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Original Research Article

Lifestyle Mediates Seasonal Changes in Metabolic Health Among the Yakut (Sakha) of Northeastern Siberia

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Objectives: Among indigenous circumpolar populations, extreme seasonality influences food availability and energy metabolism. Furthermore, subsistence patterns and wage labor opportunities shift with season. Thus, health measures among circumpolar populations likely exhibit seasonal changes that are influenced by lifestyle factors. This study examines how markers of cardio-metabolic health vary between summer and winter as a function of an individual's lifestyle and sex among the Yakut of northeastern Siberia.

Methods: Anthropometric dimensions, serum lipids and glucose levels, blood pressure, and lifestyle data were collected for a sample of 115 Yakut participants (71 women, 44 men) in Berdygestiakh, Sakha Republic, Russia in the summer of 2009 and winter of 2011.

Results: Men and women experienced significant increases in total and HDL cholesterol and triglyceride levels from summer to winter. Women exhibited winter-time increases in adiposity and glucose levels. Men who reported greater market integration were more likely to have lower winter blood pressure levels. Additionally, time spent fishing was associated with lower winter-time LDL cholesterol, while foraging time was associated with higher HDL cholesterol.

Conclusions: While seasonal changes in anthropometric dimensions were modest, Yakut men and women experienced significant increases in total cholesterol and HDL cholesterol from summer to winter. These results also suggest that while Yakut individuals with greater subsistence participation are more buffered from adverse seasonal changes in cholesterol levels, they may be at a greater risk for winter increases in blood pressure. Furthermore, the interactions between lifestyle and seasonal change in metabolic health appear to differ between Yakut women and men. Am. J. Hum. Biol. 28:868–878, 2016.

Consistent with a global pattern, markers of cardiovascular disease and type II diabetes risk, such as obesity, hypertension, hyperlipidemia, and high fasting glucose levels, are increasing across populations indigenous to circumpolar regions. Today, obesity rates are at moderate to high levels among nearly all indigenous subarctic and arctic groups (Châteu-Degat et al., 2011; Jørgensen, 2010; Jørgensen and Young, 2008; Snodgrass, 2013; Snodgrass et al., 2006b; Young, 2012). Historically, investigations have reported low average blood glucose and relatively favorable lipid levels among indigenous high-latitude populations (Bang et al., 1971; Bang and Dyerberg, 1980; Young et al., 1993). In fact, the dose-dependent effects of obesity on serum lipid levels appear to be reduced among indigenous circumpolar populations compared to other groups across the globe (Young, 1996; Young et al., 2007). This unique metabolic pattern may be linked to adaptive elevations in metabolic rate, traditional diets that are high in n-3 fatty acids and low in LDL cholesterol, and high physical activity levels due to subsistence participation (Himms-Hagen, 1972; Shephard and Rode, 1996; Snodgrass, 2013; Snodgrass et al., 2007). Additionally, previous work has reported high rates of hypertension among indigenous circumpolar groups, which may be tied to high metabolic rates (Kozlov et al., 2003; Snodgrass et al., 2008). Recent work, however, documents a relationship between ongoing lifestyle changes and the population burden of metabolic and cardiovascular diseases. Such studies have revealed two main secular trends among circumpolar populations with increasing economic modernization and acculturation: (1) decreasing energy expenditure due to more sedentary lifestyles (Leonard et al., 2002; Shephard and Rode, 1996; Snodgrass, 2013; Snodgrass et al., 2006a,b); and (2) increasing intake of refined carbohydrates due to shifts from traditional to market food sources (Bjerregaard and Jørgensen, 2008; Leonard et al., 2002, 2008, 2009; Shephard and Rode, 1996; Snodgrass, 2013; Young et al., 1995).

These secular trends, however, provide only a partial explanation for variation in metabolic and cardiovascular health among northern communities. Previous work among indigenous circumpolar populations indicates that transitions in metabolic and cardiovascular health are structured by the interaction of lifestyle changes and biological adaptations to local ecological stressors (Cepon et al., 2011; Fumagalli et al., 2015; Leonard et al., 2009;

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Levy et al., 2012;Snodgrass et al., 2007, 2008). Arctic environments are characterized by extreme seasonal changes in temperature and day length and low overall energy availability. Indigenous high-latitude populations adapt physiologically to these stressors through seasonal changes in hormone dynamics (Levy et al., 2013; Pääkönen and Leppäluoto, 2002). For example, the Yakut of northeastern Siberia adapt to the cold climate through seasonal declines in circulating thyroid hormone due to a higher rate of hormone uptake into tissues in the winter. In turn, enhanced thyroid hormone dynamics facilitates winter-time increases in basal metabolic rate (Leonard et al., 2014). Yakut individuals with greater subsistence activity participation exhibited more pronounced seasonal changes in metabolism and thyroid hormone levels. Physiological adaptations to extreme seasonality such as these likely influence variations in biomarkers of cardio-metabolic health. For instance, among three indigenous Siberian populations (Evenki, Buriat, and Yakut) higher basal metabolic rates were significantly associated with lower LDL cholesterol levels after controlling for body size, composition, and smoking status (Snodgrass et al., 2007). Thus, seasonal change in indicators of cardiovascular disease and diabetes are likely the results of an amalgamation of adaptive and behavioral factors.

In support of this hypothesis, previous work across high-latitude populations has identified seasonal patterns in metabolic health indicators, such as body composition, blood pressure, and serum lipids and glucose (Hopstock et al., 2013; Marti-Soler et al., 2014; Rode and Shephard, 1973). This work has not been extensive and, additionally, few investigations have directly examined how socioeconomic and lifestyle factors shape seasonal changes in metabolic health. Stressors associated with seasonality do not affect all members of a population in the same manner (Leonard and Thomas, 1989). Rather, factors such as sex and socioeconomic status likely structure the effects of seasonal forces on health. The present study addresses this issue by examining changes in biological markers of cardiovascular and metabolic health (body composition, blood pressure, serum lipids, and glucose) between summer and winter as a function of an individual's lifestyle and sex among the Yakut of northeastern Siberia. We expect that seasonal changes in metabolic health among Yakut adults will be mediated by lifestyle influences on activity and diet patterns.

METHODS

Study population

The Sakha Republic (Yakutia) is an autonomous state within the Russian Federation. Located in northeastern Siberia, the Sakha Republic spans 3,103,200 km^2 and 40% of this area falls above the Arctic Circle. Temperatures can range from $-60°C$ ($-76°F$) in the winter to $40°C$ ($104°F$) in the summer. The majority of the population is ethnically Yakut (Sakha), an indigenous population of around 500,000 individuals (National Russian Population Census, 2010).

Beginning in the 1930s, the Soviet Union forcibly organized Yakut communities into predominantly-male herding and farming collectives in order to end "backward" nomadism and promote "civilization" (Forsyth, 1992). Yakut women were relocated to villages and charged with childcare and wage labor (Snodgrass, 2004). The Soviet government made promises of technological modernization, but few came to fruition (Forsyth, 1992). Pika (1999) identifies five critical consequences of Soviet collectivization among the Yakut: loss of economic self-sufficiency; a decline in the number of individuals participating in traditional subsistence with an increase in unskilled labor; increased alcoholism, isolation, and psychological stress; demographic decline; and deterioration of the health care infrastructure.

Yakut in rural areas now face a variety of both challenges and opportunities related to new subsistence strategies (Crate, 2006). To obtain the food and economic resources that were once provided by the Soviet government, many families have chosen to return to subsistence practices commonly performed before the Soviet era, such as breeding cattle or horses, planting domestic gardens, fishing and hunting wildlife, or harvesting wild roots and berries (Crate, 2006; Sorensen, 2003). Additionally, as state farms were dismantled, the distribution of livestock was not equitable. Differences in livestock ownership have had profound consequences on socioeconomic status and have led to an increase in economic inequality (Snodgrass, 2004).

Not all households wish to return to subsistence lifestyles practiced prior to the Soviet era, and many rely completely on private salaries and government pensions (Crate, 2006; Jordan and Jordan-Bychkov, 2001). However, a majority of Yakut individuals living in rural villages depend on a mixed cash economy that consists of a combination of traditional subsistence practices and cash inputs (Crate, 2006). In rural Yakut villages, there is a large degree of variation in the types of subsistence activities performed as well as variation in the avenues of market economy participation, such as government wages, private-sector salaries, and profits from home production. This variation exists not only between communities, but also within communities and even within individual households. This pattern has been described as lifestyle heterogeneity (Snodgrass, 2004).

Participants

Data were collected from participants of the rural community of Berdygestiakh (62° N; 127° W; population 4,900) in the Gorny *ulus* of the Sakha Republic (Yakutia). The sample includes 44 men and 71 women who were measured on two occasions: July/August of 2009 (summer) and January of 2011 (winter). The ages of the study participants ranged from 18 to 81 years at the time of the first measurement. All data were collected at the Gorny Regional Medical Center in Berdygestiakh. Participants were recruited on a voluntary basis through word of mouth and advertising of the study in the community. All participants were healthy at the time of measurement with no known acute or chronic conditions, and pregnant or lactating women were excluded. The study protocol was approved by the Institutional Review Board of the University of Oregon.

Anthropometry

In each field season, anthropometric dimensions were collected by one trained observer (LAT) following procedures of Lohman et al. (1988). Stature was measured to the nearest 1.0 mm using a field stadiometer (Seca Corporation, Hanover, MD). Body weight was assessed to the nearest 0.1 kg using a Tanita digital bioelectrical impedance analysis (BIA) scale (Tanita Corporation, Tokyo, Japan). Percent body fat was calculated using the body density equations of Durnin and Womersely (1974) from four skinfold measurement (tricep, bicep, subscapular, suprailiac). Body mass index (BMI) was calculated by dividing an individual's weight in kilograms by height in meters squared (kg m^{-2}).

Serum biomarkers

Whole blood samples were obtained by a trained nurse using venipuncture from fasted participants in the morning. Glucose, total cholesterol, high-density lipoprotein (HDL) cholesterol, and triglyceride levels were measured from whole blood samples using a CardioChek PA analyzer and Glucose and Lipid Panel test strips (Polymer Technology Systems, Indianapolis, IN). Low density lipoprotein (LDL) levels were calculated from total cholesterol, HDL, and triglycerides using the Friedwald et al. (1972) equation. The CardioChek PA professional lipid and glucose testing system meets clinical guidelines for accuracy and precision.

Sociodemographic and lifestyle measures

Socioeconomic status (SES) and lifestyle data were collected using an extensive questionnaire. The survey inquired about monthly income, occupation, and education level. In addition, to assess material style of life (SOL), participants were asked about their ownership of 20 items: car, motorcycle, bicycle, television, stereo, VCR, video camera, camera, computer, telephone, washing machine, bath house, ice cellar, barn, tractor, house, cows, horses, pigs, and chickens. Participants were also asked to estimate how many hours per day they spent watching television and about their participation in various subsistence activities (i.e., tending animals, hay cutting, fishing, hunting, foraging, and farming). To evaluate the impact of lifestyle on diet, participants were asked to estimate the percentage of their food that came from the market/store.

An SOL scale was created based on the work of Bindon et al. (1997) to evaluate overall patterns in subsistence activity participation, diet, and ownership of common consumer goods and livestock. Low SOL scores indicate more traditional ways of life (i.e., participation in more subsistence activities, less market food consumption, less formal education, and fewer consumer goods), whereas a high SOL suggests greater integration to the market. The individual components of the SOL score are presented and discussed in more detail in Cepon et al. (2011:161).

Statistical analyses

Statistical analyses were performed using STATA 13.0. All variables were tested for normality, and summer and winter-time triglyceride levels were log-transformed. In regard to variables describing subsistence activity participation, the distribution was non-normal and many participants reported spending zero days engaging in various activities; therefore, multiple regressions that included these variables (number of days spent foraging, hunting, fishing, and cutting hay) required transforming these variables into quartiles. Paired *t* tests were used to examine seasonal changes in anthropometric measurements, blood pressure, and serum glucose and lipid levels. Seasonal differences were considered statistically significant at $P \leq 0.05$. Multiple regression analyses were used to examine the relationships between seasonal changes in blood biomarkers of health and changes in body composition. Because these analyses involve multiple comparisons, the Bonferroni correction was applied and correlations were considered statistically significant at a $P \leq 0.0125$. Mann–Whitney U-tests were used to compare differences in subsistence activity participation between men and women, and *t* tests were used to examine sex differences in SOL score. Sex differences were considered statistically significant at $P \leq 0.05$. Finally, multiple regression analyses were used to assess the relationships between seasonal changes in blood and anthropometric biomarkers of cardiovascular disease and diabetes risk and variables describing lifestyle. Associations were considered statistically significant at $P \leq 0.05$.

RESULTS

Seasonal changes in body composition and blood biomarkers

Tables 1 and 2 display patterns of seasonal change in body composition and blood biomarkers for men and women, respectively. Among Yakut men, seasonal change in mean body mass (+0.7%) and mean percent body fat (−3.5%) were modest and did not reach significance. Seasonal increases in waist circumference, however, were statistically significant ($P < 0.001$). Change in serum lipids was pronounced, particularly winter-time increases in total cholesterol, HDL cholesterol, and triglycerides.

Among women, seasonal change in body mass (+0.8%) was also modest. Both waist and hip circumference increased significantly ($P < 0.001$), while grip strength decreased from summer to winter ($P < 0.001$). Similar to the pattern among men, Yakut women experienced significant increases in serum lipids from summer to winter, particularly total cholesterol, HDL cholesterol, and triglycerides. Blood glucose levels also increased significantly among women.

Table 3 presents multiple regression analyses between seasonal change in body composition and seasonal change in blood biomarkers controlling for age. Among men, seasonal change in triglyceride levels is negatively correlated with change in waist circumference. The same is true for change in glucose levels. There is a significant negative relationship between change in HDL levels and change in percent body fat ($P < 0.0125$). Additionally, seasonal change in grip strength of the right hand was negatively correlated with hip circumference and age ($P < 0.001$ and $P < 0.0125$, respectively). Among Yakut women, few measures of change in body composition were significantly correlated with change in blood biomarkers of metabolic health. Seasonal change in HDL cholesterol and systolic blood pressure were both positively correlated with change in fat-free mass ($P < 0.0125$).

Socioeconomic and lifestyle influences on seasonal changes

Table 4 displays the descriptive statistics for lifestyle variables collected in the summer of 2009 for Yakut men and women. While Yakut women reported spending more time participating in foraging activities per year, Yakut men recounted greater participation in hunting, fishing, and hay cutting. SOL scores were significantly higher among women, thus suggesting greater market integration compared to men ($P < 0.001$).

These sex differences in subsistence activity participation appear to translate into sex differences in the

TABLE 1. Seasonal changes in anthropometric dimensions and blood biomarkers in Yakut men (n = 44)

Measure	Summer mean ± SD	Winter mean ± SD	t statistic[a]	Inter-season r[b]
Anthropometric				
Weight (kg)	69.7 ± 12.9	70.2 ± 13.1	−1.37	0.95***
BMI (kg/m^2)	25.1 ± 4.3	25.5 ± 4.5	−2.00	0.94***
Percent body fat (%)	28.7.0 ± 8.2	27.7 ± 7.90	1.67	0.76***
Fat-free mass (kg)	52.3 ± 6.4	52.1 ± 6.2	0.58	0.90***
Waist circumference (cm)	88.1 ± 10.6	91.4 ± 11.1	−4.66***	0.83***
Hip circumference (cm)	95.6 ± 7.6	96.5 ± 7.5	−1.55	0.76***
Grip strength—left (kg)	37.0 ± 7.3	36.6 ± 7.8	0.54	0.67***
Grip strength—right (kg)	39.5 ± 7.8	38.7 ± 9.0	1.25	0.81***
Systolic blood pressure (mm Hg)	135 ± 26.1	137.1 ± 27.5	−0.69	0.60***
Diastolic blood pressure (mm Hg)	81.2 ± 14.9	83.8 ± 13.7	−1.34	0.33***
Blood Biomarkers:				
Glucose (mg/dL)	95.5 ± 29.8	100.3 ± 16.1	−1.02	0.01
Total cholesterol (mg/dL)	184.9 ± 34.3	205.2 ± 50.8	−3.26**	0.33***
HDL cholesterol (mg/dL)	57.7 ± 18.1	67.3 ± 19.2	−5.26**	0.61***
LDL cholesterol (mg/dL)	112.0 ± 27.0	120.0 ± 42.6	−1.38	0.13
Log-triglycerides (mg/dL)[c]	1.84 ± 0.18	1.90 ± 0.18	−3.11**	0.51***

[a]Paired t tests; seasonal differences are significant at: *$P \leq 0.05$; **$P \leq 0.01$; ***$P \leq 0.001$.
[b]Pair-wise correlations between summer and winter measures; significant at: *$P \leq 0.05$; **$P \leq 0.01$; ***$P \leq 0.001$.
[c]Variable is $\log_{10}$ transformed.

TABLE 2. Seasonal changes in anthropometric dimensions and blood biomarkers in Yakut women (n = 71)

Measure	Summer; Mean ± SD	Winter; Mean ± SD	t statistic[a]	Inter-season r[b]
Anthropometric:				
Weight (kg)	62.9 ± 11.3	63.4 ± 11.6	−1.56	0.93***
BMI (kg/m^2)	26.0 ± 4.2	26.3 ± 4.3	−1.49	0.92***
Percent body fat (%)	41.7 ± 4.8	41.6 ± 4.7	0.80	0.82***
Fat-free mass (kg)	40.7 ± 3.9	40.9 ± 3.8	−0.93	0.88***
Waist circumference (cm)	84.4 ± 10.3	87.3 ± 10.9	−6.43***	0.86***
Hip circumference (cm)	99.0 ± 8.6	100.7 ± 8.9	−3.22**	0.77***
Grip strength—left (kg)	25.3 ± 5.5	22.9 ± 4.9	8.14***	0.78***
Grip strength—Right (kg)	26.7 ± 5.6	24.2 ± 5.4	7.10***	0.74***
Systolic blood pressure (mm Hg)	129.3 ± 24.5	128.9 ± 25.6	0.18	0.49***
Diastolic blood pressure (mm Hg)	80.3 ± 15.1	78.2 ± 13.2	1.44	0.42***
Blood biomarkers:				
Glucose (mg/dL)	87.8 ± 14.6	103.3 ± 25.5	−6.38***	0.35***
Total cholesterol (mg/dL)	194.9 ± 26.1	205.4 ± 43.9	−2.53**	0.36***
HDL cholesterol (mg/dL)	61.1 ± 15.3	69.1 ± 17.7	−4.81***	0.42***
LDL cholesterol (mg/dL)	117.3 ± 22.4	117.3 ± 41.3	−0.02	0.24***
Log triglycerides (mg/dL)[c]	1.88 ± 0.17	1.94 ± 0.18	−3.29**	0.39***

[a]Paired t tests: seasonal differences are significant at: *$P \leq 0.05$; **$P \leq 0.01$; ***$P \leq 0.001$.
[b]Pair-wise correlations between summer and winter measures; significant at: *$P \leq 0.05$; **$P \leq 0.01$; ***$P \leq 0.001$
[c]Variable is $\log_{10}$ transformed.

relationship between lifestyle and seasonal change in blood biomarkers. Table 5 presents multiple regression analyses of the influence of lifestyle factors on seasonal fluctuations in blood biomarkers, controlling for age and change in percent body fat. Table 6 displays the relationship between change in blood biomarker variables and SOL for men and women.

Among men, seasonal change in total cholesterol was positively associated with time spent fishing, while change in LDL cholesterol was negatively correlated with time spent fishing ($P < 0.05$). Time spent foraging was positively correlated with change in HDL cholesterol and negatively associated with change in systolic and diastolic blood pressure ($P < 0.05$). Men with greater seasonal increases in diastolic blood pressure were more likely to have lower SOL scores, suggesting less market integration ($P < 0.01$). The negative relationship between change in total cholesterol and SOL score and the relationship between change in systolic blood pressure and SOL score both approached statistical significance ($P = 0.084$ and $P = 0.051$, respectively). Similarly, the positive relationship between change in glucose levels and SOL score approached statistical significance ($P = 0.087$). Among Yakut women, changes in triglyceride levels from summer to winter were positively associated with number of days spent hunting, and the negative relationship between hunting and SOL approached significance ($P = 0.072$).

Table 7 describes the relationships between seasonal change in body composition and lifestyle variables while controlling for age. Similarly, Table 8 displays multiple regressions between SOL score and change in body composition while controlling for age. Among men, change in body mass from summer to winter was negatively associated with foraging time and positively associated with time spent cutting hay ($P < 0.05$). Additionally, the positive relationship between change in body mass and time spent hunting approached significance ($P = 0.056$). Finally, seasonal change in BMI was also negatively correlated to time spent foraging, and the positive association between change in BMI and hay cutting time approached significance ($P = 0.052$). Among women, seasonal change in percent body fat was significantly

TABLE 3. Multiple regression analyses[a] of the influence of seasonal changes in body composition on changes in health outcome measures controlling for age in Yakut men and women

Measure	Δ Percentbody fat β coefficient	Δ Fat-free mass β Coefficient	Δ Waist Circumference β Coefficient	Δ Hip Circumference β Coefficient	Age β Coefficient	Adjusted R^2
Men (*n* = 44):						
Δ Glucose (mg/dL)	−2.16	−0.14	−3.92**	−0.31	−0.22	0.124
Δ Total cholesterol (mg/dL)	−0.38	−4.60	−1.20	2.36	0.39	0.008
Δ HDL cholesterol (mg/dL)	−1.21*	1.09	−0.23	0.10	−0.25	0.060
Δ LDL cholesterol (mg/dL)	−0.66	4.98	0.16	−1.26	−0.63	0.009
Δ Log triglycerides (mg/dL)[b]	−0.002	0.01	−0.01*	0.01	−0.001	0.107
Δ Systolic blood pressure (mm Hg)	−1.40	1.43	0.81	0.65	0.13	−0.007
Δ Diastolic blood pressure (mm Hg)	0.36	0.43	−0.45	0.09	0.12	0.061
Δ Grip strength—left (kg)	−0.16	−0.03	−0.003	−0.35	−0.06	−0.048
Δ Grip strength—right (kg)	0.13	−0.19	0.23	−0.55**	−0.12*	0.200
Women (*n* = 71):						
Δ Glucose (mg/dL)	0.12	2.01	−0.65	−0.85	0.34	0.082
Δ Total cholesterol (mg/dL)	2.75	−0.76	−1.12	1.29	0.69	0.027
Δ HDL cholesterol (mg/dL)	1.79	2.85*	0.82	0.11	−0.07	0.042
Δ LDL cholesterol (mg/dL)	−0.21	4.12	2.16	−1.10	−0.75	0.050
Δ Triglycerides (mg/dL)[b]	0.15	0.01	0.01	−0.001	−0.0003	−0.020
Δ Systolic blood pressure (mm Hg)	0.26	4.50*	0.31	−0.16	0.14	0.036
Δ Diastolic blood pressure (mm Hg)	0.22	2.19	0.33	0.10	−0.09	−0.016
Δ Grip strength—left (kg)	0.12	−0.38	−0.08	0.03	−0.02	0.002
Δ Grip strength—right (kg)	0.36	−0.16	0.10	0.09	−0.01	−0.002

[a]Significance level: $^{*}P \leq 0.0125$; $^{**}P \leq 0.001$.
[b]Variable is $\log_{10}$ transformed.

TABLE 4. Selected lifestyle measures in Yakut men and women

Measure	Men (*n* = 44) Mean ± SD	Women (*n* = 71) Mean ± SD	*z* score[a]
Days foraging	6.58 ± 5.80	12.88 ± 10.46	−3.83***
Days hunting	15.30 ± 17.07	0.11 ± 0.89	7.60***
Days fishing	6.45 ± 8.65	0.35 ± 1.56	6.61***
Days hay cutting	1275 ± 13.19	4.12 ± 10.90	5.26***
Measure	Mean ± SD	Mean ± SD	*t* statistic[b]
SOL	11.1 ± 3.62	14.41 ± 2.73	−5.21***

[a]Mann–Whitney U-tests, sex differences are significant at: $^{*}P \leq 0.05$; $^{**}P \leq 0.01$; $^{***}P \leq 0.001$.
[b]*T* tests, sex differences are significant at: $^{*}P \leq 0.05$; $^{**}P \leq 0.01$; $^{***}P \leq 0.001$.

associated with time spent foraging ($P < 0.01$), while change in fat-free mass was negatively correlated with foraging time ($P < 0.05$).

DISCUSSION

The present study examined seasonal variation in biomarkers of metabolic and cardiovascular health among the Yakut, an indigenous Siberian population. Cardiovascular disease is a leading cause of death among circumpolar populations and rates of diabetes are on the rise (Chateau-Degat et al., 2010; Krümmel, 2009; Snodgrass, 2013; Snodgrass et al., 2009). Furthermore, past work has highlighted significant sex differences in biomarkers of cardiometabolic disease risk and proposed that lifestyle likely shapes these patterns among indigenous circumpolar groups (Hopkins et al., 2015). Our results indicate that seasonal changes in biomarkers of metabolic health vary as a function of lifestyle and sex. While Yakut men with greater subsistence participation and more traditional lifestyles appeared to be more buffered from adverse fluctuations in serum lipid levels, they also exhibited larger seasonal increases in blood pressure levels. The relationship between lifestyle and seasonal changes in biomarkers of CVD and diabetes among Yakut women was less clear.

Seasonal changes in anthropometric measures

Similar to the results of our study, a majority of the previous work among high-latitude populations reported small seasonal increases in body weight and adiposity from summer to winter (Hopstock et al., 2013; Rode and Shephard, 1973; Tam et al., 2013; van Ooijen et al., 2004; Visscher and Seidell, 2004;) while a few populations displayed small decreases in body mass (Hassi et al., 2001; Rode and Shephard, 1973). It is possible that the small

TABLE 5. Multiple regression analyses[a] of the influence of lifestyle factors on seasonal changes in blood biomarkers controlling for percent body fat and age in Yakut men and women

Measure	Days Foraging[b] β Coefficient	Days Hunting[b] β Coefficient	Days Fishing[b] β Coefficient	Days Hay Cutting[b] β Coefficient	Δ % Body Fat β Coefficient	Age β Coefficient	Adjusted R^2
Men (*n* = 44):							
Δ Glucose	3.04	6.58	−3.87	−3.86	0.89	−0.06	−0.046
Δ Total cholesterol	−0.68	−7.97	13.75*	4.80	−1.01	0.32	0.093
Δ HDL cholesterol	4.10*	−1.76	1.00	−0.43	−0.80	−0.31	0.122
Δ LDL cholesterol	2.51	7.76	−12.15*	−5.04	0.49	−0.63	0.100
Δ Triglycerides[c]	−0.02	0.02	0.02	−0.02	0.006	−0.001	0.069
Δ Systolic blood pressure	−7.68*	3.13	1.23	3.58	−0.64	0.34	0.108
Δ Diastolic blood pressure	−4.87*	0.91	1.37	3.22	0.62	0.26	0.104
Women (*n* = 71)							
Δ Glucose	−2.84	−1.10	−0.80	1.18	1.82	0.19	−0.035
Δ Total cholesterol	3.29	5.69	6.08	4.62	2.06	0.83*	0.046
Δ HDL cholesterol	1.11	3.95	2.21	0.69	1.11	0.03	−0.009
Δ LDL cholesterol	−2.27	4.36	−3.96	−3.91	−0.39	−0.76	−0.004
Δ Log Triglycerides[c]	0.001	0.12*	−0.004	−0.01	−0.01	0.0003	0.033
Δ Systolic blood pressure	−2.66	−2.37	1.10	−1.17	0.86	0.16	−0.054
Δ Diastolic blood pressure	1.39	−5.24	0.73	0.17	−0.04	−0.04	−0.046

[a]Significance (1-tailed): $*P < 0.05$; $**P \leq 0.01$; $***P \leq 0.001$.
[b]Variables regarding the number of days spent conducting subsistence activities have been divided into quartiles.
[c]Variable is $\log_{10}$ transformed.

TABLE 6. Multiple regression analyses[a] of the influence of style of life score on seasonal changes in blood biomarkers controlling for change in percent body fat and age in Yakut men and women

Measure	SOL β Coefficient	Δ % body fat β Coefficient	Age β Coefficient	Adjusted R^2
Men (*n* = 44):				
Δ Glucose	2.31	0.48	−0.14	0.011
Δ Total cholesterol	−3.24	−1.00	0.28	0.034
Δ HDL cholesterol	0.29	−0.97*	−0.26	0.083
Δ LDL cholesterol	−3.95	2.88	0.56	0.004
Δ Triglycerides[b]	0.006	0.005	−0.002	0.014
Δ Systolic blood pressure	−1.48	−0.46	0.13	0.048
Δ Diastolic blood pressure	−1.39**	0.78	0.14	0.137
Women (*n* = 71):				
Δ Glucose	0.41	1.23	0.28	0.010
Δ Total cholesterol	−2.29	2.77	0.65	0.059
Δ HDL cholesterol	−0.60	1.36	−0.03	0.007
Δ LDL cholesterol	−1.37	−1.70	−0.003	0.053
Δ Log triglycerides[b]	−0.01	0.013	−0.010	0.031
Δ Systolic blood pressure	0.71	0.31	0.22	0.021
Δ Diastolic blood pressure	0.16	−0.43	−0.05	0.037

[a]Significance (1-tailed): $*P < 0.05$; $**P \leq 0.01$; $***P \leq 0.001$.
[b]Variable is $\log_{10}$ transformed.

increase in body mass and percent body fat and the significant increase in waist circumference among men and women were due to overall declines in metabolic and cardiovascular health over time, since our data were collected 1.5-years apart. This interpretation is particularly likely among women since they exhibited significant concomitant declines in grip strength. Alternatively, seasonal increases in adiposity and declines in grip strength among women may also be due to reduced physical activity and subsistence participation in the winter compared to the primary subsistence activity performed by women was foraging, which is not normally carried out during the winter months (Crate, 2006). This interpretation is further supported by investigations of variation in physical activity levels. An analysis of accelerometry data collected in the summer of 2009 from a subsample of participants ($n = 68$) indicated that men spent significantly more time in moderate to vigorous physical activity than women (Wilson et al., 2014).

Seasonal changes in blood lipid levels

Fluctuations in serum lipids from summer to winter were pronounced. Mean total cholesterol shifted from

TABLE 7. Multiple regression analyses[a] of the influence of lifestyle factors on seasonal changes in body composition, controlling for age in Yakut men and women

Measure	Days foraging[b] β Coefficient	Days hunting[b] β Coefficient	Days fishing[b] β Coefficient	Days hay cutting[b] β Coefficient	Age β Coefficient	Adjusted R^2
Men (*n* = 44):						
Δ Weight	−1.08*	0.73	−0.37	0.83*	0.07	0.104
Δ BMI	−0.37*	0.23	−0.13	0.30	0.02	0.058
Δ % body fat	−0.74	−0.33	−0.003	−0.08	−0.07	0.035
Δ FFM	0.23	−0.06	−0.06	−0.37	−0.02	−0.074
Δ Waist Circumference	0.13	−0.63	0.41	−0.76	−0.02	−0.072
Δ Hip circumference	0.14	−0.29	0.34	−0.76	−0.10	−0.018
Women (*n* = 71):						
Δ Weight	−0.04	1.38	−0.62	−0.04	−0.06	0.012
Δ BMI	−0.06	0.38	−0.20	−0.002	−0.02	−0.014
Δ % body fat	0.68**	0.17	−0.18	−0.10	−0.02	0.106
Δ FFM	−0.31*	0.51	−0.07	0.02	0.001	0.009
Δ Waist circumference	0.03	−1.72	0.78	−0.31	0.07	−0.012
Δ Hip circumference	0.03	1.46	1.01	−0.03	0.13**	0.087

[a]Significance (1-tailed): $*P < 0.05$; $**P \leq 0.01$; $***P \leq 0.001$.
[b]Variables regarding the number of days spent conducting subsistence activities have been divided into quartiles.

TABLE 8. Multiple regression analyses[a] of the influence of style of life score on seasonal changes in body composition, controlling for age in Yakut men and women

Measure	SOL[b] β Coefficient	Age β Coefficient	Adjusted R^2
Men (*n* = 44)			
Δ Weight	−0.15	0.03	0.004
Δ BMI	−0.05	0.01	−0.008
Δ % body fat	0.08	−0.05	0.031
Δ FFM	0.11	−0.004	−0.008
Δ Waist circumference	0.16	0.01	−0.030
Δ Hip circumference	0.23	−0.07	0.059
Women (*n* = 71):			
Δ Weight	0.01	−0.06	0.023
Δ BMI	0.01	−0.02	0.010
Δ % body fat	0.07	−0.04	0.032
Δ FFM	−0.01	0.01	0.024
Δ Waist circumference	0.14	0.07	0.011
Δ Hip circumference	−0.13	0.11*	0.081

[a]Significance (1-tailed): $*P < 0.05$; $**P \leq 0.01$; $***P \leq 0.001$.

under to above cutoffs recommended by the American Heart Association (AHA) and the percentage of men and women above this threshold increased from summer to winter (see Table 9) (Lichtenstein et al., 2006). This change was primarily driven by increases in HDL cholesterol, which has protective effects for metabolic health.

Significant increases in total cholesterol from summer to winter among Yakut men and women may be due to increased consumption of fatty foods or overall health declines related to aging since the mean age of the sample was 50 years old. In accordance with these explanations, one would expect a significant relationship between rates of change in adiposity and serum lipid levels. The results reveal, however, the opposite pattern. For example, a significant negative relationship existed between change in triglyceride levels and shifts in waist circumference in men.

Seasonal changes in metabolic fuel utilization may also help to explain the changes in lipid levels. Leonard and colleagues (2014) have found that the Yakut show significant declines in basal/resting fat oxidation of 12–14% between summer and winter. These marked reductions in fat metabolism and increased reliance on carbohydrates during the winter are likely contributing to the increase in winter serum lipid levels.

Among Yakut men, the degree of seasonal change in serum lipids appears to be moderated by variation in lifestyle factors. For example, greater participation in fishing was positively correlated with change in total cholesterol levels but negatively associated with seasonal change in LDL levels. Furthermore, men who reported spending more time foraging exhibited greater winter-time increases in HDL levels. Interestingly, both fishing and foraging are activities that improve access to foods high in healthy HDL cholesterol. The relationship between seasonal changes in serum lipids and lifestyle was less pronounced among Yakut women. The results revealed a significant, positive relationship between seasonal change in triglyceride levels and time spent hunting.

Historically, researchers have thought that indigenous circumpolar populations exhibited low LDL and high HDL levels due to the protective effects of a traditional diet high in fish and marine mammals (Jørgensen et al., 2006). The Yakut of northeastern Siberia, however, consume large amounts of beef, horse meat, and processed carbohydrates such as bread, pasta, and rice, in addition to fish. On average Yakut men and women ingest over twice the daily amount of saturated fats recommended by the AHA (Sorensen et al., 2005). Previous work has hypothesized that moderate increases in alcohol consumption can lead to higher serum HDL levels by raising the transport rates of the major apolipoproteins, apoA I and II (Brien et al., 2011; e Silva et al., 2000). However, data analyses did not detect a significant relationship between seasonal change in alcohol consumption and change in HDL levels in this Yakut sample (data not shown).

Individuals with greater subsistence activity participation may exhibit healthier blood lipid profiles across the seasons due to higher physical activity levels. A dose-dependent relationship exists between physical activity and blood lipid levels, particularly increased HDL and lower triglyceride levels (Durstine et al., 2001; Leon et al., 2000; Tejo-Gutierrez and Fletcher, 2007). Exercise is thought to influence HDL levels by altering the expression of proteins, such as lipoprotein lipase, that control cholesterol efflux, maturation, and delivery to receptors (Tejo-Gutierrez and Fletcher, 2007). Additionally, previous work has provided mixed support for exercise-induced reductions in LDL and total cholesterol levels (Durstine

TABLE 9. Percentage of Yakut men and women in sample with blood biomarkers of cardio-metabolic disease risk above the levels recommended by the American Heart Association (AHA)[a]

Measure	Men ($n = 44$)		Women ($n = 71$)	
	Summer	Winter	Summer	Winter
Total cholesterol (>200 mg/dL)	34%	50%	41%	52%
HDL cholesterol (<40 mg/dL for men; <50 mg/dL for women)	10%	5%	21%	14%
LDL Cholesterol (>129 mg/dL)	18%	25%	18%	25%
Triglycerides (>100 mg/dL)	14%	33%	21%	30%
Glucose (>100 mg/dL)	12%	40%	18%	39%
Systolic blood pressure (>120 mm Hg)	68%	68%	62%	55%
Diastolic blood pressure (>80 mm Hg)	46%	46%	45%	32%

[a]AHA cutoff values published in Lichtenstein et al, 2007.

et al., 2001; Kraus et al., 2002). Greater winter-time physical activity levels, however, is an unlikely explanation for seasonal changes in serum lipids, particularly among women, since there is evidence for concomitant declines in grip strength and increases in adiposity.

Among circumpolar populations, winter serum lipid levels may be sensitive to heighted thermogenesis. Indigenous high-latitude populations are known to adapt to cold temperature stress by increasing their basal metabolic rates (Froehle et al., 2008; Leonard et al., 2005, 2014). This may lead to a higher rate of cellular turnover of cholesterol and increase the rate of serum lipid utilization (Eisenberg et al., 2010). A previous investigation of the metabolic health of the Evenki and Buryat, two populations that are also indigenous to Siberia, detected a significant, negative relationship between basal metabolic rate and LDL cholesterol levels. This relationship remained significant after adjusting for body size, composition, age, and smoking status (Leonard et al., 2009; Snodgrass et al., 2007). Thus, seasonal changes in cholesterol levels among the Yakut may be influenced by adaptation to cold temperature stress and the protective effects of heightened metabolic turnover of serum lipids. On the contrary, the degree to which high-latitude groups exhibit winter-time increases in serum lipid levels (Hedstrand and Wide, 1973; Hopstock et al., 2013; Keys et al., 1958; Mjøs et al., 1979; Nazir et al., 1999; Paloheimo, 1961; Ulmer et al., 2004) is similar to populations living in temperate zones (Blüher et al., 2001; Chen et al., 2006; Cucu et al., 1991; Donahoo et al., 2000; Kanikowska et al., 2013; MacRury and Hume, 1992; Mustad et al., 1996; Ockene et al., 2004; Rastam et al., 1992; Robinson et al., 1993; Woodhouse et al., 1993). This may be due to the confounding effects of seasonal dietary fluctuations.

Seasonal changes in blood glucose levels

Winter increases in fasting blood glucose levels were statistically significant among women but not men. The average winter levels for both men and women, however, were above the threshold considered to be prediabetic by the AHA (see Table 9) (Lichtenstein et al., 2006). In fact, the percentage of participants with glucose levels above the recommended level increased dramatically from summer to winter for both sexes.

Historically, indigenous Siberian populations and other groups native to circumpolar regions have reported low rates of diabetes and impaired fasting glucose (Snodgrass et al., 2007). After measuring fasting blood glucose levels among a rural Yakut community in August of 2007, Snodgrass et al. (2009) reported lower average fasting glucose levels (79.9 mg/dL), but warned that, with increasing consumption of market foods high in refined sugar in rural communities, the presence of impaired fasting glucose was likely to increase. Unfortunately, this appears to be the case; the positive relationships between change in glucose levels and SOL score among men approached significance ($P = 0.087$) suggesting that individuals with greater market integration were more likely to experience winter increases in fasting blood glucose.

Seasonal changes in blood pressure

While Yakut men and women did not experience significant seasonal changes in blood pressure, average systolic and diastolic blood pressure levels were all above the AHA recommended levels, with the exception of average winter systolic blood pressure among women (Lichtenstein et al., 2006). In fact, the percentage of women in our sample with unhealthy blood pressure values decreased from summer to winter, while the proportion stayed the same for men (see Table 9). Previous reports documented high rates of hypertension among indigenous Siberian populations (~20–35%; Kozlov et al., 2007; Snodgrass, 2013; Snodgrass et al., 2008).

Yakut men who reported spending more time foraging exhibited lower winter-time systolic and diastolic blood pressure levels. In contrast to this pattern, however, a more traditional lifestyle characterized by a lower SOL score was significantly associated with higher diastolic blood pressure, and the negative relationship between SOL score and systolic blood pressure approached statistical significance ($P = 0.051$). Evidence suggests that diets high in fibrous plant foods may lead to lower blood pressure levels (Beilin et al., 1988; Margetts et al., 1988; Steffen et al., 2005); thus, foraging may have protective effects by improving access to plant foods in the winter. A lower SOL score overall, on the other hand, may be indicative of activities that facilitate a diet high in animal products, such as tending livestock and hunting, which is associated with elevations in blood pressure (Steffen et al., 2005). The data revealed few significant relationships between seasonal change in markers of metabolic health and lifestyle variables among women.

SUMMARY

This study provides additional evidence that the relationship between metabolic health and seasonal environmental stressors is dependent upon social and economic factors (Himmelgreen and Romero-Daza, 1994; Leonard, 1989; Leonard and Thomas, 1989; Leonard et al., 2014; Levy et al., 2013). High-latitude indigenous groups with greater subsistence activity participation appear to be more buffered from adverse seasonal changes in cholesterol, but are at greater risk for hypertension. Subarctic groups with greater adoption of Western, sedentary lifestyles, however, exhibit a higher population burden of serum lipids, glucose, and other cardiovascular disease risk factors (Ford et al., 2006; Leonard et al., 2002; Rode and Shephard, 1995; Sorensen et al., 2005; Tam et al., 2013; Young et al., 1995). Thus, socioeconomic resources interact with seasonal environmental factors to direct the physical activity and nutritional options open to different sectors of the population (Himmelgreen and Romero Daza, 1994; Leonard and Thomas, 1989).

There are several limitations to this study. First, conditions in this remote part of Siberia prevent the recruitment of a truly random sample. The study sample, therefore, may be biased toward individuals who are open to health and physiological research and have the resources and time available to visit the health clinic.

Second, this study lacks high resolution data that would allow us to link seasonal changes in physical activity and diet to shifts in markers of health. The adjusted R-square values presented in Tables 3 and 5 through 8 are relatively low, suggesting that the explanatory power of the models is modest. More fine-grained measures of physical activity and diet would shed light on seasonal fluctuations in biomarkers of cardiovascular disease and diabetes. Collecting data at multiple time-points over the course of the year would likely reveal stronger relationships between seasonal shifts in health and lifestyle factors.

Finally, the winter and summer data were not collected in the same year, but rather 1.5-years apart. It is possible that the patterns in health biomarkers we describe reflect age-related increases in cardiovascular disease and diabetes risk, or are due to ongoing processes of acculturation over time in this community rather than seasonal patterns. This interpretation is particularly salient for Yakut women since the data suggest women experienced declines in multiple health measures. Before the Soviet Era, both men and women participated in most subsistence activities. Through the process of collectivization under the Soviet Union, however, Yakut women were forcibly relocated to villages where they were largely stripped of a majority of subsistence activity responsibilities (Forsyth, 1992). Our data suggest that, today, the primary subsistence activity performed by women is foraging. Reduced participation in a variety of subsistence activities may account for the lack of relationships between lifestyle variables and seasonal change in metabolic health among Yakut women.

CONCLUSION

In summary, this study describes seasonal changes in metabolic health among a rural indigenous Siberian population. While seasonal fluctuations in body mass and composition are modest, serum lipid levels increased significantly from summer to winter and these changes varied with lifestyle and sex. Specifically, individuals with greater subsistence activity participation seem more buffered against adverse seasonal changes in metabolic health. Future work examining health and adaptation to seasonal stressors should consider the ways in which socioeconomic and lifestyle factors influence the relationship between adaptive strategies and disease risk.

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LITERATURE CITED

Bang HO, Dyerberg J. 1980. Lipid metabolism and ischemic heart disease in Greenland Eskimos. In: HH Draper, editor. Advances in Nutritional Research. New York: Plenum Publishing. p 1–22.
Bang HO, Dyerberg J, Nielsen AB. 1971. Plasma lipid and lipoprotein pattern in Greenlandic west-coast Eskimos. Lancet 297:1143–1146.
Beilin LJ, Rouse IL, Armstrong BK, Margetts BM, Vandongen R. 1988. Vegetarian diet and blood pressure levels: incidental or causal association. Am J Clin Nutr 48:806−810.
Bindon J, Knight A, Dressler W, Crews D. 1997. Social context and psychosocial influences on blood pressure among American Samoans. Am J Phys Anthropol 103:7–18.
Bjerregaard P, Jørgensen M E. 2008. Diet, nutrition, and physical activity. In: Young TK, Bjerregaard P, editors. Health Transitions in Arctic Populations. Toronto: University of Toronto Press. p 192–204.
Blüher M, Hentschel B, Rassoul F, Richter V. 2001. Influence of dietary intake and physical activity on annual rhythm of human blood cholesterol concentrations. Chronobiol Int 18:541–557.
Brien SE, Ronksley PE, Turner BJ, Mukamal KJ, Ghali WA. 2011. Effect of alcohol consumption on biological markers associated with risk of coronary heart disease: systematic review and meta-analysis of interventional studies. BMJ 342.
Cepon TJ, Snodgrass JJ, Leonard WR, Tarskaia LA, Klimova TM, Fedorova VI, Baltakhinova ME, Krivoshapkin VG. 2011. Circumpolar adaptation, social change, and the developmental of autoimmune thyroid disorders among the Yakut (Sakha) of Siberia. Am J Hum Biol 23: 703–709.
Chateau-Degat M-E, Dewailly E, Charbonneau G, Laouan-Sidi EA, Tremblay A, Egeland GM. 2011. Obesity risks: toward an emerging Inuit pattern. Int J Circumpol Health 70:166−177.
Château-Degat M-E, Dewailly E, Noël M, Valera B, Ferland A, Counil E, Poirier P, Egeland GM. 2010. Hypertension among the Inuit from Nunavik: Should we expect an increase because of obesity? Int J Circumpol Health 69:361–372.
Chen S-H, Jen I-A, Chuang S-Y, Lin K-C, Chou P. 2006. Community-based study on summer-winter differences of component of metabolic syndrome in Kinmen, Taiwan. Prev Med 43:129–135.
Crate S. 2006. Cows, Kin and Globalization: An Ethnography of Sustainability. Lanham, MD: AltaMira Press. p 99–121, 141.
Cucu FL, Purice S, Schioiu-Costache L, Damsa TR, Suciu A, Cherciu A, Stenbach M. 1991. Seasonal variations of serum cholesterol detected in the Bueharest Multifactorial Prevention Trial of Coronary Heart Disease. Ten Years Follow-up (1971-1982). Rev Roum Med Inst 29:1–21.
Donahoo WT, Jensen DR, Shepard TY, Eckel RH. 2000. Seasonal variation in lipoprotein lipase and plasma lipids in physical active, normal weight humans. J Clin Endocrin Metab 85:3065–3068.
Durnin JVGA, Womersley J. 1974. Body fat assessed from total body density and its estimation from skinfold thickness: measurements on 481 men and women aged from 16 to 72 years. Br J Nutr 32:77–97.
Durstine LJ, Grandjean PW, Davis PG, Ferguson MA, Alderson NL, DuBose KD. 2001. Blood lipid and lipoprotein adaptations to exercise: a quantitative analysis. Sports Med 31:1033–1062.
Eisenberg DTA, Kuzawa CW, Hayes MG. 2010. Worldwide allele frequencies of the human apolipoprotein E gene: climate, local adaptations, and evolutionary history. Am J Phys Anthro 143:100–111.
Ford JD, Smit B, Wandel J. 2006. Vulnerability to climate change in the Arctic: a case study from Arctic Bay, Canada. Global Eniron Chang 16: 145–160.
Forsyth J. 1992. A History of the peoples of Siberia: Russia's North Asian colony 1581–1990. Cambridge: Cambridge University Press. p 455.
Friedwald WJ, Levy RI, Fredrickson DS. 1972. Estimation of the concentration of low-density liporotein cholesterol in plasma, without use of the preparative ultracentrifuge. Clin Chem 18:499–502.
Froehle A. 2008. Climate variables as predictors of basal metabolic rate: new equations. Am J Hum Biol 20:510–529.
Fumagalli M, Moltke I, Grarup N, Racimo F, Bjerregaard P, Jørgensen ME, Korneliussen TS, P Gerbault, Skotte L, Linneberg A, Christensen C, Brandslund I, Jørgensen T, Huerta-Sánchez E, Schmidt EB, Pedersen O, Hansen T, Albrechtsen A, Nielsen R. 2015. Greenlandic

Inuit show genetic signature of diet and climate adaptation. Science 349:1343–1347.
Hassi J, Sikkilä K, Ruokonen A, Leppäluoto J. 2001. The pituitary-thyroid axis in healthy men living under subarctic climatological conditions. J Endocrinol 169:195–203.
Hedstrand H, Wide L. 1973. Serum thyrotrophin an lipid levels in summer and winter. Brit Med J 4:420.
Himmelgreen DA, Romero-Daza N. 1994. Changes in body weight in Basotho women: seasonal coping in households with different socioeconomic conditions. Am J Hum Biol 6:599–611.
Himms-Hagen J. 1972. Lipid metabolism during cold exposure and cold acclimation. Lipids 7:310–320.
Hopkins SE, Austin MA, Metzger JS, Koller KR, Umans JG, Kaufman C, Wolfe AW, Howard BV, Boyer BB. 2015. Sex differences in obesity prevalence and cardiometabolic factors among Western Alaska Native people. Nutr Metabl Cardiovasc Dis 25:312–318.
Hopstock LA, Barnett AG, Bønaa KA, Mannsverk J, Njølstad I, Wilsgaard T. 2013. Seasonal variation in cardiovascular disease risk factors in a subarctic population: the Tromsø Study 1979-2008. J Epidemiol Community Health 67:113–118.
Jordan BB, Jordan-Bychkov TG. 2001. Siberian village: land and life in the Sakha Republic. Minneapolis: University of Minnesota Press. p 140.
Jørgensen ME. 2010. Obesity and diabetes: an Arctic challenge. Int J Circumpol Health 69:320–321 [PMC][20863452].
Jørgensen ME, Borch-Johnsen, Bjerregaard P. 2006. Lifestyle modifies obesity-associated risk of cardiovascular disease in a genetically homogenous population. Am J Clin Nutr 84:29–36.
Jørgensen ME, Young TK. 2008. Cardiovascular disease, diabetes, and obesity. In: TK Young, Bjerregaard P, editors. Health Transitions in Arctic Populations. Toronto: University Toronto Press. p 291–307.
Kanikowska D, Sato M, Iwase S, Shimizu Y, Nishimura N, Inukai Y, Sugenoya J. 2013. Effects of living at two ambient temperatures on 24-h blood pressure and neuroendocrine factors among obese and non-obese humans: a pilot study. Int J Biometeorol 57:475–481.
Keys A, Karvonen MJ, Fidanza F. 1958. Serum-cholesterol studies in Finland. Lancet 272:175–178.
Kozlov AI, Vershubsky G, Kozlova M. 2003. Stress under modernization in indigenous populations of Siberia. Int J Circumpol Health 62:158–166.
Kraus WE, Houmard JA, Duscha BD, Knetzger KJ, Wharton MB, McCartney JS, Bales CW, Henes S, Samsa GP, Otvos JD, Kulkarni KR, Sletz CA. 2002. Effects of the amount and intensity of exercise on plasma lipoproteins. N Engl J Med 347:1483–1492.
Krümmel EM. 2009. The Circumpolar Inuit Health Summit: a summary. Int J Circumpol Health 68:509–518.
Leon AS, Rice T, Mandel S, Deprés JP, Bergeron J, Gagnon J, Rao DC, Skinner JS, Wilmore JH, Bouchard C. 2000. Blood lipid response to 20 weeks of supervised exercise in a large biracial population: the HERITAGE Family Study. Metabolism 49:513–520.
Leonard WR. 1989. On the adaptive significance of energetic efficiency. Hum Ecol 17:465–470.
Leonard WR. 2008. Lifestyle, diet, and disease: comparative perspectives on the determinants of chronic health risks. In: Stearns SC, Koella JC. Evolution in Health and Disease. Oxford, UK: Oxford University Press. p 265–276.
Leonard WR, Galloway, V., Ivakine, E., Osipova L. and Kazakovtseva, M. 2002. Ecology, health and lifestyle change among the Evenki herders of Siberia. In: Leonard WR and Crawford MH, editors. Human Biology of Pastoral Populations. Cambridge: Cambridge University Press. p 206–235.
Leonard WR, Levy SB, Tarskaia LA, Klimova TM, Fedorova VI, Baltakhinova ME, Krivoshapkin VG, Snodgrass JJ. 2014. Seasonal variation in basal metabolic rates among the Yakut (Sakha) of Northeastern Siberia. Am J Hum Biol 26:437–445.
Leonard WR, Snodgrass JJ, Sorensen MV. 2005. Metabolic adaptation in indigenous Siberian populations. Annu Rev Anthropol 34:451–471.
Leonard WR, Snodgrass JJ, Sorensen MV. 2009. Health consequences of social and ecological diversity among indigenous Siberian populations: biocultural and evolutionary interactions. In Panter-Brick C, Fuentes A, editors. Health, Risk, and Adversity: A New Synthesis from Biological Anthropology. New York: Bergham. p 26–51.
Leonard WR, Thomas B. 1989. Biosocial responses to seasonal food stress in highland Peru. Hum Biol 61:65–85.
Levy SB, Leonard WR, Tarskaia LA, Klimova TM, Fedorova VI, Krivoshapkin VG, Snodgrass JJ. 2012. The Indigenous Siberian Health and Adaptation Project: Seasonality in thyroid function and metabolic health among the Yakut (Sakha) of Eastern Siberia. Am J Hum Biol 24:231.
Levy SB, Leonard WR, Tarskaia LA, Klimova TM, Fedorova VI, Baltakhinova ME, Krivoshapkin VG, Snodgrass JJ. 2013. Seasonal and socioeconomic influences on thyroid function among the Yakut (Sakha) of Eastern Siberia. Am J Hum Biol 6:814–820.
Lichtenstein AH, Appel LJ, Brands M, Carnethon M, Diels S, Franch HA, Franklin B, Kris-Etherton P, Harris WS, Howard B, Karanja N, Lefevere M, Rudel L, Sacks F, Van Horn L, Winston M, Wylie-Rosett J. 2006. Diet and lifestyle recommendations revision 2006: a scientific statement from the American Heart Association Nutrition Committee. Circulation 114:82–96.
Lohman TG, Roche AF, Martorell F, editors. 1988. Anthropometric standardization reference manual. Champaign: Human Kinetics Books. P 96.
MacRury SM, Muir M, Hume R. 1992. Climatic variation in cholesterol and vitamin C: effect of vitamin supplementation. Scot Med J 37:49–52.
Margetts BM, Beilin LJ, Armstrong BK, Vandongen R. 1988. Vegetarian diet in mild hypertension: effects of fat and fiber. Am J Clin Nutr 48:801–805.
Marti-Soler H, Gubelmann C, Aeschbacher S, Alves L, Bobak M, Bongard V, Clays E, de Gaetano G, Di Castelnuovo, Elosua R, Ferrieres J, Guessous I, Igland J, Jørgensen T, Nikitin Y, O'Doherty M, Palmieri L, Ramos R, Simons J, Sulo G, Vanuzzo D, Vila J, Barros H, Borglykke A, Conen D, De Bacquer D, Donfrancesco C, Gaspoz J-M, Giampaoli S, Giles G, Iacoviello L, Kee F, Kubinova R, Malyutina S, Marrugat J, Prescott E, Ruidavets J, Scragg R, Simons L, Tamosiunas A, Tell G, Vollenweider P, Marques-Vidal P. 2014. Seasonality of cardiovascular risk factors: an analysis including over 230,000 participants in 15 countries. Heart. 100:1517–1523.
Mjøs OD, Rao SN, Bjøru L, Henden T, Thelle DS, Førd OH, Miller NE. 1979. A longitudinal study of the biological variability of plasma lipoproteins in healthy young adults. Atherosclerosis 34:75–81.
Mustad V, Derr J, Reddy CC, Pearson TA, Kris-Etherton PM. 1996. Seasonal variation in parameters related to coronary heart disease in young men. Atherosclerosis 126:117–129.
National Russian Census (Всероссийская Перепись Населения). 2010. Urban and rural population by sex (Численность городского и сельского населения по полу). Retrieved April 22, 2014 from http://www.gks.ru/free_doc/new_site/perepis2010/croc/perepis_itogi1612.htm.
Nazir DJ, Roberts RS, Hill SA, McQueen MJ. 1999. Monthly intra-individual variation in lipids over a 1-year period in 22 normal subjects. Clin Biochem 32: 381–389.
Ockene IS, Chiriboga DE, Stanek EJ, Harmatz MG, Nicolosi R, Saperia G, Well AD, Freedson P, Merriam PA, Reed G, Ma Y, Matthews CE, Hebert JR. 2004. Seasonal variation in serum cholesterol levels – treatment implications and possible mechanisms. Ach Intern Med 164:863–870.
Pääkkönen T, Leppäluoto J. 2002. Cold exposure and hormonal secretion: A review. Int J Circumpolar Health 61:265–276.
Paloheimo J. 1961. Seasonal variations of serum lipids in healthy men. Ann Med Exp Biol Fen 39:1–88.
Pika AI. 1999. Neotraditionalism in the Russian North: Indigenous Peoples and the Legacy of Perestroika. Seattle: University of Washington Press. p 9–10.
Rastam L, Hannan PJ, Luepker RV, Mittelmark MB, Murray DM, Slater JS. 1992. Seasonal variation in plasma cholesterol distributions: implications for screening and referral. Am J Prev Med 8:360–366.
Robinson D, Hinohara S, Bevan EA, Takahashi T. 1993. Seasonal variation in serum cholesterol levels in health screening populations from the U.K. and Japan. J Med Syst 17:207–211.
Rode A, Shephard RJ. 1973. Fitness of the Canadian Eskimo – the influence of season. Med Sci Sports 5:170–173.
Rode A, Shepard RJ. 1995. Modernization of lifestyle, body fat content and body fat distribution: a comparison of Igloolik Inuit and Volochanka nGanasan. Int J Obesity 19:709–716.
Shephard RJ, Rode A. 1996. The health consequences of modernization: evidence from circumpolar peoples. Cambridge: Cambridge University Press. p 58–150.
e Silva ERDO, Foster D, Harper MM, Seidman CE, Smith JD, Breslow JL, Brinton EA. 2000. Alcohol consumption raises HDL cholesterol by increasing the transport rate of apolipoproteins A-I and A-II. Circulation 102:2347–2352.
Snodgrass JJ. 2004. Energetics, health, and economic modernization in the Yakut (Sakha) of Siberia: a biocultural perspective on lifestyle change in a circumpolar population. PhD Thesis. Evanston, IL: Northwestern University. p 23–49, 203.
Snodgrass JJ. 2013. Health of indigenous circumpolar populations. Ann Rev Anthropol 42:69–87.
Snodgrass JJ, Leonard WR, Sorensen MV, Tarskaia LA, Alekseev VP, Krivoshapkin V. 2006b. The emergence of obesity among indigenous Siberians. J Physiol Anthropol 25:75–84.
Snodgrass JJ, Leonard WR, Sorensen MV, Tarskaia LA, Mosher MJ. 2008. The influence of basal metabolic rate on blood pressure among indigenous Siberians. Am J Phys Anthropol 137:145–155.
Snodgrass JJ, Leonard WR, Tarskaia LA, Egrova AG, Maharova NV, Pinigina IA, Halyev SD, Matveeva NP, Romanova AN. 2009. Impaired fasting glucose and metabolic syndrome in an indigenous Siberian population. Int J Circumpol Health 69:87–98.
Snodgrass JJ, Leonard WR, Tarskaia LA, Schoeller DA. 2006a. Total energy expenditure in the Yakut (Sakha) of Siberia as measured by the doubly labeled water method. Am J Clin Nutr 84:798–806.

Snodgrass JJ, Sorensen MV, Tarskaia LA and Leonard WR. 2007. Adaptive dimensions of health research among indigenous Siberians. Am J of Hum Biol 19:165–180.

Sorensen MV. 2003. Social and Biological Determinants of Cardiovascular Risk among Rural and Urban Yakut: The Impact of Socioeconomic Upheaval. PhD thesis. Northwestern University, Evanston. p 14–30.

Sorensen MV, Snodgrass JJ, Leonard WR, Tarskaia A, Ivanov KI, Krivoshapkin VG, Spitsyn VA. 2005. Health consequences of postsocialist transition: dietary and lifestyle determinants of plasma lipids in Yakutia. Am J Hum Biol 17:576–592.

Steffen LM, Kroenke CH, Yu Xinhua, Pereira MA, Slattery ML, Van Horn L, Gross MD, Jacobs DR. 2005. Associations of plant food, dairy product, and meat intakes with 15-y incidence of elevated blood pressure in young black and white adults: the Coronary Artery Risk Development in Young Adults (CARDIA) Study. Am J Clin Nutr 82:1169–1177.

Tam BY, Gough WA, Edwards V, Tsuji LJS. 2013. Seasonal and weather-related behavioral effects among urban Aboriginal, urban non-Aboriginal, and remote Aboriginal participants in Canada. Popul Environ 35:45–67.

Tejo-Gutierrez JF, Fletcher G. 2007. Impact of exercise on blood lipids and lipoproteins. J Clin Lipid 1:175–181.

Ulmer H, Kelleher C, Diem G, Concin H, Ruttmann E. 2004. Estimation of seasonal variations in risk factor profiles and mortality from coronary heart disease. Wein Klin Wochenschr 116:662–668.

van Ooijen AMJ, van Marken Lichtenbelt WD, van Steenhoven AA, Westerterp KR. 2004. Seasonal changes in metabolic and temperature responses to cold air in humans. Physiol Behav 82: 545–553.

Visscher TLS, Seidell JC. 2004. Time trends (1993-1997) and seasonal variation in body mass index and waist circumference in the Netherlands. Int J Obesity 28:1309–1316.

Wilson HJ, Loneard WR, Tarskaia LA, Klimova TA, Krivoshapkin VG, Snodgrass JJ. 2014. Objectively measured physical activity and sedentary behaviour of Yakut (Sakha) adults. Ann Hum Biol 41:180–186.

Woodhouse PR, Khaw K-T, Plummer M. 1993. Seasonal variation of serum lipids in an elderly population. Age Ageing 22:273–278.

Young TK. 1996. Obesity, central fat patterning, and their metabolic correlates among the Inuit of the Central Canadian Arctic. Hum Biol 68:245–263.

Young TK. 2012. Circumpolar Health Atlas. Toronto: University of Toronto Press. p 107–110. Young TK, Moffatt MEK, O'Neill JD. 1993. Cardiovascular diseases in a Canadian Arctic population. Am J Public Health 83: 881–887.

Young TK, Bjerregaard P, Dewily E, Risica PM, Jörgensen ME, Ebbesson SEO. 2007. Prevalence of obesity and its metabolic correlates among the circumpolar Inuit of 3 countries. Am J Public Health 97: 691–695.

Young TK, Nikitin YP, Shubnikov EV, Astakhova TI, Moffat MEK, O'Neil JD. 1995. Plasma lipids in two indigenous arctic populations with low risk for cardiovascular disease. Am J Hum Biol 7:223–236.