Original Research Article

Circumpolar Adaptation, Social Change, and the Development of Autoimmune Thyroid Disorders Among the Yakut (Sakha) of Siberia

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Objectives: Alterations in thyroid function appear to play a central role in adaptation to Arctic environments. Increased thyroid activity in indigenous circumpolar populations is associated with upregulated metabolism, including elevated basal metabolic rate (BMR); however, little is known about the possible health consequences of these climate-induced changes on thyroid function. The focus of the present study is to determine the prevalence of autoimmune thyroid disorders and their lifestyle and metabolic correlates among a sample of indigenous Yakut adults from northeastern Siberia.

Methods: Anthropometric dimensions, health data, and plasma samples were collected among 281 adults (143 women, 138 men; ≥18 years old) from the rural community of Berdygestiakh (62°N, 127°E; pop. 4,900), Sakha Republic (Yakutia), Russia. BMR measurements were available for 96 women and 98 men. Free triiodothyronine (T_3), free thyroxine (T_4), thyroid stimulating hormone (TSH), and anti-thyroid peroxidase antibody (TPOAb) levels were determined using enzyme immunoassay.

Results: Twenty-two percent of women and 6% of men had clinically elevated (>30 IU/ml) TPOAb. TPOAb was positively correlated with TSH ($P < 0.01$), T_3 ($P < 0.05$), and T_4 ($P < 0.05$) in women and showed a positive trend with T_4 ($P = 0.06$) in men. Monthly household income was significantly positively correlated with TPOAb in men ($P < 0.01$) and showed a trend among women ($P = 0.06$).

Conclusions: Although preliminary, these findings document higher than expected TPOAb levels among Yakut women and suggest possible consequences of increased thyroid activity associated with circumpolar adaptation and social change. Am. J. Hum. Biol. 23:703–709, 2011.

Alterations in thyroid function appear to play a central role in adaptation to circumpolar environments through their link with elevated basal metabolic rate (BMR; Leonard et al., 1999 , 2005). Indigenous Siberians have significantly higher BMRs than reference populations, likely as a result of enhanced non-shivering thermogenesis and heat production related to exposure to chronic cold stress (Leonard et al., 2005; Snodgrass et al., 2007). Production and utilization of thyroid hormones—in particular triiodothyronine (T_3) and thyroxine (T_4)—appears to be a central element of this adaptation (Itoh, 1974; Leonard et al., 1999; Shephard and Goode, 1988; Tkachev et al., 1991). This is supported by research that documents a positive correlation between BMR and T_3 and T_4 (Leonard et al., 1999), as well as studies that show increased thyroid hormone production in both non-indigenous and indigenous human groups and animals in response to acute seasonal cold stress (Eastman et al., 1974; Levine et al., 1995; Young, 1981).

One potential consequence of these physiological responses to stressors encountered in circumpolar environments may be an increased rate of autoimmune thyroid disorders (AITDs) as indicated by elevated serum levels of anti-thyroid peroxidase antibody (TPOAb) (Andersen et al., 1999; Chiovato and Pinchera, 1996; Oomen et al., 1996). Thyroid peroxidase is the main enzyme necessary for thyroid hormone synthesis (Bassett and Williams, 2003; Guyton and Hall, 2006). AITDs occur when the body produces antibodies such as TPOAb or anti-thyroglobulin antibodies (TgAb) that attack proteins necessary for thyroid function. High levels of TPOAb often result in progressive development of hypothyroidism, whereas overstimulation-induced hyperthyroidism occurs with thyroid stimulating hormone (TSH) receptor autoantibodies (TRAb); however, some overlap in the conditions does exist (Davies, 2000; Hollowell et al., 2002; Marcocci and Chiovato, 2000).

Clinical manifestations of AITDs include myxoedema, Hashimoto's thyroiditis, and Graves' disease; complete thyroid failure may occur if any of these conditions are left untreated (Bryhni et al., 1996). AITDs have also been shown to be linked with pulmonary arterial hypertension (Chu et al., 2002), type 1 diabetes (Kordonouri et al., 2002), diet and pregnancy (Davies, 2000), and chronic psy-

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chosocial stress (Chiovato and Pinchera, 1996; Oomen et al., 1996).

Previous studies have documented that in most populations the prevalence of clinically elevated TPOAb is 7–9% in adults and 3–4% in children (Bryhni et al., 1996; Buchanan and Lee, 2001; Carta et al., 2002; Kabelitz et al., 2003; Nyström et al., 1981; Tunbridge, 1977). As with most autoimmune disorders, women are at greater risk for AITDS. However, little attention has been paid to the development and progression of AITDs among northern groups, including indigenous circumpolar populations. This is unfortunate given the fundamental role of thyroid function in metabolic adaptation among these groups. Further, lifestyle changes that occur as a population transitions away from traditional lifeways may increase risk of autoimmunity as a result of dietary changes, which are known to affect thyroid function.

The present study was conducted among the Yakut (Sakha) of northeastern Siberia with the following three objectives. First, the study was designed to determine the overall prevalence of elevated TPOAb among Yakut men and women. We expect that both sexes will have elevated levels of TPOAb when compared with other populations, with Yakut women having higher TPOAb than Yakut men. Second, this study examines correlations among TPOAb, BMR, TSH, T_3, and T_4 in order to better understand the relationship between thyroid antibody levels and circumpolar adaptation. If AITDs are a side effect of elevated BMR due to circumpolar adaptation, we would expect to see a positive correlation between TPOAb and the thyroid hormones TSH, T_3, and T_4, as well as BMR. Finally, this research explores the relationship between AITDs and lifestyle factors related to rapid social and economic change, including alterations in subsistence participation and ownership of consumer goods. We expect that greater levels of market integration and higher socioeconomic status (SES) will be related to an increased presence of AITDs.

METHODS

Study population

The Yakut (Sakha) are a large indigenous herding population from northeastern Siberia. With a population of about 380,000, the Yakut make up nearly 40% of the Sakha Republic/Yakutia of the Russian Federation (Balzer, 1983; Balzer and Vinkurova, 1996; Forsyth, 1992; Jordan and Jordan-Bychkov, 2001; Snodgrass et al., 2005). They traditionally practiced a complex and regionally variable subsistence strategy that was determined by local ecological conditions. Subsistence in the Lena River Valley centered on horse and cattle herding. In more remote, forested areas, subsistence typically involved fishing and hunting (Tokarev and Gurvich, 1964). During the Soviet period, the Yakut experienced forced collectivization, industrialization, and Russification. Economic self-sufficiency decreased, whereas adult mortality and morbidity increased (Forsyth, 1992).

When the Soviet Union collapsed in 1991, many Yakut in rural areas were forced to return to a more subsistence-oriented lifestyle that included herding, fishing, horticulture, and gathering. Health declined in this period with life expectancy for indigenous Siberians declining four years for women and six years for men from 1991 to 1995 (Sorensen, 2003). Further, there has been a steep rise in alcohol-related deaths from trauma, injury, and suicide, as well as increased cardiovascular mortality and declining mental health (Sorensen, 2003). The population today is simultaneously experiencing the continued effects of the collapse of the Soviet Union and economic development associated with the diamond and petroleum industries (Balzer, 1995; Balzer and Vinokurova, 1996; Crate, 2006; Jordan and Jordan-Bychkov, 2001).

Fig. 1. Map of the Sakha Republic/Yakutia showing the study community of Berdygestiakh. Reproduced with permission from Snodgrass et al., 2005.

Participants

Study participants were volunteers from the rural community of Berdygestiakh (62°N, 127°E; pop. 4900), Gorny *ulus*, Sakha Republic/Yakutia (see Fig. 1). Although conditions in this remote part of Siberia prevented us from obtaining a random sample of residents, we made every effort possible to enroll a sample of participants that was representative of the community in terms of age, sociodemographics, and lifestyle. Participants were recruited on a voluntary basis based on word of mouth and advertising of the study in the community. Although useful for recruiting participants, this method only recruits individuals who are open to health and physiological research, and may over-enroll participants concerned about their health. All data were collected in the Gorny Regional Medical Center in Berdygestiakh during July and August of 2009.

Anthropometric, metabolic, and health data were obtained from 281 adults (≥18 years; 143 women, 138 men). All participants were healthy at the time of measurement (with no known acute or chronic conditions) and gave informed consent for participation in the study. Pregnant and lactating women were excluded. BMR data was available for a subset of 96 women and 98 men. The Office for Protection of Human Subjects at the University of Oregon, which monitors conflicts of interest and ethics related

to research, approved the study protocol, and informed consent was obtained from all participants.

Anthropometry

Anthropometric measurements were recorded by one trained observer (L.A.T.) following procedures outlined by Lohman et al. (1988). Stature was measured to the nearest 1.0 mm using a field stadiometer (Seca Corporation, Hanover, MD). Body weight was calculated to the nearest 0.1 kg using a Tanita bioelectrical impedance analysis (BIA) scale (Tanita Corporation, Tokyo, Japan). Percent body fat was measured using BIA. Body mass index (BMI) was calculated by dividing an individual's mass in kilograms by height in meters squared (kg/m^2).

Thyroid hormones and anti-thyroid antibodies

Fasting blood samples were obtained by a trained nurse using venipuncture. Whole blood samples were immediately centrifuged, and the plasma fraction was separated and stored at $-20^{\circ}C$ until laboratory analysis of thyroid hormones. Free T_3, free T_4, TSH, and TPOAb levels were determined using enzyme immunoassay with XEMA assay kits (Moscow, Russia). This study focused on TPOAb, as these antibodies are more easily detected and more indicative of AITDs than TgAb (Marcocci and Chiovato, 2000). All laboratory analyses were conducted in the Yakutsk Medical Center Department of Endocrinology (Yakutsk, Russia) under the supervision of Dr. Elizaveta Popova.

Basal metabolic rate

BMR [kilocalories per day (kcal/d)] was measured by a single experienced researcher (W.R.L.) in a thermoneutral laboratory (23–27°C) following procedures used in our previous studies (Galloway et al., 2000; Snodgrass et al., 2005). Participants were fasted for 12 h prior to measurement. BMR was measured via indirect calorimetry using a MedGraphics VO2000 open-circuit metabolic analyzer (St. Paul, MN) with pre-Vent masks and Breeze Lite software. The VO2000 instrument was used to measure oxygen consumption (VO_2, l/min) and CO_2 production (VCO_2, l/min). Heart rate was simultaneously measured with a Polar S610 heart rate monitor (Polar-Electro, Woodbury, NY) in order to assess participant anxiety. Participants rested in a supine position for 20 min prior to measurement. BMR was then recorded for 15–20 min with the participants in a relaxed supine position. Measurements occurred in the morning or early afternoon. BMR was calculated by converting VO_2 to kilocalories per day based on the respiratory quotient ($RQ = VCO_2/VO_2$).

Lifestyle data

Lifestyle was assessed using an extensive questionnaire about socioeconomic status (including monthly income and occupation), subsistence participation, and ownership of consumer goods. For each item owned, participants were asked to rank whether the item was (0) not at all important, (1) somewhat important, or (2) very important for living a good life. Two composite variables ("Consumer Goods Ownership" and "Agricultural Goods Ownership") were calculated by summing the number of consumer and agricultural goods owned by each individual. Composite variables ("Importance of Consumer Goods" and "Importance of Agricultural Goods") were also created by summing importance ratings for consumer and agricultural goods, respectively. These variables were then compared by subtracting ownership variables from importance variables to assess the imbalance between ownership and importance for living a good life. The measure of lifestyle incongruity used here is a modified version of an approach used by other researchers (Bindon et al., 1997; Dressler, 1991, 2004; Sorensen et al., 2009).

Subsistence participation was assessed based on the amount of time (in number of days per year) individuals spent in subsistence activities like growing food, foraging, hunting, fishing, horticulture, and tending domesticated animals. Individuals were asked to estimate the quantity of food (as a percent) that they regularly purchased from a store. A style of life (SOL) scale was created based on that of Bindon et al. (1997) that considered participation in subsistence activities, diet, and ownership of common consumer goods and livestock. Total SOL scores were calculated by summing all of the item scores. Correlation of each item to SOL scores was determined and items not strongly correlated (i.e., <0.15) were not included in the final SOL scale. The final SOL scale, which includes 15 items, is presented in Table 1. Low SOL scores were indicative of more traditional ways of life that included participation in more subsistence activities, less market food consumption, and reduced ownership of consumer goods.

Statistical analyses

Statistical analyses were conducted using SPSS 16.0. Student's *t*-tests (two-tailed) were used to examine sex differences in anthropometric and lifestyle measures. TPOAb values were $\log_{10}$-transformed. *t*-Tests were used to compare variables between TPOAb groups, and Pearson's correlations were used to examine relationships between variables. Comparisons were considered statistically significant at $P < 0.05$.

RESULTS

Table 2 presents descriptive statistics for anthropometric, thyroid, and lifestyle data for 143 women and 138 men. Women had significantly higher TSH ($P < 0.01$), TPOAb ($P < 0.001$), and SOL scores ($P < 0.001$), as well as significantly lower BMRs ($P < 0.001$) than men. Clinically elevated levels of TPOAb (>30 IU/ml; Pederson et al., 2003) were present at a greater frequency among Yakut women compared with Yakut men, with women making up 80% (32 of 40) of individuals with clinically elevated TPOAb. Age had no significant relationship with TPOAb in men or women.

To assess the differences in thyroid and metabolic function in individuals with elevated TPOAb, participants were divided into two groups based on their TPOAb level (normal and clinically elevated). Mean TSH, free T_3, free T_4, and BMR were then compared in relation to TPOAb. With sexes combined, TPOAb was significantly related to higher T_4 ($P < 0.05$). Analyzed separately, women with elevated TPOAb showed a trend for higher levels of TSH ($P = 0.08$). TPOAb was also positively correlated with TSH ($P < 0.01$), T_3 ($P < 0.05$), and T_4 ($P < 0.05$) among Yakut women (Table 3). Among men, for which we had a much smaller sample size of individuals with clinically

elevated TPOAb ($n = 8$), none of the comparisons with thyroid or metabolic variables rose to the level of statistical significance. There was, however, a positive trend in a correlation between TPOAb and T_4 in Yakut men ($P = 0.06$; Table 4). There were no significant differences in BMR associated with TPOAb status for the 194 women and men for whom BMR was measured.

Few anthropometric dimensions and health measures varied significantly with TPOAb status. There were no relationships between body size and TPOAb. However, men with elevated TPOAb had higher total cholesterol ($P < 0.05$) and showed a positive trend in relation to high-density lipoprotein ($P = 0.08$). There were no significant relationships with anthropometric and health measures among Yakut women.

Several sociodemographic and lifestyle measures were significantly related to TPOAb. Men with elevated TPOAb had bigger households ($P < 0.01$) than those with normal TPOAb levels, whereas women with elevated TPOAb had smaller households ($P < 0.05$) and found fewer agricultural goods important ($P < 0.01$). There were no relationships between SOL score and TPOAb for either sex. Our measure of SES was positively associated with TPOAb in both sexes, with monthly household income having a significant positive relationship in men ($P < 0.01$; Table 4) and showing a positive trend in women ($P = 0.06$; Table 3). Lifestyle incongruity was not significantly correlated with TPOAb in either sex.

TABLE 1. Style of life (SOL) scale for combined sample of males and females; see text for details

	Score	Value label	%	Correlation[a]
Bicycle ownership	0	No	56.7	0.259
	1	Yes	43.3	
TV ownership	0	No (≤2 TVs)	47.9	0.255
	1	Yes (>2 TVs)	52.1	
Stereo ownership	0	No	55.6	0.326
	1	Yes	44.4	
VCR ownership	0	No	33.0	0.324
	1	Yes	67.0	
Video camera ownership	0	No	73.9	0.171
	1	Yes	26.1	
Camera ownership	0	No	34.9	0.260
	1	Yes	65.1	
Computer ownership	0	No	23.6	0.287
	1	Yes	76.4	
Telephone ownership	0	No	59.0	0.348
	1	Yes	41.0	
Tractor ownership	0	Yes	10.9	0.366
	1	No	89.1	
Domestic animal ownership	0	Yes (≥5 animals owned)	27.0	0.505
	1	Yes (1–4 animals owned)	22.5	
	2	No	50.5	
Domestic animal tending	0	Yes	32.3	0.464
	1	No	67.7	
Subsistence hunting	0	Yes (>10 days per year)	19.8	0.434
	1	Yes (1–10 days per year)	14.3	
	2	No	65.9	
Subsistence fishing	0	Yes (>5 days per year)	22.4	0.424
	1	Yes (1–5 days per year)	12.1	
	2	No	65.5	
Subsistence cutting hay	0	Yes (>15 days per year)	23.5	0.600
	1	Yes (1–15 days per year)	20.7	
	2	No	55.8	
Market food purchased	0	<51%	19.1	0.483
	1	51–75%	21.9	
	2	>75%	59.0	

[a]Correlation between item and total score (<0.15 not included).

DISCUSSION

The present study documented sex differences in TPOAb prevalence and the development of AITDs, as well as associations between anthropometric, health and lifestyle factors, and TPOAb. Across populations, women are much more susceptible to most autoimmune disorders (including AITDs), and for AITDs specifically women make up over 80% of the clinical patient base in the United States (Whitacre, 2001). Both TPOAb and TgAb

TABLE 2. Descriptive statistics for 281 individuals for whom all necessary data was available

	Women ($n = 143$)	Men ($n = 138$)
Age (years)	44.3 (13.4)	47.8 (16.4)
TPOAb (U/ml)	92.83 (210.46)[a]	33.60 (117.53)
T_3 (pg/dl)	303.41 (80.45)	303.12 (79.56)
T_4 (ng/dl)	1.22 (0.56)	1.28 (0.23)
TSH (mlU/l)	1.98 (3.98)[b]	1.31 (0.77)
Height (cm)	155.7 (6.2)[c]	168.4 (7.4)
Weight (kg)	62.8 (12.0)[c]	71.8 (13.3)
Body fat (%)	32.5 (8.0)[c]	23.0 (7.5)
BMI (kg/m^2)	25.9 (4.7)	25.3 (4.5)
Total cholesterol (mg/dl)	185.1 (29.6)	177.9 (33.0)
BMR (kcal/day)[d]	1313.9 (203.0)[c]	1624.9 (322.6)
Style of life (SOL) score	14.2 (2.7)[c]	11.2 (3.4)
Monthly family income (Rubles)	26,958 (14,135)	26,552 (15,925)

Values presented as mean (SD).
[a]Differences between females and males are statistically significant at $P < 0.05$.
[b]Differences between females and males are statistically significant at $P < 0.01$.
[c]Differences between females and males are statistically significant at $P < 0.001$.
[d]BMR was available for 96 women and 98 men.

TABLE 3. Correlation matrix for measures of thyroid function and lifestyle measures for Yakut women[a,b]

	TPOAb (log)	T_3 (pg/dl)	T_4 (ng/dl)	TSH (mlU/l)	AGI	IT	MFI (Rubles)	NIH	SOL
log TPOAb	–	0.170*	0.187*	0.222**	−0.292**	−0.280**	0.162	−0.174*	0.112
T_3		–	0.722***	−0.271**	0.107	0.130	0.024	0.162	0.035
T_4			–	−0.199*	0.064	0.086	0.038	0.151	0.083
TSH				–	−0.016	−0.161	0.021	−0.047	0.005
AGI					–	0.786***	−0.025	0.219*	−0.245*
IT						–	0.115	0.297**	0.109
MFI							–	0.099	0.188*
NIH								–	0.058
SOL									–

[a]Abbreviations: AGI, agricultural goods important; IT, importance total; MFI, monthly family income; NIH, number in household; SOL, style of life score.
[b]Correlations were statistically significant at: *$P < 0.05$; **$P < 0.01$; ***$P < 0.001$.

TABLE 4. Correlation matrix for measures of thyroid function and lifestyle measures for Yakut men[a,b]

	TPOAb (log)	T_3 (pg/dl)	T_4 (ng/dl)	TSH (mlU/l)	AGI	IT	MFI (Rubles)	NIH	SOL
log TPOAb	–	0.037	0.163	−0.030	0.091	0.075	0.236**	0.198*	0.000
T_3		–	−0.017	−0.027	0.015	0.057	0.030	0.031	−0.033
T_4			–	−0.156	0.142	0.138	0.108	0.120	0.019
TSH				–	−0.156	−0.138	−0.045	−0.231**	0.104
AGI					–	0.781***	0.084	0.080	−0.267**
IT						–	0.108	0.188*	−0.001
MFI							–	0.331*	0.053
NIH								–	0.114
SOL									–

[a]Abbreviations: AGI, agricultural goods important; IT, importance total; MFI, monthly family income; NIH, number in household; SOL, style of life score.
[b]Correlations were statistically significant at: *$P < 0.05$; **$P < 0.01$; *** $P < 0.001$.

are typically found in greater concentrations among women in multiple study populations (Al-Naqdy et al., 2003; Bryhni et al., 1996; Hollowell et al. 2002; Kabelitz et al., 2003). As expected, clinically elevated levels of TPOAb (>30 IU/ml; Pederson et al., 2003) were present at a greater frequency among Yakut women compared with Yakut men, non-indigenous circumpolar populations, and lower latitude groups (Table 5). Similar to the findings from Whitacre (2001) of sex differences in AITDs in the US, Yakut women made up the majority of cases of elevated TPOAb. Contrary to our expectations, however, Yakut men did not have higher rates of elevated TPOAb when compared with males from other populations for which data were available. These sex differences may be, in part, due to increased stresses placed on women during pregnancy (Davies, 2000) and parity may contribute to high rates of AITDs in Yakut women. However, Sgarbi et al. (2010) found no relationship between parity and AITDs in a study on Japanese and Brazilian populations. In the present study, household size, which may roughly represent parity, was negatively related to TPOAb for women. This effect of household size may reflect changing lifestyle conditions which affect disease risk through mechanisms such as diet.

TABLE 5. Cross-cultural comparison of the percent of individuals with elevated TPOAb in the Yakut and other populations

Population	Females	Males	Combined sexes
Yakut (this study)	22.0%	6.0%	14%
Denmark (Pedersen et al., 2003)[a]	21.3%	11.3%	18.8%
Western Australia (O'Leary et al., 2006)	15.3%	8.0%	10.7%
United States (Zelaya et al., 2010)[b]	8.8%	0%	7.7%
Norway (Bryhni et al., 1996)	8.5%	3.6%	6.1%
Sri Lankan School Girls 1998	9.0%	N/A	N/A
Sri Lankan School Girls 2001 (Mazziotti et al., 2003)[c]	15.2%	N/A	N/A

[a]Study was conducted specifically among populations with mild and moderate iodine deficiency.
[b]Study was conducted specifically among individuals with high normal range TSH. Studies were not included if they set normal TPOAb at any level other than 30 IU/ml or were conducted in clinical settings on non-healthy individuals.
[c]Study was conducted specifically among school aged girls undergoing iodine prophylaxis over a three-year period.

Another reason for the disparity in TPOAb levels between men and women in this study may be due to differences in market integration-measured here using dietary and lifestyle variables-with women consuming more sugars and processed foods and participating in fewer traditional subsistence activities and men consuming more traditional foods higher in protein and fats. Unfortunately, the lack of data in this study on other dietary variables, as well as data on physical activity and total number of pregnancies, precludes us from assessing the relationship between these variables and TPOAb. One particularly important dietary component missing from this study is iodine intake (Mazziotti et al., 2003; Pedersen et al., 2003; Völzke et al., 2003). A link between dietary factors, iodine nutrition, and AITDs is supported by a single published reference study conducted among two high-latitude Danish populations with mild and moderate iodine deficiency (Pedersen et al., 2003). Although Pedersen et al. (2003) found no significant difference in TPOAb levels between the moderate and mild iodine deficient populations in individuals younger than 60 years of age, elevated TPOAb was more common in the moderate group for individuals 60–65 years of age. Interestingly, this is the only reference study with TPOAb levels similar to those reported in the present study. Further, a study by Mazziotti et al. (2003) documented increased occurrence of hypothyroidism in the presence of thyroid autoimmunity in association with iodine prophylaxis among indigenous people in Sri Lanka. Unfortunately, there are few studies that assess the prevalence of AITDs at the population level, making it difficult to compare groups and to identify the factors that contribute to higher levels of AITDs.

Our previous research among the Yakut and other native Siberian populations has documented metabolic elevation consistent with adaptation to chronic cold stress (Leonard et al., 2005; Snodgrass et al., 2005 , 2007). Although we have documented links between elevated BMR and increased hypertension risk (Snodgrass et al., 2008), little is known about the possible health consequences of metabolic adaptation on thyroid function among indigenous northern populations, including within the context of transitioning lifeways. The potential for negative health effects in these environments is suggested by studies of northern residents that document the increased prevalence of certain physical and mental conditions. For example, non-indigenous visitors and inhabitants of circumpolar regions have been shown to be at higher risk for Polar T_3 syndrome, resulting from increased production and clearance of T_3 for heat production (Lugg, 2000). There is suggestive evidence that the resulting lack of T_3 for normal brain and body function leads to impaired cog-

nitive function, mood disorders, and the decreased ability to perform simple tasks (Pääkkönen, 2010; Palinkas and Suedfeld, 2008). Physiological and behavioral adaptations may buffer indigenous populations from experiencing these negative side effects, but this issue has not been extensively studied.

Assessing the role of circumpolar adaptation in structuring AITD risk is difficult due to differing physiological responses to TPOAb. Functionally, TPOAb is associated with a progressive development of hypothyroidism, though overstimulation-induced hyperthyroidism can occur when TRAb is also present. This complicates analyses and makes it difficult to test evolutionary tradeoffs. We expected to find positive correlations between TPOAb, TSH, T_3, T_4, and BMR, but our results were mixed. The higher prevalence of TPOAb and positive correlations with TSH, T_3, and T_4 in Yakut women, and a positive trend with T_4 in men suggest a relationship between upregulated metabolism for cold adaptation and the likelihood of developing AITDs. Contrary to our expectations, however, BMR was not significantly correlated with TPOAb in either sex, which is surprising given that our previous research among indigenous Siberians documented increased thyroid function in association with elevated BMR (Leonard et al., 1999, 2005). Future studies are clearly needed to sort out the effects of TPOAb-induced hypo- and hyperthyroidism on BMR.

Several lines of evidence suggest that market integration may play an important role in the development of AITDs, although our support for this link was also mixed. Although the cross-sectional nature of this preliminary research makes it impossible to establish causality, we found that women who found less agricultural goods important were more likely to suffer from AITDs. Previous studies have used lifestyle incongruity and SOL measures to assess the negative health effects of psychosocial stress and market integration (Bindon et al., 1997; Dressler, 1991 , 2004; Sorensen et al., 2009). Lifestyle incongruity, which is meant to indirectly measure this psychosocial stress, was not significantly correlated with TPOAb in this study, though some individual measures of SOL, like household size, have interesting ramifications for TPOAb levels. Men with larger households and women with smaller households were significantly more likely to have elevated TPOAb levels. Although speculative, this may be due to chronic psychosocial stress in men due to the increased financial responsibility associated with larger households, whereas in women it may indicate less traditional lifeways, suggesting a relationship between level of market integration, especially between the sexes, and risk of AITDs.

A mechanism for linking increasing market integration with increased risk of AITDs is the hygiene hypothesis, which focuses on the relationship between pathogen exposure (especially parasitic worms) and the development of autoimmune diseases and allergies (Bach, 2002; Yazdanbakhsh et al., 2002). This perspective suggests that individuals who are exposed to fewer pathogens throughout their lives, especially during early postnatal life, are more likely to develop AITDs. Although the present study is not able to evaluate this directly, individuals who consume fewer traditional foods and participate in fewer subsistence activities (and have less contact with cattle and other domesticated animals) would likely be exposed to fewer pathogens and be more likely to develop AITDs. Our data present limited data to support this prediction, with women who relied on less agricultural goods and individuals of each sex with higher SES having higher levels of TPOAb.

There are several limitations to this study. First, the non-random selection of participants and the relatively small sample size limits generalization to other populations. In particular, the small number of men with clinically elevated TPOAb makes it impossible to determine the role of various metabolic and lifestyle factors in shaping risk for the development of AITDs. Second, limited dietary data, especially related to iodine excretion, make it difficult to sort out the role that nutritional factors play in the development of AITDs. Despite these limitations, this study provides important information on the prevalence of elevated TPOAb in an indigenous Siberian population, especially as it relates to circumpolar adaptation and lifestyle change.

In summary, the present study documented much higher than predicted overall levels of TPOAb among Yakut women. It additionally documented several associations between TPOAb levels and anthropometric, metabolic, and lifestyle variables. It is possible that AITDs may be more common among indigenous circumpolar populations due to the interplay between adaptations to cold stress through elevated thyroid activity, but this study suggests that shifts in AITD prevalence may also reflect changes in lifestyle and diet that are occurring with increasing market integration. Although preliminary, this is the first study to examine AITDs among indigenous northern populations within the context of market integration.

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