

# Obesity studies in the circumpolar Inuit: a scoping review

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**Background.** Among circumpolar populations, recent research has documented a significant increase in risk factors which are commonly associated with chronic disease, notably obesity.

**Objective.** The present study undertakes a scoping review of research on obesity in the circumpolar Inuit to determine the extent obesity research has been undertaken, how well all subpopulations and geographic areas are represented, the methodologies used and whether they are sufficient in describing risk factors, and the prevalence and health outcomes associated with obesity.

**Design.** Online databases were used to identify papers published 1992–2011, from which we selected 38 publications from Canada, the United States, and Greenland that used obesity as a primary or secondary outcome variable in 30 or more non-pregnant Inuit (“Eskimo”) participants aged 2 years or older.

**Results.** The majority of publications (92%) reported cross-sectional studies while 8% examined retrospective cohorts. All but one of the studies collected measured data. Overall 84% of the publications examined obesity in adults. Those examining obesity in children focused on early childhood or adolescence. While most (66%) reported 1 or more anthropometric indices, none incorporated direct measures of adiposity. Evaluated using a customized quality assessment instrument, 26% of studies achieved an “A” quality ranking, while 18 and 39% achieved quality rankings of “B” and “C”, respectively.

**Conclusions.** While the quality of studies is generally high, research on obesity among Inuit would benefit from careful selection of methods and reference standards, direct measures of adiposity in adults and children, studies of preadolescent children, and prospective cohort studies linking early childhood exposures with obesity outcomes throughout childhood and adolescence.

Keywords: *health; Aboriginal; north; overweight; adult; child; systematic; Canada, Greenland, Alaska*

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The human biology of Arctic populations has interested scientists since the 1800s. Narrative accounts exist from as early as the 18th and 19th centuries (1,2) and the anthropometry of Inuit populations was the subject of early studies by noted anthropologists Boas (3) and Hrdlička (4,5). Comprehensive nutritional surveys were conducted in the mid-20th century on subpopulations in the Arctic by United States and Canadian government agencies (6,7) and by the International Biological Program (IBP) in 1968–1972 (8).

It is well documented that in recent decades, rapid social and economic changes have resulted in a health transition characterized by changes in diet and physical activity patterns and the emergence of health problems such as obesity, diabetes, hypertension, ischemic heart disease and stroke (9–14).

Since 2000, a number of large-scale health and nutrition surveys have been undertaken in Alaska, Canada and Greenland. These have been supplemented by other more localized studies which examine various aspects of the health transition currently underway in

circumpolar regions. The present study undertakes a comprehensive scoping review of this literature with the goal of examining the subject of obesity in the circumpolar Inuit.

## Materials and methods

### Target population

Our populations of interest are collectively referred to as Inuit, which extend from the Chukotka peninsula in Russia across Alaska and northern Canada to Greenland. They are known by a variety of self-designated names in different regions (including Yuit, Yupik, Inupiat, Inuvialuit, Inuit and Kalaallit). Our search revealed no English-language studies of obesity on Inuit living in Russia and they are excluded from our scoping review.

### Research questions

In 2005 Arksey and O'Malley (15) published a methodological framework which presented 4 purposes for which a scoping review is appropriate:

- (a) To examine the extent, range and nature of research activity.
- (b) To determine the value of undertaking a full systematic review.
- (c) To summarize and disseminate research findings.
- (d) To identify research gaps in the existing literature.

In a subsequent evaluation of the application of this framework, Levac et al. (16) recommended that researchers add clarity and direction by clearly articulating research questions that guide the scope of the review, specifying concepts, target populations and health outcomes of interest, an approach which we have adopted in our study.

The present study centres on the first purpose, namely to explore the extent, range and nature of research activity on obesity in the circumpolar Inuit: To what extent has obesity research been undertaken in the circumpolar context? Are all subpopulations and geographic areas represented? What methodologies are employed and are they sufficient to the task of describing risk factors, prevalence and health outcomes associated with obesity?

Our study also addresses the third and fourth purposes: What is the prevalence of obesity? What temporal trends, environmental risk factors and health outcomes are associated with obesity in this population?

Finally, we undertake comprehensive assessment of the field as a whole and identify gaps in the existing literature: What subgroups of this population are under-researched, what methodologies are underutilized, and what further research is needed?

### Definitions and search strategies

We operationalized "obesity" as a condition defined by direct or indirect assessment of excess body fat or adiposity, including body mass index (BMI), various measures of abdominal obesity including waist circumference (WC) and waist-hip ratio (WHR), percent body fat and sum of skinfold thicknesses.

We wanted to explore obesity in the widest possible age range. Both the Dietitians of Canada and the Canadian Pediatric Society recommend the use of BMI to screen for overweight and obesity in children 2 or more years of age (17), and a variety of guidelines exist for the identification of obesity in children 2 years and older (18–21). Under the age of 2 years, rapid growth and variety in feeding practices make it difficult to identify children at risk of obesity (21). We have therefore excluded studies of infants and children under 2 years.

The online databases Cochrane Library, JSTOR, Medline, PubMed, Science Citation Index, Science Direct and Scopus were used to compile a list of English-language papers. Search terms included a combination of medical subject headings and keywords related to the inquiry: Greenlandic, Inuit, Eskimo, Inupiat, Alaska(n), Aboriginal, indigenous, health, overweight, obesity, adiposity, body fat, body mass index, waist circumference, waist-hip ratio, diabetes, metabolic disease. The websites of national and regional governments and health agencies were searched for relevant published and unpublished documents. The publication records of authors and the reference lists of identified papers were combed for additional related resources. Duplicate citations from the multiple databases were removed. The search identified 115 citations which were assembled in an online Refworks (Refworks-COS, Bethesda, MD) file available to members of the team throughout the review.

### Study selection

Inclusion and exclusion criteria were developed based on the objectives of the research. Studies were included in the review on the following basis:

- (a) The study was published during the 20-year period spanning 1992–2011.
- (b) Participants were age 2 years or greater.
- (c) Participants were identified in the study as "Greenlandic", "Inuit" or "Eskimo" or any of the regional self-designated terms.
- (d) The study included 30 or more participants.
- (e) "Obesity" or "abdominal obesity" was a primary or secondary outcome variable or associated factor.
- (f) The study was the result of primary research.

Studies on diabetes or cardiovascular diseases were included only if obesity was studied as a risk factor and assessed through direct or indirect means. Studies that

included pregnant women or focused on gestational diabetes were excluded.

Study selection (Fig. 1) was conducted independently by both the principal reviewer (TG) and a second reviewer (HB). Inter-rater reliability was assessed by the Kappa statistic ( $K$ ). The review team included authors of several of the papers identified in the literature search. These authors were excluded from selection, data extraction or quality assessment (QA) of their own papers.

### Data extraction

A customized data extraction instrument was developed to explore the scope of the available literature and to compare study design, methodology and results. The instrument summarizes study characteristics and findings, allows for expansion of sections relevant to each study under review, and permits comparisons across studies. Data collected were entered into a spreadsheet made available to the entire review team.

### Quality assessment (QA)

We undertook QA of all selected studies using a modified version of the STROBE instrument (22,23) (STrengthening the Reporting of OBServational studies in Epidemiology), a checklist of 22 items designed for cohort, case-control, and cross-sectional studies and intended as a tool to improve the consistency, quality and transparency of epidemiologic reporting. It is not designed to evaluate the quality of the research studies themselves (24,25). A review of 86 published QA instruments yielded no

clear candidate for a generic QA tool as the majority of reviewers develop subject-specific instruments (26).

We followed the recommendation of Sanderson et al. (26) and used the comprehensive STROBE statement as a starting point for our own QA instrument. However with its emphasis on reporting, STROBE may inflate the quality of studies which are methodologically weak due to small sample size or lack of geographic representativeness. We therefore incorporated elements from the Scottish Intercollegiate Guidelines Network (SIGN) (27) methodology checklist in the development of our QA instrument. The resulting instrument yields a numeric QA score with maximum values that range from 27 to 29 depending on study design. We calculated percentage scores based on the maximum score for each category of study design and classified results as follows: “A” studies (QA score >85%); “B” studies (QA score 76–85%); “C” studies (QA score 61–75%); and “D” studies (QA score ≤60%). In accordance with recommendations (28), the QA was piloted prior to implementation. Two reviewers (TG and HB) performed QA on 4 randomly-selected studies (11% of those selected) and the results were compared using the  $K$ -statistic. Then QA was performed by one of the reviewers (either TG or HB) on each of the studies reviewed.

We use the term “study” in this paper to refer to journal articles and reports. These publications ultimately were based on a far smaller number of research studies or projects conducted in specific regions and are thus not independent. Several publications from one study thus share the same methodological features of the parent study and only the reporting may differ. These publications may report on different “cuts” of the master dataset in terms of age–sex categories or other criteria. Furthermore, some publications report on the result of merging of the datasets of one or more of these studies.

### Results

Application of study selection criteria resulted in the inclusion of 38 studies in the review (Tables I and II). The inter-rater reliability for the study selection was extremely strong (weighted  $K=0.90$ ,  $p<0.001$ ).

#### Geographic coverage, participants and study design

Thirty-nine percent of studies examined obesity among Canadian Inuit; 24% were set in Alaska and 33% in Greenland. Two studies compared obesity prevalence among all 3 countries. No studies of Siberian Inuit were located.

The majority of studies (84%) examined obesity in adults. The age range of adult participants tended to be broad, however, the lower age limit varied considerably (Table I). The exclusion of pregnant subjects was reported in 28% of studies. The study design was exclusively cross-sectional; however, 19% of studies made comparisons

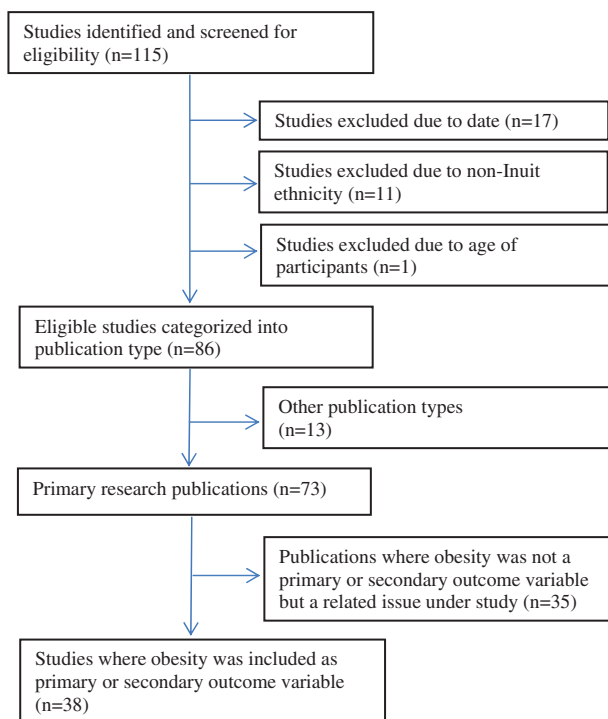


Fig. 1. Flow chart describing study selection process.

**Table 1.** Studies of adult circumpolar Inuit included in the review by country of study, sample size, participants, study design and anthropometric measures/indices

Author(s) and year	Country	Participants	n	Study design	Anthropometric measures/indices
Carter et al. 2006 (29)	Canada	Adults 18+ years	1,056	Cross-sectional	BMI, WC
Charbonneau-Roberts et al. 2007 (30)	Canada	Adults 19–77 years	45	Cross-sectional	BMI, WC, % body fat
Chateau-Degat et al. 2008 (31)	Canada	Adults 18–74 years	2,613	Cross-sectional	BMI, WC, WHR
Chateau-Degat et al. 2010 (32)	Canada	Adults 18+ years	887	Cross-sectional	BMI, WC
Chateau-Degat et al. 2010 (33)	Canada	Adults 18–74 years	832	Cross-sectional	BMI, WC, WHR, % body fat
Counil et al. 2009 (34)	Canada	Adults 18+ years	795	Cross-sectional	BMI, WC
Dewailly et al. 2007 (11)	Canada	Adults 18–74 years	925	Cross-sectional	BMI, WC, WHR
Hopping et al. 2010 (35)	Canada	Adults 19–89 years	218	Cross-sectional	BMI
Lawn and Harvey 2001 (36)	Canada	Adults 18–44 years	178	Cross-sectional	BMI
Liu et al. 2006 (37)	Canada	Adults 18+ years	238	Cross-sectional	BMI, WC
Nolin et al. 2007 (38)	Canada	Adults 18–74 years	925	Cross-sectional	BMI, WC
Young 1996 (28)	Canada	Adults 18–74 years	434	Cross-sectional	BMI, WC, WHR, skinfold thicknesses
Bjerregaard et al. 2002 (39)	Greenland	Adults 18+ years	2,046	Cross-sectional	BMI, WC, WHR
Bjerregaard et al. 2007 (40)	Greenland	Adults 25+ years	1,542	Cross-sectional	BMI, WC
Bjerregaard et al. 2010 (41)	Greenland	Adults 18–95 years	2,302	Cross-sectional	BMI
Jørgensen 2004 (42)	Greenland	Adults 30–60 years	917	Cross-sectional	BMI, WC, WHR
Jørgensen et al. 2002 (43)	Greenland	Adults 35+ years	917	Cross-sectional	BMI, WHR
Jørgensen et al. 2003 (44)	Greenland	Adults 30–60 years	7,892	Cross-sectional	BMI, WC, WHR
Jørgensen et al. 2004 (45)	Greenland	Adults 35+ years	917	Cross-sectional	BMI, WC, WHR
Jørgensen et al. 2006 (46)	Greenland	Adults 35–86 years	2,311	Cross-sectional	BMI, WC, WHR
Jørgensen et al. 2006 (47)	Greenland	Adults 35–86 years	917	Cross-sectional	BMI, WC, WHR
Ebbesson et al. 1998 (48)	USA	Adults 25+ years	454	Cross-sectional	BMI
Ebbesson et al. 2005 (12)	USA	Adults 25–91 years	454	Cross-sectional	BMI, WC, WHR, % body fat, skinfold thicknesses
Ebbesson et al. 2010 (49)	USA	Adults 34–75 years	625	Cross-sectional	BMI, WC, % body fat
Mohatt et al. 2007 (50)	USA	Adults 18+ years	753	Cross-sectional	BMI, WC, % body fat
Murphy et al. 1992 (51)	USA	Adults 40+ years	616	Cross-sectional	BMI
Murphy et al. 1995 (52)	USA	Adults 20+ years	1,124	Cross-sectional	BMI
Risica et al. 2000 (53)	USA	Adults 25+ years	454	Cross-sectional	BMI, WC, WHR, % body fat
Risica et al. 2000 (54)	USA	Adults 25+ years	454	Cross-sectional	BMI
Tejero et al. 2010 (55)	USA	Adults 18+ years	1,214	Cross-sectional	BMI, WC, WHR, % body fat, skinfold thicknesses
Bjerregaard et al. 2003 (56)	Canada, Greenland and USA	Adults 25+ years	2,509	Cross-sectional	BMI, WHR
Young et al. 2007 (57)	Canada, Greenland and USA	Adults 18+ years	2,545	Cross-sectional	BMI, WC, WHR

**Table II.** Studies of circumpolar Inuit children included in the review by country of study, participants, study design and anthropometric indices

Author(s) and year	Country	Participants	n	Study design	Anthropometric index	Reference
Egeland et al. 2010 (58)	Canada	Children 3–5 years	388	Cross-sectional	BMI	IOTF
Galloway et al. 2010 (59)	Canada	Children 3–5 years	376	Cross-sectional	BMI	CDC
Johnson-Down and Egeland 2010 (60)	Canada	Children 3–5 years	388	Cross-sectional	BMI	IOTF
Niclasen et al. 2007 (61)	Greenland	Children 5–7 and 13–17 years	4,213	Retrospective cohort	BMI	IOTF
Schnohr et al. 2005 (62)	Greenland	Children 2–15 years	3,094	Retrospective cohort	BMI	IOTF
Schnohr et al. 2008 (63)	Greenland	Children 5–7 years	2,801	Retrospective cohort	BMI	IOTF

to earlier research in order to report temporal trends in obesity metrics.

There were 6 studies on children from Canada and Greenland, and none from Alaska. Three of these were retrospective cohorts constructed from Greenland health surveillance data based on growth measures taken in doctors' offices at age 2 years, at school entry and at various points during childhood and adolescence, which permitted the authors to examine the pattern of obesity onset in Greenland Inuit children and youth ages 2–17 years.

#### Measurement, metrics and reference standards

All but one of the studies collected measured, rather than reported data. Age-standardized prevalence of obesity was reported in 47% of studies; the remainder reported only crude prevalence.

BMI was used as an index of body size in all studies reviewed and was the only metric employed in studies in children. Overall, the majority of studies (66%) employed a combination of anthropometric markers; the most common combinations were BMI+WC (17%) and BMI+WC+WHR (25%). No direct measures of adiposity, such as dual-energy X-ray absorptiometry or computerized tomography, were used.

Studies at the oldest end of the date range, prior to the publication of universal reference values for BMI, WC and WHR, used a variety of reference standards, such as the 1987 US National Center for Health Statistics standards for men and women (51,52,64) and Bray's BMI cutoff of 26 kg/m<sup>2</sup> (28,65). The majority of studies of adults (63%) employed BMI, WC and WHR cutoffs defined by the World Health Organization (WHO) (66–68).

All studies of children undertaken in Greenland used the International Obesity Task Force (IOTF) reference values to define childhood obesity (18). Both the IOTF and the 2000 Centers for Disease Control (CDC) reference (20) were used in the 3 Canadian publications derived from the Nunavut Inuit Child Health Survey (58–60).

#### Quality assessment

During the QA pilot, there was moderate inter-rater reliability ( $K=0.43$ ,  $p=0.046$ ). Raters subsequently reviewed the QA protocol together step-by-step to improve the consistency of rating prior to undertaking QA during the review.

The QA rated 26% of studies "A", 18% "B", 39% "C" and 16% "D". Failure to achieve optimal quality scores resulted from a lack of clear definition of variables and data sources, in particular the failure to define obesity as a study variable. In 61% of studies, the authors did not provide adequate rationale for the obesity metric or the reference criteria used. A second major factor in study quality ranking was a lack of discussion of biases and limitations of the selected methodology; this occurred in 76% of studies.

#### Prevalence of obesity, associated risk factors and health outcomes

We compared the obesity prevalence reported in studies of Inuit adults (Table III). In general, higher abdominal obesity prevalence was observed in women than in men. This gender difference was particularly marked in studies reporting abdominal obesity, the sole exception being a Greenland study of adults aged 35–86 years (46) which employed lower WC cutoff values for abdominal obesity.

Eighty-two percent of studies analyzed risk factors associated with obesity, most commonly metabolic risk factors: lipid profile (44%); serum glucose values (56%); and either serum insulin or insulin resistance or both (13%). Prevalence of hypertension was reported in 34% of adult studies. The tendency for obesity to be significantly associated with insulin resistance, impaired glucose metabolism, and unfavourable lipid profile was widely reported among adults. The metabolic syndrome (MetS) has received increasing interest. Four studies examined the impact of variation in existing diagnostic criteria for MetS (31,37,45,47). Among these studies, reported prevalence of MetS was consistently near 20%. There was considerable discussion about whether abdominal obesity



**Table III.** Prevalence (%) of obesity and abdominal obesity among Inuit adults by sex and country of study

Author(s) and year	Country	Prevalence (%) of obesity <sup>a</sup>		Prevalence (%) of abdominal obesity <sup>b</sup>	
		Males	Females	Males	Females
Hopping et al. 2010 (35)	Canada	34	46	–	–
Charbonneau-Roberts et al. 2007 (30)	Canada	27	68	36	86
Chateau-Degat et al. 2010 (32)	Canada	22	22	15	50
Nolin et al. 2007 (38)	Canada	29	30	21	55
Dewailly et al. 2007 (11)	Canada	26	31	10	71
Liu et al. 2006 (37)	Canada	–	–	11	43
Bjerregaard et al. 2002 (39)	Greenland	16	22	–	–
Bjerregaard et al. 2010 (9)	Greenland	19	25	–	–
Jørgensen 2004 (42)	Greenland	18	25	16	58
Jørgensen et al. 2003 (44)	Greenland	18	25	16	58
Jørgensen et al. 2004 (45)	Greenland	30	32	19	51
Jørgensen et al. 2006 (46)	Greenland	16	22	67 <sup>c</sup>	66 <sup>c</sup>
Tejero et al. 2010 (55)	USA	21	39	37 <sup>c</sup>	70 <sup>c</sup>

<sup>a</sup>Obesity classified using WHO cutoff of BMI  $\geq$  30.

<sup>b</sup>WC > 102 cm for males and WC > 88 cm for females, unless otherwise noted.

<sup>c</sup>WC > 94 cm for males and WC > 80 cm for females.

(indicated by high WC) had as deleterious an effect on metabolic risk relative to non-Inuit populations. Two papers called for improved diagnostic criteria for MetS (31,45) and 2 others documented moderate agreement between WHO and National Cholesterol Education Program diagnostic criteria for MetS (37,47).

Relatively few studies looked at diet and physical activity as risk factors for obesity among Inuit. Twenty-three percent of studies documented increased obesity prevalence in individuals with high energy intake, low physical activity measures, or some combination of both. The Nunavut Inuit Child Health Survey was unable to establish a relationship between obesity risk and the consumption of market foods (59,60). In Greenland a study showed that overweight at school entry (age 7 years) predicted overweight in late childhood and adolescence (60).

The association between obesity and SES, specifically education, employment, job type and childhood socio-economic conditions, was examined in 7 studies. Two studies one in adults (58) and one in children (58) failed to find any association between household food insecurity and obesity outcomes. In Greenland, Westernization influenced the development of obesity and metabolic risk, although the processes differed among men and women. For men, risk of obesity and metabolic disease arose through a decrease in traditional hunting and fishing activities; for women, the negative health consequences of Westernization seem to be mediated through differences in SES, mainly educational attainment (47).

## Discussion

In terms of overall scope, the literature on obesity in Inuit populations is presently skewed toward studies of adults. This is likely due to the fact that obesity is a strong risk factor of diabetes and cardiovascular disease, which are primarily diseases of adults. There is strong evidence that obesity is increasing, that abdominal obesity is widely prevalent among Inuit women, and that (above a certain threshold not yet well-defined) obesity has a deleterious effect on metabolic and cardiovascular health. In 1996 Young observed that, in past studies, the low prevalence of obesity among Inuit set them apart from other North American Aboriginal populations (28). Studies published since 2000 document a consistent rise in obesity prevalence with increasing prevalence in the WHO class II (BMI 35–39.9) and III (BMI  $\geq$  40) categories of obesity (38,50,53,54,69). Many studies report disproportionately high prevalence of obesity (measured by BMI) and centripetal fat patterning (measured by WC and WHR) among Inuit women (11,30,32,37,38,52,55).

There is substantial evidence that obesity prevalence is increasing in children, which is particularly well documented in Greenland (62,63). The most recent data come from the Nunavut Inuit Child Health Survey, where the prevalence of overweight and obesity (using IOTF cut-offs) in this preschool age sample were 39 and 28%, respectively (58). Such high prevalence raises significant concern over future health and metabolic disease risk in children.

There is also strong evidence from Greenland and Nunavut that the age of obesity onset is decreasing, such

that obesity has emerged as a significant health concern in Inuit preschoolers (59,62). The decreasing age of onset of overweight is part of a constellation of biological processes (including earlier skeletal maturity, earlier adolescent growth spurt, and decreasing age at menarche) accompanying rapid acculturation to a Western lifestyle (70,71).

There are pronounced gaps in our knowledge of obesity among Inuit children, especially adolescents (our review located only 2 studies) (61,63) and no recent data on obesity prevalence among children aged 10–12 years. There are no studies of obesity among children and youth living in Alaska. It is increasingly recognized that many adult health problems have their origin in childhood, and socioeconomic factors operating during childhood has been shown to be associated with adult obesity among Greenlanders (41). Prospective cohort studies offer the opportunity to examine associations between early childhood environment and obesity as well as the relative contribution of obesity and other risk factors to metabolic and cardiovascular health outcomes in Inuit adults.

In terms of international comparison, this review located only 2 studies that compared obesity prevalence in adult populations (56,57). While it is likely that obesity and its concomitant health effects are influenced by processes particular to each country, there is nevertheless marked consistency in patterns of risk factors, prevalence and health-related outcomes among Inuit. Examples are changes in diet and physical activity patterns (9,50,58,72) and the role of a marine diet in mitigating some of the negative health effects of acculturation to a Western lifestyle (32,73–76).

We make several observations regarding the methodologies currently in use to assess obesity in the circumpolar Inuit. First, while the link between obesity and metabolic/cardiovascular disease risk in this population is well established, there is evidence that current diagnostic thresholds may not reflect the levels of risk experienced by Inuit. Studies demonstrate that for given levels of obesity, Inuit have lower blood pressure, lower levels of glucose, insulin, triglyceride and higher levels of HDL cholesterol than non-Inuit subjects (31,44), prompting some researchers to call for Inuit-specific cutoffs for central obesity measures associated with diabetes and cardiovascular disease outcomes (31,44,57). However, we find consistency in the relationship between rising adiposity and health risks. There is ample evidence that Inuit mortality from cardiovascular disease is at least as high as in non-Inuit populations and that Inuit mortality from cerebrovascular disease is significantly higher (56). Rather than developing ethnic-specific cutoff values, we propose that researchers first undertake validation studies to determine the accuracy of indirect measures of adiposity in Inuit adults and children.

There is a dearth of body composition studies among the Inuit. The accumulation of intra-abdominal or visceral fat is a marker of considerable metabolic risk. However without imaging studies (e.g. dual X-ray absorptiometry, computerized tomography, ultrasonography and magnetic resonance imaging) it is not known whether central obesity is predominantly intra-abdominal or subcutaneous. While attempts have been made to more accurately describe fat- and lean-mass distribution in Inuit (77,78) we still know relatively little about fat distribution at various levels of BMI or waist circumference in this population.

Finally, we observe a general failure to define obesity as a variable. The quality of studies would be significantly improved by careful selection of metrics and reference standards and consistent reporting of limitations. Our review found multiple metrics employed in 66% of studies however BMI was the sole indirect measure of adiposity employed in studies of children. There is evidence that methodologies such as WC, triceps skinfolds and mid-upper arm circumference (MUAC) may be effective tools for obesity screening in children (79,80). Inclusion of these methodologies may assist in the improvement of health surveillance programs for Inuit children. Standardized protocols incorporating hold-out samples and repeat measures would permit reporting of inter- and intra-observer error and technical error of measurement (81), features which would improve both the rigour and comparability of anthropometric studies.

Given the logistical challenges of conducting obesity research in the north, it is likely that the majority of future studies will continue to employ indirect measures of adiposity. In order to improve consistency in the use of cutoffs for classifying body weight in Inuit populations, we recommend the following: (a) The use and reporting of WHO cutoffs for adults (67,68) and (b) Until international consensus is reached on the appropriate reference for children, the use and reporting of prevalence determined by *both* the IOTF (18) *and* WHO growth standard and reference for children (19,21).

## Conclusion

The results of this review indicate that concerted research effort has yielded substantial knowledge about the prevalence and factors associated with obesity in the circumpolar Inuit. With the exception of Inuit in Chukotka, Russia, there is broad geographic coverage of the regions where Inuit reside. Obesity prevalence is high among adults and has risen significantly in selected populations of preschool- and school-aged children. Inuit women are at greater risk of abdominal obesity than Inuit men however in both sexes obesity is associated with elevated metabolic risk factors such as insulin resistance, impaired glucose metabolism and negative trends in lipid profile.

While the quality of studies is generally high and relies on measured, rather than reported, data, research on obesity among Inuit would benefit from emphasis on several areas: careful selection of metrics and reference standards; direct measures of adiposity in adults and children which can be used to determine accurate anthropometric markers of disease risk; studies of pre-adolescent children; and prospective cohort studies linking early childhood exposures with obesity outcomes throughout childhood and adolescence.

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The authors have no conflict of interest to declare.

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