**Inverse associations between obesity indicators and thymic T-cell production levels in aging atomic-bomb survivors**

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**Detailed methods of generalized estimating equation (GEE) analysis**

Bivariate responses, the natural logs of CD4 TREC and CD8 TREC, are assumed to be normally distributed with heteroscedastic variances. The scaling for these two response variables was performed by division by the square roots of the residual sum of squares from two multiple regressions. To obtain those values, two multiple linear regressions for the normal responses Yj, natural logs of CD4 TREC for j=1 and of CD8 TREC for j=2, were made,

1. Yj = 1 + gender + age + dose + smoking + alcohol + errj,

where 1 stands for intercept, and errj (j=1, 2) are normally distributed with zero means and different variances. The square roots of the residual sum of squares for these two responses are denoted as Hj (j=1, 2) with H1 = 1.3787 (N = 1,002) and H2 = 1.9191 (N = 952). We transformed Yj to Zj = Yj/Hj and also transformed the variables Xk in the regression of Zj to Wjk = Xk/Hj for j=1, 2, where Xk is gender for k=1, age for k=2, dose for k=3, smoking for k=4 and alcohol for k=5.

We used the generalized estimating equation (GEE) for bivariate responses with equal scales, GEE1. Due to the heteroscedasticity of the responses, we could not apply the bivariate GEE1 to Yj (j=1, 2): We instead applied bivariate GEE1 to Zj for j=1, 2, where bivariate normal responses, Zj (j=1, 2), have a similar variance approximately equal to one, and have a correlation. The GEE1 model for Zj (j=1, 2) is,

(2) Zj = 1 + Wj1 + Wj2 + Wj3 + Wj4 + Wj5 + D(j) + I(j=2)\*Wj1

+ I(j=2)\* Wj2 + I(j=2)\*Wj3 + I(j=2)\*Wj4 + I(j=2)\*Wj5 + ERRj,

where I(j=2) is indicator variable, i.e., I(j=2)=0 if j=1 and I(j=2)=1 if j=2; D(j)=(j-1)/SDj stands for the difference between the intercepts of two responses of Z1 and Z2, I(j=2)\*Wjk is the interaction term between indicator variable I(j=2) and variable Wjk, and ERRj for j=1, 2 represent the correlated bivariate normal errors with a 2 by 2 covariance matrix, each diagonal element being approximately equal to one. The estimated correlation using GEE1 was 0.438.

The parameter estimates from GEE1 for Zj (j=1, 2) and from GEE1 for Yj (j=1, 2) are both consistent with the true parameters. In our setting, the application of the former GEE1 for Zj (j=1, 2) is correct for homoscedastic working variances, and the application of the latter GEE1 for Yj (j=1, 2) is incorrect for homoscedastic working variances. Due to the correct specification of working variances, the GEE1 for Zj (j=1, 2) gives more efficient estimates with smaller standard errors than the GEE1 for Yj (j=1, 2). In addition, the GEE1 estimates with Zj (j=1, 2) are highly efficient (Liang, K. Y and Zeger, S. L. Longitudinal data analysis using generalized linear models. *Biometrika* 1986;73: 13-22). The Wald tests for the significance of the parameters were made using robust standard errors derived from GEE1 for the bivariate responses Zj (j=1, 2).

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| Table S1. Correlation between TRECs and naive T cell percentages in lymphocytes | | | |
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|  |  | CD4 naive T-cells |  |
| CD4 TREC | correlation coefficienta | 0.26 |  |
|  | p-value | < 0.00001 |  |
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|  |  | CD8 naive T-cells |  |
| CD8 TREC | correlation coefficienta | 0.38 |  |
|  | p-value | < 0.00001 |  |
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| aAdjusted for age, gender, radiation dose, alcohol consumption, and smoking. | | |  |

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| Table S2. Regression analyses of TRECs using HbA1c | | |
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| Regression of CD4 TRECsa | coefficient | p-value |
| BMI | 0.016 | 0.33 |
| Past BMI | -0.043 | 0.035 |
| Total cholesterol | -0.117 | 0.36 |
| HbA1c | -0.077 | 0.16 |
| CRP | -0.205 | 0.062 |
| Fatty liver | -0.188 | 0.086 |
| Hypertension | -0.026 | 0.80 |
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| Regression of CD4 TRECsa, b | coefficient | p-value |
| Past BMI | -0.033 | 0.054 |
| HbA1c | -0.087 | 0.10 |
| CRP | -0.205 | 0.056 |
| Fatty liver | -0.149 | 0.15 |

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| Regression of CD8 TRECsa | coefficient | p-value |
| BMI | 0.006 | 0.80 |
| Past BMI | -0.019 | 0.50 |
| Total cholesterol | 0.180 | 0.33 |
| HbA1c | -0.085 | 0.27 |
| CRP | -0.203 | 0.19 |
| Fatty liver | -0.411 | 0.009 |
| Hypertension | -0.150 | 0.29 |
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| Regression of CD8 TRECsa, b | coefficient | p-value |
| CRP | -0.260 | 0.084 |
| Fatty liver | -0.388 | 0.006 |

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| aAge, gender, radiation dose, alcohol consumption, smoking, and cancer were also adjusted. |
| bA forward stepwise procedure was used for 7 obesity-related variables: BMI, past BMI, total cholesterol, HbA1c, CRP, fatty liver, and hypertension. Four variables (past BMI, HbA1c, CRP, and fatty liver) were consequently selected (significant level to select, p < 0.2) to construct statistical models. |

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| Table S3. Regression analyses of absolute TREC numbers using an obesity indicator | | |
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| Regression of CD4 TRECsa | coefficient | p-value |
| BMI | 0.004 | 0.79 |
| Past BMI | -0.038 | 0.040 |
| Total cholesterol | 0.058 | 0.67 |
| HbA1c | -0.114 | 0.043 |
| CRP | -0.251 | 0.029 |
| Diabetes | -0.355 | 0.003 |
| Fatty liver | -0.182 | 0.091 |
| Hypertension | 0.003 | 0.97 |

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| Regression of CD8 TRECsa | coefficient | p-value |
| BMI | -0.017 | 0.39 |
| Past BMI | -0.038 | 0.14 |
| Total cholesterol | 0.324 | 0.089 |
| HbA1c | -0.103 | 0.18 |
| CRP | -0.265 | 0.094 |
| Diabetes | -0.356 | 0.031 |
| Fatty liver | -0.401 | 0.007 |
| Hypertension | -0.221 | 0.124 |

aAge, gender, radiation dose, alcohol consumption, smoking, and cancer were also adjusted in each regression analysis.