0.86); and GG: 0.98(0.46–2.08). Similar patterns for symptoms of hay fever and pollen sensitization. CD14/-1721 also modified association between farm milk and CD14 gene expression

Authors	Study population	Countries	Exposure	Main results
Loss et al. [10]	Rural farm, nonfarm exposed and nonfarm nonexposed children aged 6-12 (n = 8334) with blood sample; subsample (n = 895) with milk analysis [GABRIEL Advanced Study]	Austria, Germany, Switzerland	Boiled or unboiled farm milk	Adj. OR and (95% CI) for first unboiled farm milk prior to 1 year of age and asthma: 0.55 (0.43-0.70); daily unboiled farm milk and current asthma: 0.51 (0.36-0.72); daily unboiled farm milk and atopy: 0.68 (0.57-0.82); any unboiled farm milk and hay fever: 0.51 (0.37-0.69); daily unboiled farm milk and atopic dermatitis: 0.72 (0.55-0.96); farm milk and food allergen sensitization: 0.84 (0.69-1.03); inverse associations between asthma and whey proteins α-lactalbumin, β-lactoglobulin, BSA levels in milk; no association between total fat content or bacterial counts with health outcomes
Ege et al. [11]	Rural farm, nonfarm exposed and nonfarm nonexposed children aged 5-13 (n = 9668); subsample (n = 1708) with genotyping [GABRIEL Advanced Study]	Austria, Germany, Switzerland	Farm milk consumption	Screen for gene-environment interactions with farm exposure and asthma: slight effect of CD14 SNP with farm milk consumption and asthma; overall, protective effect of farm environment is independent of genotype.
Illi et al. [12]	Rural farm, nonfarm exposed and nonfarm nonexposed children aged 6-12 (n = 79888); exposure-stratified subsample (n = 9668) [GABRIEL Advanced Study]	Austria, Germany, Switzerland	Consumption of farm milk from pregnancy to age 3	Phase I demonstrated protective effect of farm environment on atopic dermatitis, hay fever, asthma, wheeze. Adj. OR and (95% CI) from Phase II for consumption of farm milk and asthma: 0.77 (0.66-0.90); hay fever: 0.64 (0.53-0.77); atopic sensitization: 0.73 (0.64-0.84); not significant association with atopic dermatitis. Protective effects are independent of effect of contact with cows
Sozańska et al. [13]	Small town and adjacent village inhabitants, age 6 to adult (n = 1700)	Poland	Consuming unpasteurized milk: in first year of life and currently	OR and (95% CI) for regular consumption of raw milk during first year and atopy in town: 0.46 (0.37–0.52); in villages: 0.59 (0.44–0.70).. Wheeze reduced in farmers regularly drinking raw milk: 0.75 (0.53–0.95). For regular raw milk consumption in infancy and asthma: 0.59(0.42–0.74) in villages and 0.51 (0.32–0.74) in town. Raw milk during infancy protective against hay fever and rhinitis in town nonfarmers. Adj. OR and (95% CI) for regular raw milk consumption in infancy and atopy in villages: 0.59 (0.44– 0.70) in children and 0.69 (0.24–3.70) in adults; in town: 0.46 (0.17–0.92) in children and 0.53 (0.30–0.89) in adults. Evidence that consumption of raw milk as adult confers additional protection beyond or in absence of early life consumption.
Horak et al. [14]	Farm, rural non-farm and town primary school children (n = 17 810) (GABRIEL Advanced Study group)	Austria	Regular farm milk consumption (at least weekly, for 6 months or more)	Protective effect of drinking raw farm milk: adj. OR and (95% CI) and asthma: 0.6 (0.4–0.9); and hay fever: 0.7 (0.5–0.9); no effect on atopic dermatitis, not significant effect on wheezing.
Müller-Rompa [15]	GABRIEL Advanced Study subset (n = 2565)	Germany	Farm milk consumption from birth to age 6	Geocoded distance of residence to farm negatively correlated with asthma and atopy; correlation explained mainly (non-farm children) or partially (farm children) by unprocessed farm milk consumption

Authors	Study population	Countries	Exposure	Main results
Prospective & cohort studies				
Ege et al. [16]	Rural farm and non-farm children (n = 922) followed since pregnancy (PASTURE study)	Finland, France Austria, Germany, Switzerland	Maternal consumption of boiled and unboiled farm milk during pregnancy	Maternal consumption of farm milk during pregnancy not related to IgE to seasonal allergens in cord blood of neonates. Boiled farm milk consumption during pregnancy positively associated with specific IgE to cow's milk: adj. OR and (95% CI): 1.78 (1.08–2.93)
Schaub et al. [17]	Neonates (n = 82) of rural farm and non-farm mothers (PAULCHEN Study)	Germany	Maternal consumption of farm milk during pregnancy	Demethylation of FOXP3 higher for maternal farm milk drinkers (P = 0.02); reflects maturation of immune cells. Treg cell markers and cytokine levels not significantly different in cord blood of farm milk drinkers.
Pfefferle et al. [18]	PASTURE study	Finland, France Austria, Germany, Switzerland	Skimmed and unskimmed farm milk, farm produced butter and yogurt during pregnancy	Maternal consumption of farm produced butter during pregnancy associated with increased IFN-g and TNF-a production in cord blood, farm produced yogurt inversely associated with these cytokines
Loss et al. [19]	PASTURE study subset with cord blood (n = 938) and one year (n = 752) blood samples	Finland, France Austria, Germany, Switzerland	Boiled or unboiled farm milk *in utero* and during first year	Unboiled farm milk consumption during first year showed strongest association with mRNA expression of innate immunity receptors CD14, TLR4, TLR5, TLR6, and TLR7: no significant association with other farming-related exposures or with prenatal farm milk exposure
Depner et al. [20]	PASTURE Study subset (n = 793) with cord blood and one year blood samples	Finland, France Austria, Germany, Switzerland	Boiled or unboiled farm milk *in utero* and during first year	Adj. OR and (95% CI) for cow's milk IgE and consumption of boiled: 1.71 (1.03-2.84) or unboiled: 0.76 (0.40-1.44) farm milk; ie boiled milk consumption sensitizes to milk allergy while raw milk consumption protects against milk allergy
Lluis et al. [21]	Rural farm and non-farm birth cohort (n = 298) followed to age 4.5 (PASTURE /EFRAIM study)	France, Germany	Farm milk consumption within the last 12 months	Adj. GMR and (95% CI) for farm milk consumption at 4.5 years and increased Treg cell numbers on stimulation by LPS: 1.41 (1.18-1.69); or PI: 1.37 (1.17-1.61); increased FOXP3 demethylation in farm milk consumers (associated with immune maturation of Treg cells). No clear difference between boiled and raw milk consumption; effects independent of other farm exposures
Loss et al. [22]	Rural farm and non-farm children (n = 983) followed since pregnancy (PASTURE study)	Finland, France Austria, Germany, Switzerland	Boiled or raw farm milk *in utero* and during first year	Adj. OR and (95% CI) for raw farm milk and rhinitis: 0.71 [0.54-0.94], respiratory tract infection: 0.77 [0.59-0.99], otitis: 0.14 [0.05-0.42], fever: 0.69 [0.48-1.01]; similar effects for boiled farm milk on respiratory tract inefction and fever but weaker for rhinitis and otitis; inverse association between raw farm milk and level of inflammatory marker hsCRP (high-sensitivity C-reactive protein)
Kääriö [23]	4.5 year old children from PASTURE study (n = 88) with blood samples	Finland	Farm milk consumption (mean > 10 mL /day)	Farm milk consumption assiciated with higher spontaneous IFN-γ levels in peripheral blood mononuclear cells (PBMCs); additive with other farm exposures. Two or more farm exposures (including raw milk consumption) associated with higher production of IL-1β and TNF in LPS-stimulated PBMCs

Authors	Study population	Countries	Exposure	Main results
Brick et al. [24]	PASTURE study (n = 934) with serum sample at age 4 and asthma diagnosis at age 6; subsample with milk analysis (n = 84)	Finland, France Austria, Germany, Switzerland	Unprocessed farm milk consumption, subsample with fatty acid composition determined	Adj. OR and (95% CI) for unprocessed farm milk consumption on asthma: 0.51 (0.15-1.73) at 1 year, 0.29 (0.11-0.76) at 6 years of age; for ω-3 polyunsaturated fatty acid level on asthma: 0.29 (0.11-0.81)
Martikainen [25]	PASTURE/EFRAIM Study subset (n = 168) age 6 rural farm & nonfarm	Finland, France	Farm milk consumption, from pregnancy through age 6	Adj. OR (95% CI) for persistent farm milk & asthma: 0.3 (0.09–0.97); nonsignificant effect on atopy. Association between farm milk & circulating dendritic cells at age 6: lower % MDC-2 cells for unpasteurized milk exposure during pregnancy (P=0.002) and lifetime (P=0.003)
Jonsson et al. [26]	Rural farming and non-farming birth cohort (n = 65) followed to age 3 (FARMFLORA Study)	Sweden	Detailed dietary assessment, including unpasteurized farm milk	Only farm children consumed unpasteurized milk and majority of allergies occurred in control group, so study could not determine whether unpasteurized milk consumption contributed to protective effect against allergy
Schröder et al [27]	Rural farm and non-farm birth cohort (n = 1133) followed to age 6 (PASTURE /EFRAIM study)	Finland, France Austria, Germany, Switzerland	High or low farm milk consumption and animal-stable exposure	When % regulatory T cells (Tregs) were considered longitudinally from 4.5 to 6 yrs, a significant decrease was found in high but not low farm-milk/animal-stable-exposed children. Asthma protection through farm exposure partly mediated by Tregs present at 4.5 yrs (11) vanished at 6 yrs, defining a critical time window in immune maturation between 4.5 and 6 yrs.
House et al. [28]	Adult farmers and spouses with and without asthma (n = 3229), (Agricultural Lung Health Study)	United States	Consumption of raw milk before age 6: ever or as main milk source	Adj. OR and (95% CI) for raw milk as primary milk source in childhood and adult atopy: 0.73 (0.58-0.90). No significant association with adult asthma
Wyss et al [29]	Adult farmers and spouses (n = 3061), (Agricultural Lung Health Study)	United States	Childhood raw milk consumption	Raw milk consumption was associated with higher lung function in adults, most notable for consumption beginning before age 6: FEV1: β=51.3mL (95% CI 2.8 - 99.8 mL, p=0.04); FVC: β=76.7 mL(95% CI 21.7 - 131.7mL, p=0.006).
***In vitro* and *in vivo* studies**				
Hodgkinson [30]	Gastrointestinal allergy mouse model (n = 40 mice)	N/A	Raw, heated, or gamma-irradiated milk	Mice fed raw milk had higher MMCP-1 and IgE levels on antigen challenge; splenocytes from mice fed raw, heated or sterilized milk produced more IL-4 than contols; splenocytes from raw but not heated or sterilized milk fed mice produced more IL-10 regulatory cytokine, which suppresses inflammation
Böcking et al. [31]	Mouse model of allergic airway inflammation (n = 24 mice)	N/A	High or low conjugated linoleic acid (CLA) milk fat (pasteurized) added to diet	No allergy-protective effects of CLA-rich milk fat observed, suggesting the relatively high CLA content of farm milk is not the component responsible for immunological effects.

Authors	Study population	Countries	Exposure	Main results
McCarthy et al. [32]	Human intestinal cell line	N/A	Raw or pasteurized milk	Human whole genome microarray analysis of cells exposed for 6 hours to raw or pasteurized milk revealed differential expression of 1041 genes. The 442 genes upregulated by raw milk were determined by gene ontology analysis to relate primarily to immune response, antigen processing and cell surface signalling. Data suggests that intestinal cells may increase antigen sampling and presentation via MHC class II molecules, potentially leading to an increase in allergen tolerance.
Hodgkinson et al [33]	Mice fed raw milk following antibiotic exposure (n = 60 mice)	N/A	High or low IgA-containing raw milk	Antibiotic treatment reduces diversity of Intestinal microbiota; milk feeding alters re-establishment of microbiota. Mice fed water showed increased Mycoplasma levels (associated with Crohn's disease); mice fed milk showed increased Barnesiella levels (provides protection against pathogens); high-IgA milk correlated with increased Lactobacillus levels (reduces intestinal inflammation and protects against Clostridium difficile).
Fotschki et al [34]	Mouse model of cow's milk allergy (n = 32 mice)	N/A	Raw horse milk	Pro-inflammatory IL-4 increased by sensitization to cow's milk; decreased by feeding horse milk. TLR-4 level increased by horse milk feeding. Increased intestinal Bifidobacterium levels in milk-fed mice.
Abbring et al. [35]	House dust mite-induced asthma mouse model (n = 54 mice)	N/A	Raw or heated farm milk	Raw but not heated milk consumption: reduced production of pulmonary type 2 cytokines; reduced airway hyper-responsiveness and pulmonary inflammation. Both raw and heated farm milk: reduced dendritic cell-derived inflammatory mediators; reduced pulmonary Th2 cells and related cytokines.
Reviews and syntheses				
Braun-Fahrländer & von Mutius [36]	Epidemiological studies of farm milk consumption and asthma, hay fever and atopic sensitization	N/A	Farm milk consumption	Cross-sectional studies show reduced risk of asthma, hay fever & atopic sensitization if farm milk consumed in first year of life, independent of being a farm child. Prospective birth cohort studies show maternal consumption of unboiled whole farm milk, farm butter and farm yoghurt modulate cytokine patterns of neonates. Homogenization, skimming and heating of commercial milk may interfere with protective effects.
Lluis & Schaub [37]	Population-based studies of farm effect on atopic diseases	N/A	Farm milk consumption	Farm milk consumption contributes to modulating immune reaction toward Th1/Treg predominance, involving epigenetic changes. Early exposure, especially *in utero*, gives stronger effect than later exposure; gives long lasting lower risk of atopic diseases.

Authors	Study population	Countries	Exposure	Main results
Wlasiuk & Vercelli [38]	Studies of protective farm environment on asthma & allergy	N/A	Farm milk consumption	Contact with cows and straw and consumption of farm milk account for virtually all the protective farm effect for asthma but not atopy; significant inverse association was found between levels of whey proteins (albumin, α-lactalbumin, β-lactoglobulin) and asthma but, again, not atopy. Because α-lactalbumin and β-lactoglobulin are major milk allergens, early life exposure to these proteins may decrease the risk of asthma by promoting early tolerance; likely role of gut and lung microbiome connecting farm exposures and immune system maturation.
van Neerven et al. [39]	Studies of allergy-protective components of raw milk	N/A	Raw cow's milk as compared to human breast milk	Milk proteins, cytokines, immunoglobulins, fatty acids, lactose, oligosaccharides and microbes could all contribute to: inducing adaptive immune response, creating microenvironment favourable to Treg development, modulating microbiota and supporting intestinal barrier function.
Cakebread et al. [40]	Studies of bovine milk immunoglobulin A (IgA)	N/A	Milk IgA consumption	Human IgA in breastmilk protects newborns against pathogens, and promotes establishment and maintenance of intestinal homeostasis. Bovine milk IgA may provide similar benefits, but milk processing destroys antibody activity.
von Mutius [41]	Studies of microbial environment on early asthma prevention	N/A	Farm milk consumption	Consumption of unprocessed cow's milk, along with exposure to animals, is major relevant farm exposure. Heat-sensitive components such as whey proteins or microRNAs, and native fat composition likely more important than bacterial content for asthma protection. Strongest protection due to exposure *in utero* or during infancy. Consumption of raw but not heated farm milk during first year also associated with less rhinitis and otitis media.
Melnik et al. [42]	Studies of farm milk & regulatory T cell differentiation	N/A	Farm milk consumption	6 major signalling pathways identified that could explain raw milk induced epigenetic signalling system regulating FOXP3 expression and regulatory T cell differentiation: amino acids; long chain ω-3 fatty acids; microRNAs; exosomal Transforming Growth Factor-β; Bifidobacteria and Lactobacilli; milk oligosaccharides

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