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Seasonal Variation in Fasting Plasma Glucose Levels in Man

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Summary. A Southern California community study of 4,541 men and women (aged 20–79 years) showed significant seasonal variation in fasting plasma glucose. There was a mean 0.6 mmol/l difference between highest levels in winter and lowest levels in spring. This difference was consistent over a two-year period, similar at all ages and seen in both men and women. Fasting plasma glucose levels correlated directly with percentage possible sunshine ($p = 0.03$) and inversely with temperature ($p = 0.04$). Adjustment for the level of measured obesity did not alter the observed association, but a history of recent weight gain corresponded to the season of maximum fasting plasma glucose level.

Key words: Community study, fasting plasma glucose, obesity, seasonal variation.

With the recent emphasis on fasting plasma glucose (FPG) levels as one criterion for the diagnosis of diabetes mellitus [1], it is important to identify non-disease variables that alter FPG. Although studies in animals have shown lower insulin resistance and altered glucose metabolism during the summer months [2–7], there have been only two small studies of seasonal variation of FPG in man, both in men living in extreme climates. In Sweden a cross-sectional study of 100 male survivors of myocardial infarction showed significant seasonal variation in FPG, with the lowest levels in the warmer, lighter months of spring and summer [8]. These differences paralleled changes in log sum insulin concentrations and were said to be unexplained by body weight or age. In a prospective study, 12 young men were examined in March, June, September and December while working 900 miles from the South Pole [9]. In this environment the temperature ranges from −40 °C in winter to an average of 0 °C in summer, and there are periods of continuous daylight (summer) or continuous dark (winter). Blood glucose levels again were lowest in summer (December). No significant seasonal variation in diet or energy expenditure was noted.

Data from a large cross-sectional population-based study in Southern California have been analyzed to determine whether significant seasonal variation in FPG also occurs in a moderate climate.

Methods

From 1972 to 1974, 82% of all adult residents of a geographically defined upper middle class white community in San Diego County participated in a survey for heart disease risk factors. All subjects were asked about a history of diabetes; women were asked about current pregnancy and the use of oral contraceptives or replacement oestrogens. Venipuncture was performed on fasting subjects between 0700 and 1100 h. Blood glucose was determined by the hexokinase method. Height and weight were measured in light clothing without shoes. Obesity was calculated as body mass index (weight/height^2). A 15% random sample of the subjects was examined more extensively, including a standardized interview with questions designed to assess exercise and weight change during the preceding 2 weeks and a 24-h diet recall obtained by a certified dietitian utilizing food models to ascertain portion size. Analysis of variance methods were used to assess seasonal differences in fasting plasma glucose and other variables.

Results

Data are reported for all subjects aged 20–79 years, after exclusion of persons who had a history of diabetes, who had not fasted at least 12 h before venipuncture, or who were pregnant (Table 1). A significant seasonal variation in FPG was observed with a mean 0.6 mmol/l difference between the highest lev-

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els in the winter (December-February) and the lowest levels in the spring (March-May) (Fig. 1). This seasonal pattern was consistent across the 2-year period of investigation (Fig. 2) and across three age strata (20–39; 40–59; 60–79 years) (Table 2). Thus, although subjects studied in winter months tended to be older than those studied at other times, and although FPG increases modestly with age (0.11 mmol/l per decade), the seasonal variation was not a function of the age distribution of sampling. Also, although women had lower FPG levels than men at each season, the degree of seasonal variation was similar for men and women and was independent of current use or nonuse of exogenous oestrogens (either oral contraceptives or replacement oestrogens) in women (Table 2).

Table 1. Age-sex distribution of subjects studied by season of visit

	Men		Women	
	No.	Mean age (years)	No.	Mean age (years)
December-February	519	58.1	608	57.4
March-May	536	55.4	637	54.7
June-August	321	56.5	422	55.3
September-November	664	59.4	834	57.6
Total	2040	57.6	2501	56.4

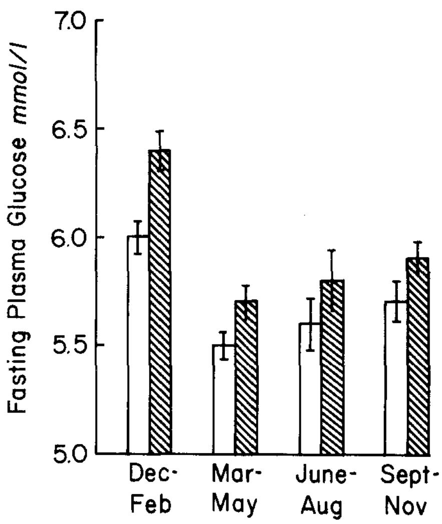

Fig. 1. Seasonal distribution of mean fasting plasma glucose levels among 2040 men ▧ and 2501 women □. Bars indicate 95% confidence interval

The seasonal variation in FPG was examined for an association with climatological phenomena and seasonal patterns of obesity, diet and exercise. As shown in Figure 2, based on local climatological data for the same years from the US Department of Commerce, FPG levels correlated directly and significantly with percentage possible sunshine ($p = 0.03$) and inversely with temperature ($p = 0.04$). In this population, the obesity index varied by season, with the highest levels in winter ($p = 0.02$ in men; $p = 0.12$ in women) corresponding to the highest FPG levels. However, seasonal variation in FPG remained essentially unchanged after adjustment for obesity (Table 3). To determine whether weight change follows the seasonal pattern of FPG, the data were analyzed from the 15% random sample who answered the question about net weight change within the past 2 weeks. The seasonal distribution presented in Table 4 shows that weight gain was reported only for winter months (December-February) by both men and women, although the reported gain was not statistically significant. No seasonal differences in total calories, protein, fat, carbohydrate, or alcohol consumption were found in this sample. Similarly, there was no significant seasonal variation in reported vigorous exercise.

Table 2. Seasonal variation in fasting plasma glucose (FPG) levels among men and women by age and hormone use

Age (years)	December-February		March-May		June-August		September-November	
	FPG (mmol/l)	No.	FPG (mmol/l)	No.	FPG (mmol/l)	No.	FPG (mmol/l)	No.
Men								
20–39	6.09 ± 0.08	83	5.50 ± 0.06	118	5.65 ± 0.10	58	5.74 ± 0.08	90
40–59	6.59 ± 0.11	135	5.97 ± 0.12	149	5.80 ± 0.12	94	5.97 ± 0.07	164
60–79	6.36 ± 0.06	301	5.72 ± 0.05	269	5.93 ± 0.12	169	5.97 ± 0.04	410
Women not on hormones								
20–39	5.79 ± 0.11	68	5.33 ± 0.07	110	5.30 ± 0.12	56	5.52 ± 0.07	93
40–59	6.09 ± 0.09	100	5.40 ± 0.08	105	5.84 ± 0.21	71	5.79 ± 0.08	115
60–79	6.07 ± 0.06	237	5.60 ± 0.05	201	5.81 ± 0.11	141	5.80 ± 0.07	297
Women on hormones								
20–39	5.66 ± 0.14	25	5.08 ± 0.14	28	5.18 ± 0.22	26	5.27 ± 0.10	31
40–59	5.87 ± 0.10	77	5.43 ± 0.08	86	5.43 ± 0.14	62	5.56 ± 0.06	128
60–79	6.17 ± 0.10	101	5.45 ± 0.06	107	5.50 ± 0.13	66	5.86 ± 0.17	170

Results expressed as mean ± SEM

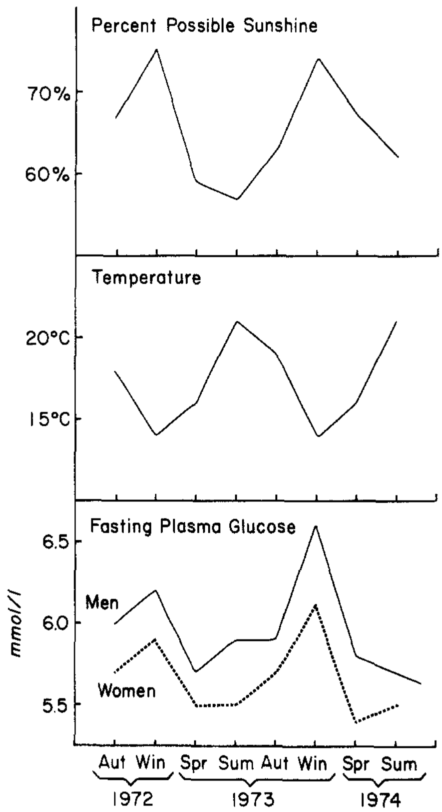

Fig. 2. Seasonal variation in percentage possible sunshine, air temperature and fasting plasma glucose levels occurring over a 2-year period (1972–1974). Aut = autumn; Win = winter; Spr = spring; Sum = summer

Table 3. Seasonal variation in fasting plasma glucose (FPG) levels adjusted for age and obesity index

	Men		Women	
	FPG (mmol/l)	No.	FPG (mmol/l)	No.
December-February	6.37 ± 0.05	519	6.01 ± 0.04	608
March-May	5.74 ± 0.04	535	5.46 ± 0.04	637
June-July	5.86 ± 0.06	321	5.62 ± 0.05	422
August-November	5.94 ± 0.04	664	5.71 ± 0.04	834
	$p < 0.0001$		$p < 0.0001$	

Results expressed as mean ± SEM

Table 4. Average weight change by season

	Men		Women	
	Weight change (kg)	No.	Weight change (kg)	No.
December-February	0.045 ± 0.036	52	0.018 ± 0.073	81
March-May	−0.150 ± 0.095	116	−0.091 ± 0.086	124
June-August	−0.082 ± 0.132	61	−0.068 ± 0.109	86
September-November	−0.159 ± 0.100	75	−0.005 ± 0.059	91

Results expressed as mean ± SEM

Discussion

These data show a significant 0.6 mmol/l seasonal variation in FPG consistent across a broad age range and for both sexes. The temperate climate of San Diego has the smallest seasonal variation in temperature (range of 13 °C in winter to 23 °C in summer for the years of study) of any major city in North America. Nevertheless the amount of seasonal variation in FPG observed in San Diego was similar to that reported from arctic and subarctic climates.

Ecological correlations do not, of course, imply causality. The seasonal variation in FPG could also reflect seasonal patterns in obesity, diet and/or exercise, individual determinants of FPG [10–15]. Others have shown that caloric intake increases with increasing cold [16–18], but no seasonal differences in total calories or specific nutrients were found in this sample, given the recognized limitations of 24-h diet recall methodology. In this climate where outdoor exercise is feasible throughout the year, there was also no significant seasonal variation in reported exercise.

The obesity index varied by season, with the highest levels in winter corresponding to the highest FPG levels. However, seasonal variation in FPG remained essentially unchanged after adjustment for obesity. Weight reduction has been shown to reduce FPG [11] and to be seasonal; under stable restriction of calories weight reduction is most difficult in winter months and most successful in the spring [19]. Correspondingly, in this population weight gain was reported only for winter months. If a seasonal pattern of weight change rather than current obesity is a determining factor of seasonal FPG variation, the weight change could alter FPG levels via hormonal or receptor mechanisms. The two major hormones known to affect glucose homeostasis, insulin which lowers FPG and glucagon which raises it, have been shown by others to have seasonal variation [20–21].

Seasonal variation in FPG across animal species suggests an evolutionary ecological mechanism. These data also suggest that caution and appropriate controls are necessary whenever drug, diet, or other behavioural changes are implicated in changing FPG levels.

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