JECH Online First, published on January 2, 2014 as 10.1136/jech-2013-203270

Household crowding is associated with higher allostatic load among the Inuit

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Received 18 August 2013
Revised 18 November 2013
Accepted 21 November 2013

To cite: Riva M, Plusquellec P, Juster R-P, *et al*. *J Epidemiol Community Health* Published Online First: [*please include* Day Month Year] doi:10.1136/jech-2013-203270

ABSTRACT

Background Household crowding is an important problem in some aboriginal communities that is reaching particularly high levels among the circumpolar Inuit. Living in overcrowded conditions may endanger health via stress pathophysiology. This study examines whether higher household crowding is associated with stress-related physiological dysregulations among the Inuit.

Methods Cross-sectional data on 822 Inuit adults were taken from the 2004 Qanuippitaa? How are we? Nunavik Inuit Health Survey. Chronic stress was measured using the concept of allostatic load (AL) representing the multisystemic biological 'wear and tear' of chronic stress. A summary index of AL was constructed using 14 physiological indicators compiled into a traditional count-based index and a binary variable that contrasted people at risk on at least seven physiological indicators. Household crowding was measured using indicators of household size (total number of people and number of children per house) and overcrowding defined as more than one person per room. Data were analysed using weighted Generalised Estimating Equations controlling for participants' age, sex, income, diet and involvement in traditional activities.

Results Higher household crowding was significantly associated with elevated AL levels and with greater odds of being at risk on at least seven physiological indicators, especially among women and independently of individuals' characteristics.

Conclusions This study demonstrates that household crowding is a source of chronic stress among the Inuit of Nunavik. Differential housing conditions are shown to be a marker of health inequalities among this population. Housing conditions are a critical public health issue in many aboriginal communities that must be investigated further to inform healthy and sustainable housing strategies.

INTRODUCTION

Housing conditions are a key determinant of health[1 2] and of aboriginal health.[3–5] In Canada household crowding is reaching particularly high levels among aboriginal populations, especially among the Inuit. In 2006 nearly a third of Inuit lived in overcrowded houses (defined by more than one person per room (PPR) by Statistics Canada[6]). This proportion is almost 10 times higher than for non-aboriginal Canadian households.[7]

Although household crowding has mainly been associated with respiratory problems among the Inuit,[8 9] living in crowded conditions may further endanger health via stress pathophysiology. A growing body of evidence suggests that household crowding may be a chronic environmental stressor; however, this hypothesis is based mainly on children. An American study found that the association between more people per room and poor health leading to school absence among six-grade boys was mediated by cardiovascular reactivity sensitive to stressful circumstances.[10] Household crowding was associated with increased blood pressure among boys from India[11] and with the incidence of hypertension among Caucasian women in the USA.[12] Work by Evans *et al* has demonstrated that as early as age 9, increased stress is associated with a cumulative risk model that combines factors like household crowding, noise, violence and single parenthood into an index representing early adversity.[13] By age 13, these cumulative risk factors in combination with low maternal responsiveness further exacerbate stress levels.[14] In these studies, chronic stress was measured using 'allostatic load (AL)' indices representing multisystemic physiological dysregulations in response to chronic exposure to stressful life circumstances.[15–17]

Stress is considered an important determinant of aboriginal health as aboriginal populations have experienced, and continue to experience, rapid social and cultural changes.[18 19] To date, only a few studies have examined biological indicators of stress responses among aboriginal populations. A study demonstrated higher glycated haemoglobin concentrations (representing cumulative glucose metabolism) among three aboriginal groups (Australian Aboriginal people, Torres Strait Islanders and Native Canadians) compared with non-aboriginal groups (Caucasian Australians and Greek migrants to Australia).[20] Among American Samoans, higher AL was observed in women compared with men and in those with type 2 diabetes.[21] Variation in stress pathophysiological indices have yet to be examined in relation to differential exposure to social determinants of aboriginal health.

The objective of this study is to test the hypothesis that higher household crowding is a source of chronic stress for Inuit adults that elevates their AL levels. Examining the influence of housing conditions in relation to comprehensive measures of chronic stress, such as AL, is likely to contribute to the understanding of the higher rates of ill-health among aboriginal populations.

METHODS

Study design, setting and sample

This study is set in Nunavik, the Inuit homeland in the province of Quebec, Canada. Almost all of the 10 570 inhabitants of the region are Inuit (90%)[22] and live in one of 14 villages located on the coasts

of Hudson Bay, Hudson Strait and Ungava Bay. Most of the population (more than 90%) lives in social housing, independently of their income levels, with the rent scale adapted to the household income. Therefore, household tenure is not a marker of socioeconomic status in Nunavik.

Cross-sectional data are from the 2004 'Qanuippitaa? How are we?' Nunavik Inuit Health Survey that is described in detail elsewhere.[23] The target population included all permanent residents from the 14 villages, aged 18 years and older, and excluded non-Inuit households and individuals living in public institutions. In each community, a stratified random sample of private households was first selected in proportion to the size of their population. Since home addresses in some communities are consecutive, the survey frame was sorted first by home addresses, followed by a systematic draw of a predetermined number of households to avoid selection of two immediate neighbours. Within a household, all eligible individuals were asked to participate. Among the 677 households invited, 521 agreed to participate giving a household response rate of 77.8%. Of the 914 participants recruited to the survey, 908 self-identified as Inuit.

Data were collected on board the research icebreaker *Amundsen*. Each participant was invited to fill out questionnaires concerning their health, and demographic and socioeconomic circumstances. Individuals aged 18–74 years were asked to attend a clinical evaluation during which biological samples were collected. The study was approved by the ethics committee of Université Laval and Institut national de santé publique du Québec. Written informed consent was provided by all participants.

Allostatic load

Recent advances in theoretical and empirical literature linking chronic stress to disease have been influenced by the concepts of allostasis and AL.[24] The term *allostasis* was introduced to describe adaptive biological processes that facilitate dynamic stabilisation to environmental demands.[25] It is postulated that the body adapts and adjusts to environmental demands by matching these demands with physiological responses.[25] In this view, allostatic recalibrations (eg, increased blood pressure) in the context of overcrowding represent adaptations to the demands of the environment. It is when these allostatic responses become cumulative that they become physiologically taxing and ultimately maladaptive.[26–28] In accordance, *AL* is defined as the 'wear and tear' bodies and brains experience when cumulatively exposed to chronic stressful situations that recalibrate biological functions.[15–17] Epidemiological studies have led to the development of AL algorithms that are advantageous due to their multisystemic nature, that is, AL indices based on diverse indicators from a range of physiological systems[15 17] that apply subclinical thresholds.[17]

In the current study, AL was measured using information derived from 14 physiological indicators from the cardiovascular, metabolic, immune/inflammatory and neuroendocrine systems as well as anthropometric information. Systolic and diastolic blood pressures were measured according to the Canadian Coalition for High Blood Pressure technique with mercury sphygmomanometers, 15-inch stethoscopes and cuffs appropriately sized to the participants' arm.[29] Height was quantified by stadiometer and body weight was recorded using a beam scale; these anthropometric measurements were transformed into body mass index (kg/m^2). Waist-to-hip ratio was calculated based on waist circumference (measured at the narrowest circumference of the trunk, at the end of a normal expiration) and hip circumference (quantified by placing the tape around the pubic symphysis and the most prominent part of the buttocks). Prior to blood sample collection, participants were advised to fast for at least 8 h. Blood specimens were analysed for total cholesterol, high density lipoprotein cholesterol, low density lipoprotein cholesterol, triglycerides, glucose, insulin, thyroid stimulating hormone (TSH), C reactive protein, interleukin 6 and tumour necrosis factor-α, in a laboratory at the Centre Hospitalier Universitaire de Québec.[23]

Physiological indicators in the 'high-risk' quartiles of the sample's distributions were assigned a value of 1 and then summed into an AL index.[17] For all physiological indicators, high risk corresponds to the highest quartile of the sample's distribution, with two exceptions: for high density lipoprotein cholesterol, high risk corresponds to the lowest quartile; for TSH, values below the 12.5th centile and above the 87.5th centile of the distribution corresponds to high risk category (for hypothyroidism or hyperthyroidism, respectively). In computing this index, we did not consider whether the person was taking medications since remediation would be reflected in biomarker levels and dichotomously represented in the AL count-based approach.

Two measures of AL were considered as dependent variables: a continuous AL index and a binary variable contrasting people with at least seven physiological indicators in the high-risk quartile.[30]

Household crowding

According to reviews of studies conducted in non-aboriginal populations, the measurement of household 'crowding' and 'overcrowding' varies across studies, with some using the number of people per dwelling, the number of people per bedroom or room, the latter being the most commonly used measure.[31 32] The threshold across which a dwelling is deemed to be overcrowded and problematic for health also differs between studies and health outcomes investigated.[31 32] For these reasons, different indicators of household crowding were considered.

Participants reported on the number and age of household members and on the number of bedrooms. From this information, two indicators of household crowding were created: (1) household size defined as a) the total number of people in the household and b) the number of children (aged less than 18 years) in the house; and (2) household overcrowding, defined as more than one PPR, in line with previously used measures.[6] For this measure, we assumed that adding two rooms (kitchen and living room) to the number of bedrooms would be a reasonable proxy of the PPR indicator (in Nunavik, the design of social housing is only differentiated by year of construction and number of bedrooms). Although the cultural relevance of such indicators to measure household crowding in the Arctic has been criticised,[33] no alternative indicators (or thresholds) have been proposed. To allow for sensitivity analyses, household size was treated as a continuous and as a dichotomous variable with the cut-off set to 1 above the median. A categorical variable contrasted households with two children or less, three, four and five or more children.

Individual covariates

Analyses were adjusted for age and sex. Personal income was also considered, as associations between socioeconomic measures and AL have been documented in general[34] and cross-cultural samples.[35–37] Participants reported their personal income as being: <$20 000; $20 000 <$40 000; ≥$40 000.

Some people did not report or did not know their personal income (12.0%); this was more frequent among women than men (χ^2=24.35; p<0.001) and increased with age (t=3.80; p<0.001). To retain this group, a category 'missing information' was created.

The Inuit way of life is undergoing a rapid transition from a physically active lifestyle and diet based on country food, towards more sedentary pursuits and consumption of market food high in saturated fats and refined sugars.[38] A higher participation in traditional activities such as hunting or fishing and higher intake of country food (especially of marine origins) may be associated with a lower AL. In the survey, respondents reported their frequency (never; less than once a month; 1–3 days per month; 1–3 days per week; and ≥4 days per week) of hunting and fishing in each of the four seasons in the previous year, from which a categorical variable was created. Eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) are the main dietary omega-3 polyunsaturated fatty acids found in high concentrations in marine fish and oils, which are associated with reduced risk of cardiovascular diseases[39] and other chronic diseases.[40] Eicosapentaenoic acid+docosahexaenoic acid profile—determined as the proportion of total fatty acids in red blood cell membranes—was used as a proxy measure for the intake of marine foods. Laboratory analyses used to determine fatty acids profile have been described in detail elsewhere.[23]

Smoking status and involvement in physical activity were also considered as potential confounders, but were not included in the final analyses. In our sample, 76.2% reported smoking. Smoking did not vary by household crowding but was associated with lower income categories in bivariate analyses (χ^2 (df=3)=29.05, p<0.001). Adjusting the final models for smoking did not significantly alter associations between household crowding and AL. To prevent multicollinearity with the indicator of socioeconomic status, smoking was therefore not considered in the analyses. Physical activity was not significantly associated with AL in bivariate analysis and therefore was not retained for the final analyses.

Statistical analyses

From the sample of 908 participants aged 18–74 years old, 860 responded to the individual questionnaire and participated in the clinical session. Of those, 839 had complete data on at least seven physiological indicators. Analyses are based on a final subset of 822 Inuit without missing information on individual covariates. Data were analysed with linear and logistic regression models performed using Generalised Estimating Equations that adjusted for the potential correlation of observations (individuals) within household clusters and weighted using sampling and bootstrap weights. Analyses were conducted using SUDAAN V.10.0.[41] Separate models were run for the different indicators of household crowding, adjusting for all individual covariates. Sex-stratified analyses were also conducted.

RESULTS

Descriptive statistics of the sample are shown in table 1. Household size ranged from 1 to 14 individuals, with a mean of 5.6 people and 2.4 children per house. Four out of 10 people lived in overcrowded dwellings. One out of 10 participants was in the high-risk quartiles on at least seven physiological indicators. The sample comprised more women than men. Half of the sample was less than 35 years old (mean age: 37 years). Almost 70% of participants had a yearly personal income below $40 000. Descriptive statistics for the 14 physiological indicators and their correlation with the overall AL index are presented in table 2.

Table 1 Descriptive statistics of the sample of 839 Nunavimmiut (Qanuippitaa? Nunavik Inuit Health Survey, 2004)

Allostatic load	
Index (mean (SD))	0.25 (0.18)
At risk ≥7 physiological indicators (n(%))	101 (12.04)
Individuals' characteristics	
Sex [n (%)]	
Men	368 (43.86)
Women	471 (56.14)
Age (mean(SD))	37.02 (14.11)
Income (n (%))	
<$20 000	387 (46.13)
$20 000≤$40 000	197 (23.48)
≥$40 000	146 (17.40)
Missing information	109 (12.99)
Fishing or hunting (n (%))*	
Never or rarely	271 (32.30)
Occasionally	212 (25.27)
Frequently	356 (42.43)
Diet	
EPA-DHA (mean(SD))	7.16 (3.01)
Household crowding	
Household size	
(A) Total number of people mean (SD); median; range	5.62 (2.52); 5; 1–14
≤5 people (n (%))	452 (53.87)
>5 people (n (%))	387 (46.13)
(B) Number of children	2.44 (1.59); 2; 0–9
0–2 children (n (%))	430 (51.25)
3 children (n (%))	196 (23.36)
4 children (n (%))	133 (15.85)
≥5 children (n (%))	80 (9.54)
Household overcrowding	
≤1 person per room (n (%))	493 (58.76)
>1 person per room (n (%))	346 (41.24)

*The category 'never or rarely' groups participants reporting fishing or hunting less than once a month, or never, in at least three seasons. The category 'frequently' groups participants who reported fishing or hunting at least 1 day per week in at least two seasons. The category 'occasionally' groups participants who did not meet the criteria for the other two categories.
DHA, docosahexaenoic acid; EPA, eicosapentaenoic acid.

Table 3 presents results for associations between household crowding and AL, adjusted for participants' covariates. Higher household size was significantly associated with an elevated AL index (β: 0.006; SE 0.002) and with being at risk on at least seven physiological indicators. Specifically, compared with people living in dwellings with five people or less, those living in houses with more than five people were more likely to have an increased AL index (β: 0.033; SE: 0.012) and were more than twice as likely to be at risk on at least seven physiological indicators (OR: 2.20; 95% CI 1.38 to 3.50). More children in the household was also significantly positively associated with AL measures. People living in overcrowded houses had elevated AL (β: 0.024, SE: 0.012) and were more likely to be at risk on at least seven physiological indicators (OR: 1.82; 95% CI 1.14 to 2.90).

With respect to individuals' characteristics, measures of AL did not significantly vary (at p < 0.05) by sex, diet or involvement in traditional activities (results not shown). Age was positively and significantly associated with AL index (β: 0.005; SE: 0.001) and being at risk on at least seven physiological

Table 2 Descriptive statistics of the physiological indicators used in the allostatic load (AL) index (n=839 Nunavimmiut in the Qanuippitaa? Nunavik Inuit Health Survey (2004) with valid data for at least seven physiological indicators)

Physiological indicators in the AL index	Geometric mean (CIs)	Criterion cut-point (high-risk quartile)*	Correlation with AL index†
Cardiovascular			
Systolic blood pressure (mm Hg)	117.14 (116.17 to 118.11)	126.50	0.455
Diastolic blood pressure (mm Hg)	73.18 (72.55 to 73.82)	80.00	0.427
Anthropometric			
Waist-hip ratio	0.89 (0.88 to 0.89)	0.93	0.563
Body mass index	26.85 (26.49 to 27.22)	30.80	0.645
Metabolic			
Glucose (mmol/L)	4.48 (4.43 to 4.54)	4.80	0.421‡
Insulin (pmol/L)	52.04 (49.93 to 54.24)	70.00	0.454‡
Triglycerides (mmol/L)	1.08 (1.04 to 1.12)	1.44	0.518‡
HDL cholesterol (mmol/L)	1.61 (1.58 to 1.64)	1.32*	−0.271
LDL cholesterol (mmol/L)	2.64 (2.58 to 2.71)	3.32	0.403
Total cholesterol (mmol/L)	4.92 (4.85 to 4.99)	5.68	0.383
Neuroendocrine			
Thyroid stimulating hormone (mIU/L)	0.99 (0.94 to 1.04)	0.46/2.06*	0.140‡
Immune/inflammatory			
C reactive protein (mg/L)	1.33 (1.21 to 1.45)	3.40	0.493‡
Interleukin 6 (pg/mL)	1.83 (1.74 to 1.93)	3.05	0.422‡
TNF α (pg/mL)	1.92 (1.84 to 2.00)	2.54	0.249‡

*For all physiological indicators, the high-risk quartile corresponds to the highest quartile of the sample's distribution, with two exceptions (as indicated in the table) that corresponds to the lowest quartile for HDL cholesterol, and to the 12.5th/87.5th centiles of the distribution for thyroid stimulating hormone.
†All Pearson correlations are significant at p<0.001.
‡Variables were log transformed to insure linearity.
HDL, high density lipoprotein; LDL, low density lipoprotein; TNF, tumour necrosis factor.

indicators (OR: 1.06; 95% CI 1.04 to 1.09) (in models also adjusting for household size). Compared with those with personal income <$20 000, people with higher income had significantly elevated AL levels ($\beta_{\$20\,000 < \$40\,000}$: 0.037; SE: 0.015; $\beta_{\geq \$40\,000}$: 0.049; SE: 0.017) and were more likely to be at risk on at least seven physiological indicators ($OR_{\$20\,000 < \$40\,000}$: 2.53; 95% CI 1.40 to 4.56; $OR_{\geq \$40\,000}$: 2.84; 95% CI 1.57 to 5.14).

Sex-stratified analyses are presented in table 4. Higher household size and overcrowding were significantly associated with higher AL, especially among women. The odds of being at risk on at least seven physiological indicators were twice as high for women living in overcrowded conditions compared with women living in dwellings not considered overcrowded. A greater number of children in the household was associated with higher AL levels among women and men, but stronger effect sizes were observed for men.

DISCUSSION

This study examined whether household crowding is a source of chronic stress among aboriginal populations. Chronic stress was measured using the AL framework applied for the first

Table 3 Adjusted‡ associations between household crowding and allostatic load (AL) for n=822 Nunavimmiut in the Qanuippitaa? Nunavik Inuit Health Survey (2004)

	AL index β (SE)	At risk on ≥7 physiological indicators OR (95% CI)
Household size		
(A) Total number of people in the house	0.006 (0.002)*	1.11 (1.00 to 1.23)*
≤5 people (ref)		
>5 people	0.033 (0.012)**	2.20 (1.38 to 3.50)***
(B) Number of children in the house	0.014 (0.004)***	1.38 (1.19 to 1.59)***
0–2 children (ref)		
3 children	0.026 (0.014)†	2.53 (1.54 to 4.14)***
4 children	0.043 (0.018)*	3.76 (2.19 to 6.48)***
≥5 children	0.071 (0.023)**	3.65 (1.55 to 8.89)**
Household overcrowding		
No (ref)		
Yes (>1 person per room)	0.024 (0.012)*	1.82 (1.14 to 2.90)*

* p<0.05; ** p<0.01; *** p<0.001; † p<0.10.
‡Models are adjusted for participants' age, sex, personal income, diet and involvement in traditional activities (ie, fishing and hunting).

Table 4 Adjusted‡ sex-stratified associations between household crowding and allostatic load (AL) in the Qanuippitaa? Nunavik Inuit Health Survey (2004)

	Women (n=460)		Men (n=362)	
	AL index β (SE)	At risk on ≥7 physiol. indicators OR (95% CI)	AL index β (SE)	At risk on ≥7 physiol. indicators OR (95% CI)
Household size				
(A) Total number of people in the house	0.006 (0.003)*	1.12 (1.01 to 1.25)*	0.003 (0.003)	1.12 (0.97 to 1.28)
≤5 people (ref)				
>5 people	0.037 (0.015)*	2.44 (1.34 to 4.43)**	0.023 (0.016)	2.08 (1.01 to 4.29)*
(B) Number of children in the house	0.013 (0.005)**	1.33 (1.11 to 1.59)**	0.012 (0.005)*	1.44 (1.14 to 1.81)**
0–2 children (ref)				
3 children	0.004 (0.016)†	1.27 (0.63 to 2.59)	0.045 (0.020)*	5.65 (2.45 to 13.01)***
4 children	0.062 (0.020)**	3.48 (1.67 to 7.25)***	0.021 (0.025)	3.95 (1.26 to 12.43)*
≥ 5 children	0.058 (0.029)*	2.74 (0.99 to 7.65)†	0.062 (0.031)*	5.07 (1.25 to 20.55)*
Household overcrowding				
No (ref)				
Yes (>1 person per room)	0.031 (0.015)*	2.07 (1.15 to 3.73)*	0.013 (0.016)	1.66 (0.78 to 3.51)

* p<0.05; ** p<0.01; *** p<0.001; †p<0.10.
‡Models are adjusted for participants' age, sex, personal income, diet and involvement in traditional activities (ie, fishing and hunting).

time to a representative sample of Inuit. Previous studies reported that living in overcrowded dwellings is associated with increased blood pressure,[11 12] cardiovascular reactivity,[10] and with increased AL[13 14] among younger age groups. Extending upon these findings, we observed positive associations between household size and overcrowding and AL among Inuit adults. These associations were independent of sex, age, personal income levels, diet and involvement in traditional activities. In addition, results show that the differential housing conditions are associated with health inequalities among the Inuit of Nunavik.

In our sample, household size was high, with a median of five people per dwelling and at least three children in 50% of households. Forty per cent of the participants lived in overcrowded dwellings, defined by more than one PPR. Living in an overcrowded house can limit the control one has over domestic situations, reduce privacy, potentially create undesirable social interactions and influence parenting behaviours. Lack of control within the home environment can in turn act as a stressor leading to 'over-arousal'[42] or 'stimulus overload'.[43] When cumulative, inadequate housing conditions may contribute to the development of pathophysiologies like cardiovascular diseases and to mortality through sustained physiological responses to chronic environmental stressors.[17 21 44]

Although measures of AL did not vary by sex, there was however variation in the association between household crowding and AL between women and men. Gender stratification and roles in the household could explain these results. Indeed studies have shown that low control at home was a stronger predictor of anxiety and depression among women[45] and significantly predicted coronary heart diseases among women.[46] As women's social roles still relate to domestic labour and emotional work, an elevated level of felt demands in more crowded households could lead to a lower sense of control, resulting in higher AL among women. Among men, 'household demand overload', for example, the pressure of providing to a large household including several children, may lead to increased stress levels.

Replication studies are warranted to assess whether inadequate housing conditions are a source of chronic stress for other aboriginal populations, and whether they explain health inequalities between aboriginal and non-aboriginal populations nationally and internationally. Future studies are also required to assess the mediating role of AL between housing conditions and cardiovascular morbidity and mortality among aboriginal populations, as research indicates that higher AL is associated with reduced life expectancy.[47]

Results of our study should be interpreted in light of some limitations. Although the use of an objective measure of chronic stress is a strength, the AL algorithm has some constraints. Each physiological indicator is considered to contribute equally to AL, which is perhaps a conservative estimate of stress pathophysiology. Moreover, our measure of AL incorporates only one indicator of the neuroendocrine system (TSH was the only indicator available from the clinical component of the Nunavik Inuit Health Survey), but several indicators of the cardiometabolic system and anthropometric measurements. Component indicators of AL models may be related to other physiological dysregulations, such as the metabolic syndrome (MetS). However, studies suggest that AL and MetS are two different (although related) physiological process.[48 49] Among the Inuit of Nunavik the prevalence of the MetS is low in comparison with other ethnic groups in the province of Quebec.[50] Future studies should strive to include additional indicators of the neuroendocrine system (eg, cortisol, epinephrine, norepinephrine, etc) in the clinical protocol.

The cultural relevance of our indicators of household crowding, but also of socioeconomic status, as applied in aboriginal contexts is questionable.[33 51] Unfortunately, studies have yet to empirically examine the associations between alternative indicators and health outcomes. This is problematic when we consider that marginalised peoples do not share the same distribution of wealth and resources as other sections of society. For example, that higher income would be associated with higher AL levels in the Inuit speaks to complex intersectionality among risk and protective factors that likely differ substantially from the general Canadian population. Given the high costs associated with accessing health-promoting goods and activities such as healthy food and hunting and fishing equipment, it could be that higher income is not as health promoting among this population. In

the operational definition of household crowding, sensitivity analyses suggest a linear relationship between household size and AL. Although a linear relationship was not observed between a continuous measure of people per room and AL (results not shown), there is indication that a deleterious health effect of household overcrowding appears when there is more than one PPR. More research is needed to conceptualise and operationalise housing conditions (but also socioeconomic status) in coherence with the Inuit culture,[33 52] and with aboriginal cultures more broadly.[51]

The cross-sectional design of the study limits ascertaining whether exposure to crowded dwellings over the life course leads to higher AL. Cohort studies are needed to better understand the role of household crowding on the incidence of poor health, including cardiovascular diseases, among aboriginal populations, in Canada and elsewhere.

Results of this study are of international relevance for several reasons. To the best of our knowledge, this is one of a few studies applying the AL model to aboriginal populations, despite clear recognition that stress is a key health determinant for this group. Although differences in AL levels in aboriginal and non-aboriginal populations were not examined in this paper, they should be the topic of future investigations. Findings demonstrate social inequalities in AL among the Inuit, further contributing to cross-cultural evidence of higher AL in vulnerable populations.

What is already known?

- The prevalence of inadequate housing conditions, such as overcrowding, is high among aboriginal communities in Canada, especially among Inuit populations.
- The health impacts associated with inadequate housing conditions extend beyond respiratory and infectious diseases, to further endanger health via stress pathophysiology.
- Although stress is an important determinant of aboriginal health, few studies have examined physiological indicators of stress responses among aboriginal populations, and none among the Inuit.
- Examining the influence of household crowding in relation to comprehensive measures of chronic stress, such as allostatic load, can inform public policies targeting housing conditions as a key strategy to improve aboriginal health.

What this study adds?

- Chronic stress was measured using the allostatic load (AL) framework applied for the first time to a representative sample of Inuit.
- Positive associations were observed between household crowding and AL among the Inuit, especially among women. These associations were independent of age, personal income levels, diet and involvement in traditional activities.
- Sensitivity analyses suggest a linear relationship between household size and AL. There is also indication that a deleterious health effect of household overcrowding appears when there is more than one person per room.
- Differential housing conditions, such as crowding levels, are a marker of health inequalities among the Inuit in Nunavik.

In conclusions, our study shows that housing conditions are an important determinant of Inuit health, and a marker of health inequalities among this population. Specifically, household size and overcrowding are believed to be a source of chronic stress that threatens the health and well-being of Inuit women and men. Despite housing conditions being identified as a key determinant of aboriginal health, their role in the expression of health and health inequalities has seldom been investigated among this population.[4] Addressing this research gap is imperative to inform public policies targeting housing conditions as a key strategy to improve aboriginal health.

Acknowledgements MR's work on this paper was supported by a Banting postdoctoral fellowship awarded from the Canadian Institutes of Health Research (funding reference number: BPF-112930). The authors would like to thank the participants who gave their time to be involved in this study. The manuscript was approved by the Nunavik Nutrition and Health Committee. The authors thank two anonymous reviewers for their useful comments.

Contributors MR and PP conceptualised and designed the study. MR, EAL-S and BA contributed to the statistical design of the study and MR and EAL-S conducted the data analyses. ML contributed to the data analysis. MR, PP, R-PJ and EAL-S interpreted the data. MR, PP and R-PJ conducted the literature search and wrote the first draft of the manuscript. ED and SD were responsible for data collection. All authors critically revised, read and approved the final version of the manuscript.

Competing interests None.

Ethics approval Université Laval and Institut national de santé publique du Québecs.

Provenance and peer review Not commissioned; externally peer reviewed.

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