BODY MASS INDEX IS ASSOCIATED WITH DIFFERENTIAL SEASONAL CHANGE IN AMBULATORY BLOOD PRESSURE LEVELS

E. Kristal-Boneh, G. Harari, J. Ribak

Occupational Health & Rehabilitation Institute, Raanana, Israel.

INTRODUCTION

Daytime blood pressure increases from summer to winter was found to be independently inversely associated with environmental temperature (1). Thermoregulatory responses are related to the surface area/body mass quotient (2-4), with the thermoneutral zone of smaller individuals occurring at higher mean body temperatures than that of larger individuals (3). Therefore we hypothesized that the increase in blood pressure (BP) from summer to winter may be inversely associated with body mass index (BMI) because of the increased thermoregulatory requirements of leaner individuals.

METHODS

The study population comprised 101 healthy normotensive men aged 28-63 years, working in the machining departments. The study was carried out on-site, on regular working days, in two identical stages (summer and winter). Participants were examined prior to the beginning of the work day, in a temperature controlled room. Three BP measurements were taken using a mercury manometer while the subject was seated. Height and weight were measured, without shoes, and with the subject wearing only light industrial cloth. 24 hour ambulatory BP was monitored by the Accutraker II, Stech, USA, Medical Instruments, Raleigh, NC, programmed to measure BP every 15 minutes during the day and every half-hour during the night. Body weight was measured using the Seca electronic scale. Quetelet's index [weight (kg)/height $(m)^2$] was used as a measure of BMI. Questionnaires were used to gather demographic data and data about health habits.

RESULTS

Mean summer outdoor temperatures and indoor temperatures were 28.4±1.1 and 27.3±2.7°C, vs. 13.1±3.4 and 18.3±4.2°C, in winter ($p < 0.0001$). Body temperatures were on the average higher in summer than winter by 0.14°C ($p < 0.0001$). To explore the relationship between BMI and BP level, the population was divided according to quartiles of BMI (quartiles limits were: ≤ 24, 24-25.5, 25.6-27.5, and >27.5). Table 1 shows means of the differences between winter and summer ambulatory BP levels. For the two seasons, men with higher BMI had higher values

Table 1. Adjusted[1] means winter-summer differences of ambulatory blood pressure levels by quartiles of BMI.

BMI	≤24	24-25.5	25.5-27.5	> 27.5	stand.β	p
Δ Casual SBP	2.0	3.3	2.8	3.6	0.07	0.5989
Δ 24-h SBP	5.1[a]	2.2[a,b]	-1.2[b,c]	-1.8[c]	-0.26	0.0149
Δ Daytime SBP	6.2[a]	3.4[a,b]	-0.3 [b,c]	-0.4 [c]	-0.26	0.0178
Δ Nighttime SBP	1.4[a]	-2.4 [a,b]	-6.3 [b,c]	-6.4 [c]	-0.24	0.0573
Δ Casual DBP	2.3	1.9	2.5	4.9	0.11	0.3225
Δ 24-h DBP	2.3	3.4	2.3	3.2	0.04	0.6868
Δ Daytime DBP	2.9	3.7	2.6	3.4	0.00	0.9384
Δ Nighttime DBP	-0.5	0.8	-0.1	1.9	0.12	0.3125

Figures are means. [1] Adjusted for age, cigarette smoking, alcohol and coffee consumption, sports activities and air-conditioning status of the industrial plant. Δ are given in mmHg. Figures having the same letter are not statistically significantly different.

for all the measures of BP; these trends remained after adjustment for age, cigarette smoking, alcohol and coffee consumption, sports activities and air-conditioning status of the work place. In general, all the measures of BP were higher in winter than in summer, although these differences were more pronounced among leaner subjects. The percentage of subjects with increases in 24-h SBP of more than 10 mmHg from summer to winter in each category of BMI are shown in Figure 1. More subjects with lower BMI had increases in SBP exceeding 10 mmHg from summer to winter than those with higher BMI. We attempted to explore the possible implications of the combined effects of season and BMI on subjects with elevated levels of BP by selecting the third of the population with highest mean casual BP values (more than 132 mmHg SBP) and sub-dividing them into categories by the median BMI (divisions by quartiles of BMI led to too few subjects in each category). Hourly SBP means by season and BMI category of this subpopulation are given in Figure 2. Daytime SBP were higher in winter than summer in the two groups, however, the increase was higher among subjects with lower BMI.

DISCUSSION

Consistent with studies based on casual measures of BP, our results indicate that for healthy subjects there is an independent positive association between all the measures of ambulatory blood pressure and BMI. Both casual and ambulatory BP measures were higher in winter than in summer. The principal novel conclusion from this study is that seasonal variations in ambulatory BP values are inversely associated with BMI. In previous studies we analyzed the role of indoor and outdoor temperatures in seasonal BP changes (1). Indoor temperature was inversely and independently associated with BP levels. This may be explained in terms of thermoregulation; it is well recognized that during exposure to cold, the cutaneous

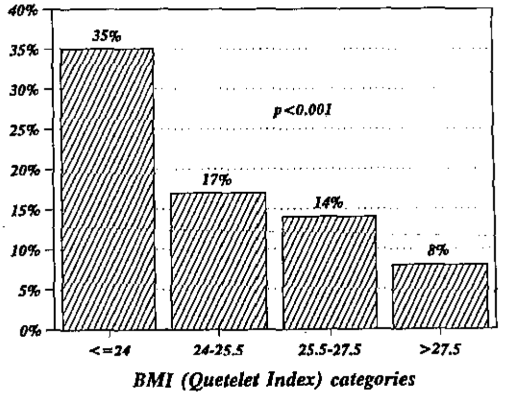

Figure 1. Percentage of subjects who had seasonal 24-h SBP differences over 10 mmHg, by BMI categories.

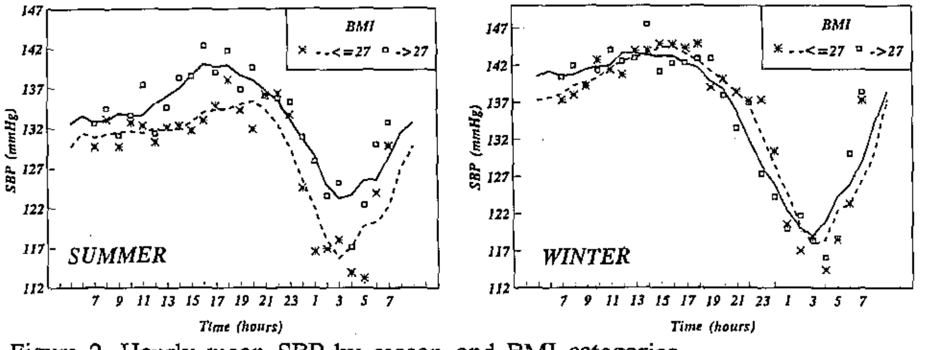

Figure 2. Hourly mean SBP by season and BMI categories.

vasculature contracts, increasing the peripheral resistance, which, in turn, augments central blood volume and raises BP. Conversely, in heat exposure, a considerable amount of cardiac output is channeled to peripheral circulation to ensure heat dissipation from the body, resulting in reduced central blood volume and lower BP. Following the same line of reasoning, we hypothesized that if thermoregulation is partially responsible for seasonal changes in BP, then leanness may be associated with increased seasonal changes in BP because of the relatively higher surface for heat exchange with the surroundings in lean subjects compared to larger subjects. This may imply that in winter lean people dissipate body heat at a higher rate than fatter people and the strain imposed by a given environmental temperature is higher. Thus, their needs for thermoregulation may be higher. In other words, the redistribution of blood occurring as a consequence of cold exposure (blood mobilization centrally from peripheral vasculature) may be more pronounced. The findings on ambulatory BP support this hypothesis. It can be seen in Figure 1 that the percentage of subjects with seasonal SBP changes up to 10 mmHg is highest (and considerable) in the lowest BMI category. The inverse association between the magnitude of seasonal BP change and BMI is clearly overlooked in a mere inspection of casual values. Differential seasonal changes affects SBP, and not DBP. This may be due to differences in regulatory mechanisms, and it is possible that our study underestimated the effects of BMI on DBP because the BMI range excluded extremely fat or lean individuals (for more details see reference 5). We attempted to clarify the possible implications of our findings for a sub-population of subjects with higher blood pressure levels. Using a BMI of 27 as a cutoff value, it was found that in the winter the differences between subjects in the two BMI categories almost disappear (Fig. 2). While subjects with high BMI had elevated BP values in both seasons, lean persons, who could be considered normotensives in summer, had much higher BP values in winter. Clearly, the diagnosis of hypertension in lean subjects may be affected by season. This finding is of interest since there have been several reports of increased mortality rates among lean hypertensives.

CONCLUSIONS

We reported seasonal changes in ambulatory systolic blood pressure which were especially considerable among lean subjects. Epidemiological blood pressure studies should take into account the relationship between season, BMI and blood pressure. It may also be important to assess hypertension and response to anti-hypertensive treatment in relation to season, particularly in lean hypertensives.

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