

Table 3 Results of single and multiple regression analyses on the association of background factors with differences in retinal arteriolar diameters before and after sodium restriction

	Single regression analysis			Multiple regression analysis model 1			Multiple regression analysis model 2			Multiple regression analysis model 3		
	B	P value (95% CI)		B	P value (95% CI)		B	P value (95% CI)		B	P value (95% CI)	
Group	0.817	0.343 (-0.878, 2.513)		-16.445	0.008** (-28.549, -4.341)		-16.418	0.008** (-28.544, -4.293)		-21.865	0.012* (-38.881, -4.850)	
Sodium restriction group	-0.496	0.684 (-2.894, 1.901)		-0.104	ns (-2.374, 2.165)		-0.195	ns (-2.491, 2.100)		-0.285	ns (-2.590, 2.020)	
Control group	0			0			0			0		
Age	-4.640	0.426 (-16.109, 6.830)										
Age	0.068	0.369 (-0.081, 0.217)		0.140	ns (-0.008, 0.287)		0.135	ns (-0.013, 0.284)		0.146	ns (-0.004, 0.296)	
Gender	-1.606	0.045* (-3.175, -0.037)										
Male	4.729	<0.001*** (2.416, 7.043)		1.906	ns (-0.593, 4.405)		2.053	ns (-0.501, 4.608)		2.517	ns (-0.409, 4.723)	
Female	0			0			0			0		
Diabetes	-0.484	0.517 (-1.957, 0.988)										
+	2.968	0.019* (0.496, 5.439)		5.538	0.001*** (1.613, 6.472)		5.657	0.001*** (2.497, 8.817)		5.867	<0.001*** (2.672, 9.062)	
-	0			0			0			0		
Hyperlipidemia	-0.984	0.272 (-2.748, 0.779)										
+	2.825	0.020* (0.446, 5.203)		4.042	0.001*** (2.410, 8.665)		4.053	0.001*** (1.619, 6.487)		4.007	0.001*** (1.570, 6.445)	
-	0			0			0			0		
Current alcohol intake	-0.624	0.369 (-1.991, 0.742)										
+	4.420	0.001* (1.791, 7.050)		5.419	<0.001*** (2.648, 8.191)		5.477	<0.001*** (2.694, 8.261)		5.580	<0.001*** (2.785, 8.374)	
-	0			0			0			0		
BMI	-8.078	0.018* (-14.781, -1.376)										
	0.361	0.010* (0.085, 0.636)		-0.005	ns (-0.313, 0.302)		0.009	ns (-0.303, 0.321)		-0.037	ns (-0.364, 0.291)	
	0.224	0.732 (-1.064, 1.511)										
Brinkman index	0.003	0.161 (-0.001, 0.008)										
	-3.807	0.556 (-16.523, 8.909)										
MABP (before surgery)	0.050	0.496 (-0.095, 0.195)										
										0.065	ns (-0.077, 0.207)	

Notes: Retinal arteriolar caliber (before - after surgery, one-week hospitalization). P < 0.05; **P < 0.01. Model 1, adjusted for age, gender, diabetes mellitus, hyperlipidemia, alcohol intake, and BMI. Model 2, adjusted for age, gender, diabetes mellitus, hyperlipidemia, Brinkman index, alcohol intake, and BMI. Model 3, a saturated model, adjusted for all factors.

Abbreviations: BMI, body mass index; CI, confidence interval; MABP, mean arterial blood pressure; ns, not significant.

Table 4 Results of single and multiple regression analyses on the association of background factors with differences in retinal venular diameters before and after sodium restriction

Group	Single regression analysis			Multiple regression analysis			Multiple regression analysis			Multiple regression analysis		
	model 1			model 2			model 3			model 3		
	B	P value (95% CI)	P value (95% CI)	B	P value (95% CI)	P value (95% CI)	B	P value (95% CI)	P value (95% CI)	B	P value (95% CI)	P value (95% CI)
Sodium restriction group	0.934	0.453 (-1.518, 3.386)	0.018 (-35.648, -3.351)	-22.666	0.006*** (-38.751, -6.58)	0.006*** (-38.751, -6.58)	-14.349	0.265 (-39.671, 10.973)	0.265 (-39.671, 10.973)	-14.349	0.265 (-39.671, 10.973)	0.265 (-39.671, 10.973)
Control group	1.903	0.280 (-1.564, 5.371)	ns (-3.573, 3.273)	0.538	ns (-2.874, 3.949)	ns (-2.874, 3.949)	0.460	ns (-2.970, 3.890)	ns (-2.970, 3.890)	0.460	ns (-2.970, 3.890)	ns (-2.970, 3.890)
	0	0	0	0	0	0	0	0	0	0	0	
Age	-24.755	0.003*** (-40.990, -8.520)	0.003*** (0.115, 0.537)	0.358	0.001*** (0.149, 0.567)	0.001*** (0.149, 0.567)	0.341	0.003*** (0.117, 0.564)	0.003*** (0.117, 0.564)	0.341	0.003*** (0.117, 0.564)	0.003*** (0.117, 0.564)
Gender	0.348	0.001*** (0.137, 0.560)	0.003*** (0.115, 0.537)	0.358	0.001*** (0.149, 0.567)	0.001*** (0.149, 0.567)	0.341	0.003*** (0.117, 0.564)	0.003*** (0.117, 0.564)	0.341	0.003*** (0.117, 0.564)	0.003*** (0.117, 0.564)
Male	2.036	0.091 (-0.330, 4.402)	ns (-3.700, 2.987)	-1.897	ns (-5.388, 1.594)	ns (-5.388, 1.594)	-0.544	ns (-4.362, 3.274)	ns (-4.362, 3.274)	-0.544	ns (-4.362, 3.274)	ns (-4.362, 3.274)
Female	-0.326	0.854 (-3.815, 3.163)	ns (-3.700, 2.987)	-1.897	ns (-5.388, 1.594)	ns (-5.388, 1.594)	-0.544	ns (-4.362, 3.274)	ns (-4.362, 3.274)	-0.544	ns (-4.362, 3.274)	ns (-4.362, 3.274)
	0	0	0	0	0	0	0	0	0	0	0	
Diabetes	1.835	0.096 (-0.330, 4.000)	0.001*** (0.115, 0.537)	0.358	0.001*** (0.149, 0.567)	0.001*** (0.149, 0.567)	0.341	0.003*** (0.117, 0.564)	0.003*** (0.117, 0.564)	0.341	0.003*** (0.117, 0.564)	0.003*** (0.117, 0.564)
+	0.144	0.938 (-3.490, 3.778)	0.001*** (0.115, 0.537)	0.358	0.001*** (0.149, 0.567)	0.001*** (0.149, 0.567)	0.341	0.003*** (0.117, 0.564)	0.003*** (0.117, 0.564)	0.341	0.003*** (0.117, 0.564)	0.003*** (0.117, 0.564)
-	0	0	0	0	0	0	0	0	0	0	0	
Hyperlipidemia	5.387	<0.001*** (2.880, 7.893)	0.001*** (0.115, 0.537)	-5.742	0.001*** (-9.092, -2.392)	0.001*** (-9.092, -2.392)	-6.575	<0.001*** (-10.203, -2.948)	<0.001*** (-10.203, -2.948)	-6.575	<0.001*** (-10.203, -2.948)	<0.001*** (-10.203, -2.948)
:	-6.365	<0.001*** (-9.744, -2.985)	0.001*** (0.115, 0.537)	-5.742	0.001*** (-9.092, -2.392)	0.001*** (-9.092, -2.392)	-6.575	<0.001*** (-10.203, -2.948)	<0.001*** (-10.203, -2.948)	-6.575	<0.001*** (-10.203, -2.948)	<0.001*** (-10.203, -2.948)
-	0	0	0	0	0	0	0	0	0	0	0	
Current alcohol intake	2.428	0.019* (0.399, 4.458)	0.001*** (0.115, 0.537)	0.358	0.001*** (0.149, 0.567)	0.001*** (0.149, 0.567)	0.341	0.003*** (0.117, 0.564)	0.003*** (0.117, 0.564)	0.341	0.003*** (0.117, 0.564)	0.003*** (0.117, 0.564)
:	-2.009	0.312 (-5.916, 1.897)	0.001*** (0.115, 0.537)	0.358	0.001*** (0.149, 0.567)	0.001*** (0.149, 0.567)	0.341	0.003*** (0.117, 0.564)	0.003*** (0.117, 0.564)	0.341	0.003*** (0.117, 0.564)	0.003*** (0.117, 0.564)
-	0	0	0	0	0	0	0	0	0	0	0	
Brinkman index	1.199	0.205 (-0.659, 3.058)	0.001*** (0.115, 0.537)	0.358	0.001*** (0.149, 0.567)	0.001*** (0.149, 0.567)	0.341	0.003*** (0.117, 0.564)	0.003*** (0.117, 0.564)	0.341	0.003*** (0.117, 0.564)	0.003*** (0.117, 0.564)
:	0.007	0.054 (0.000, 0.054)	0.001*** (0.115, 0.537)	0.358	0.001*** (0.149, 0.567)	0.001*** (0.149, 0.567)	0.341	0.003*** (0.117, 0.564)	0.003*** (0.117, 0.564)	0.341	0.003*** (0.117, 0.564)	0.003*** (0.117, 0.564)
-	2.502	0.618 (-7.378, 12.383)	0.001*** (0.115, 0.537)	0.358	0.001*** (0.149, 0.567)	0.001*** (0.149, 0.567)	0.341	0.003*** (0.117, 0.564)	0.003*** (0.117, 0.564)	0.341	0.003*** (0.117, 0.564)	0.003*** (0.117, 0.564)
BMI	-0.026	0.901 (-0.431, 0.380)	0.001*** (0.115, 0.537)	0.358	0.001*** (0.149, 0.567)	0.001*** (0.149, 0.567)	0.341	0.003*** (0.117, 0.564)	0.003*** (0.117, 0.564)	0.341	0.003*** (0.117, 0.564)	0.003*** (0.117, 0.564)
MABP (before surgery)	5.795	0.536 (-12.655, 24.245)	0.001*** (0.115, 0.537)	0.358	0.001*** (0.149, 0.567)	0.001*** (0.149, 0.567)	0.341	0.003*** (0.117, 0.564)	0.003*** (0.117, 0.564)	0.341	0.003*** (0.117, 0.564)	0.003*** (0.117, 0.564)
	-0.045	0.675 (-0.255, 0.166)	0.001*** (0.115, 0.537)	0.358	0.001*** (0.149, 0.567)	0.001*** (0.149, 0.567)	0.341	0.003*** (0.117, 0.564)	0.003*** (0.117, 0.564)	0.341	0.003*** (0.117, 0.564)	0.003*** (0.117, 0.564)

Notes: *P < 0.05; **P < 0.01. Retinal venular caliber (before - after surgery, one-week hospitalization) Model 1, adjusted for age, gender, and hyperlipidemia; Model 2, adjusted for age, gender, hyperlipidemia, and the Brinkman Index; Model 3, a saturated model, adjusted for all factors. A reference category is 0. B is the regression coefficient, and intercept B is the partial regression coefficient.

Abbreviations: BMI, body mass index; CI, confidence interval; MABP, mean arterial blood pressure; ns, not significant.

that high blood pressure is a risk factor for ischemic heart disease and cerebrovascular disorders.^{5,29, 31} The INTERSALT study has demonstrated that the sodium intake of Japanese people was about 12 g/day (based on 24-hour urine collection) and that subjects consuming 3 g or less per day of salt equivalent (based on sodium) excretion) had lower blood pressure.³² An increase in sodium intake of 100 mmol/day (equivalent to about 6 g/day) has been shown to raise SBP by 6 mmHg (by about 3 mmHg adjusted by weight). This reveals a correlation between sodium intake and blood pressure.³² The DASH-Sodium Trial also indicates that sodium intake influences blood pressure, and that a lower sodium intake is associated with a lower blood pressure.³³

A hypertensive fundus change (ie, narrowing of the retinal vessels occurring at an early stage) is an important risk factor for the onset of cerebrovascular disorders.⁶ The relationship between antihypertensive drugs and changes in the retinal vessels has been evaluated, but the relationship between sodium restriction and retinal vascular diameter has not been examined.¹² Therefore, in this study we evaluated changes in the diameter of retinal vessels and changes in mean blood pressure due to sodium restriction for one week. This short period of sodium restriction significantly reduced mean arterial blood pressure in our study, and this finding has previously been demonstrated.³³ The change in mean arterial blood pressure before and after cataract surgery also differed significantly between the sodium restriction and control groups. Sodium restriction also significantly reduced SBP. DBP was not reduced significantly, but the change after surgery differed significantly between the two groups.

It is generally understood that an excessive intake of sodium increases the volume of circulating blood, raises blood pressure, and changes arterial parameters such as vascular resistance without affecting blood pressure.¹⁻³ The decrease in blood pressure in our study probably occurred through reduction of the circulating blood volume and vascular resistance due to sodium restriction.

In the sodium restriction group, there was only a mild decrease in CRAE after surgery. However, multiple regression analyses showed that an increase in CRAE was significantly associated with diabetes mellitus, hyperlipidemia, and alcohol intake. Diabetes mellitus and hyperlipidemia are important risk factors for vascular disorders caused by arterial sclerosis, and the onset frequencies of cerebrovascular disorders and ischemic cardiac diseases increase markedly when diabetes mellitus and hyperlipidemia are both present.³⁴ Hypertension is similarly a well-defined risk factor for

arterial sclerosis. Studies in the US and Europe, such as the Framingham Study, have indicated that hypertension is a risk factor for coronary artery disease.³⁵ In Japan, the Hisayama Study also shows that a blood pressure of 140/90 mmHg or greater significantly increases the frequency of cerebral infarction.³⁶ Pathologic conditions, such as diabetes mellitus, hyperlipidemia, and hypertension, may also be closely related to metabolic syndrome, when viewed from the perspective of insulin resistance and fat accumulation around organs. Insulin resistance is a predictor of metabolic syndrome. Compared with subjects with normal blood pressure, patients with hypertension have insulin resistance,^{37,38} which may be due to increased visceral fat.³⁹

Based on these findings, the improvement of insulin resistance, due to correction of diet and establishing of a controlled diet during hospitalization, may have increased CRAE in patients with diabetes mellitus and hyperlipidemia. Diabetes mellitus apparently influences retinal arteriolar diameter because previous epidemiologic surveys have reported significantly larger retinal arteriolar diameters in people with diabetes mellitus.¹²

We also note that long-term alcohol intake results in elevation of blood pressure.⁴⁰ A reduction in alcohol intake lowers blood pressure by 80% within one to two weeks.⁴¹ Because the hospitalized patients were unable to drink alcohol, an antihypertensive effect due to reduced alcohol intake may also have contributed to the increase in CRAE.

An increase in CRVE was associated with the Brinkman Index. It has been noted that smoking causes transient blood pressure elevation, but a method for evaluating the chronic effect of smoking on blood pressure has not been established.⁴² Previous studies have shown that CRVE is significantly higher in smokers than in nonsmokers. However, it is unclear if the increase in CRVE in smokers results from a decreased blood pressure, results from compensation by the nervous system due to changes in body fluid volume, or is affected by smoking itself.¹²

The relationship between the decrease in CRVE and hyperlipidemia may be connected with an increase in HDL-C, correction of diet during hospitalization, and establishing a controlled diet.¹²

The relationship between a slight increase in CRVE and age may be connected with aging and presence of cataracts in the subjects. The resolution of the fundus photographs was low. The larger diameter of retinal venules compared with the diameter of retinal arterioles may have produced smaller errors that resulted in significant differences for CRVE.

