in patients with chronic renal failure, including hyposalivation and xerostomia, impaired immunity and wound healing, alveolar bone destruction caused by renal osteodystrophy, bleeding diathesis, diabetes mellitus, malnutrition, and a state of general disability that leads to impaired oral hygiene.[18,19] However, most researchers who have looked into chronic renal failure–periodontal disease relationships in humans used case-control studies or focused on end-stage renal disease, dialysis, and renal transplant patients and looked at the association of local inflammatory markers with renal impairment. Few studies have been community-based studies,[20] which might provide more reliable information than case-control studies. Thus, it is important to explore the link between periodontal disease and chronic renal failure in community-based studies.

To further clarify associations between renal failure and periodontal disease, we studied the mechanisms underlying the association between chronic renal failure and periodontal disease and between bone metabolism and periodontal disease after controlling for confounding factors in a community-dwelling population. This study investigated whether a link exists between periodontal disease and chronic renal function, as assessed by urinary and serum markers, in community-dwelling older adults (adults >75 years).

MATERIALS AND METHODS

Study Population and Clinical Assessments

The population for this study was drawn from the Niigata study. Briefly, the Niigata study was a prospective community-based study that was initiated to evaluate the relationship between an individual's general health status and his/her history of dental diseases in 1998. Initially, questionnaires were sent to all inhabitants (N = 4,542) 70 years of age based on a registry of residents in Niigata city in Japan; all recipients were informed of the purpose of this survey. Among those who were randomly selected to participate in the Niigata study (N = 600), 398 subjects who turned 70 in 1998 and were 77 years of age in 2005 underwent annual dental examinations. We selected 145 of the 398 subjects (76 men and 69 women) for participation in this study because they had one or more teeth and did not take medicine for bone metabolism. All subjects were Japanese, in good general health, and did not require special care for their daily activities. The subjects selected for the study were homogeneous in terms of race, and we restricted age to 77 years, thereby excluding the influence of both race and age variations on results. The examination protocol that was used in the examination was reviewed and approved by the Ethics Committee of the Faculty of Dentistry, Niigata University.

The periodontal examination included the assessment of probing depth (PD) and clinical attachment level (CAL) at six sites around each tooth. Probing was performed using a pressure constant probe[‡] at a probing force of 20 g and rounded to the nearest whole millimeter. The periodontal examination was carried out by four trained dentists under sufficient illumination using artificial light. Calibration of the examiners was carried out in volunteer patients at the Faculty Hospital. As determined by replicate examinations in 10 patients, the percent agreement (within ±1 mm) ranged from 87.5% to 100% for PD and from 83.3% to 100% for CAL. The κ ranged from 0.81 to 1.00 for PD and from 0.74 to 1.00 for CAL. We also conducted personal interviews to obtain information regarding smoking habits, educational level, dental treatment during the past year, and use of interdental brushes or dental floss.

Urine was collected over 24 hours (7:00 am to 7:00 am the day after the dental examination). During the day that urine was collected, usual food and fluid intake were encouraged. The subject's blood was taken in the morning of the dental examination. The volume of creatinine in urine per 24 hours (g/day; Cre_U) and volume of urine per 24 hours (ml/day) were used as urinary markers of kidney function; serum creatinine levels (g/l; Cre_S) were used as a blood marker of kidney function. Creatinine clearance per 24 hours was calculated as Cre_U/Cre_S. In addition, biochemical parameters of bone turnover were measured, including urinary deoxypyridinoline (nM/nM × Cr; U-DPD) as a bone resorption marker and serum osteocalcin (ng/ml; S-OC) as a bone formation marker. All laboratory tests were done at a commercial laboratory.[§]

Statistical Analysis

Means and SD were used to characterize continuous variables. We categorized subjects by tertiles according to the percentage of sites with ≥6-mm CAL. One-third and two-thirds percentiles were computed. Creatinine clearance per 24 hours, volume of urine analysis, S-OC, U-DPD, and educational level were evaluated by analysis of variance (ANOVA) and the Scheffe multiple comparison test for the first tertile as post hoc procedures. In addition, smoking habits, dental treatment during the past year, and use of interdental brushes or dental floss were evaluated by the χ^2 test. Correlations among renal function and bone metabolism markers for periodontal disease, including the number of remaining teeth and smoking habits, were evaluated using Pearson correlation coefficients.

To evaluate the relationship between periodontal disease and renal function markers (volume of urine per 24 hours [ml/day] and creatinine clearance per 24 hours [l/day]) or bone metabolism markers (U-DPD [nM/nM × Cr] and S-OC [ng/ml]), multiple

‡ Vivacare TPS Probe, Schaan, Liechtenstein.
§ BML, Tokyo, Japan.

Table 1.

Selected Characteristics of Study Subjects

Variables	Men (n = 76)		Women (n = 69)		P Value
	Mean	SD	Mean	SD	
Remaining teeth (N)	18.0	8.0	18.1	8.6	0.926
Mean CAL (mm)	3.7	0.9	3.2	1.0	0.005
Mean PD (mm)	2.2	0.5	2.2	0.5	0.366
Sites with ≥6-mm CAL (%)	11.4	12.9	7.7	12.9	0.093
Subjects with more than one site with ≥6-mm CAL (%)	88.2		69.6		0.006
Subjects with past or current smoking habit (%)	82.9		3.2		<0.001
Subjects who experienced dental treatment during past year (%)	36.0		36.2		0.977
Educational level (years)	10.6	2.7	9.5	2.1	0.009
Subjects who used interdental brushes or dental floss (%)	48.7		53.6		0.552

regression analysis was performed. For the final model, the confounding independent variables that had $P<0.05$, according to the statistical association with the percentage of sites with ≥6-mm CAL by Pearson correlation coefficients, ANOVA, or χ^2 test, were selected.

All calculations and statistical analyses were performed using the statistical software.‖ $P<0.05$ was considered statistically significant.

RESULTS

Characteristics of subjects are shown in Table 1. The percentage of subjects with at least one site with ≥6-mm CAL was 88.2% for men and 69.6% for women. This difference was statistically significant ($P = 0.006$). In addition, the mean CAL ($P = 0.005$), percentage of smokers ($P<0.001$), and educational levels ($P = 0.009$) were significantly higher in men than women. Correlations among renal function, bone metabolism markers, and periodontal disease markers, including the number of remaining teeth and smoking habits, are shown in Table 2. The percentage of sites with ≥6-mm CAL per person had a significant positive association with creatinine clearance per 24 hours ($r = 0.30$; $P<0.001$) and a negative association with volume of urine per 24 hours, S-OC, U-DPD, number of remaining teeth, and smoking habits ($r = -0.23$, -0.29, -0.22, -0.46, and -0.22 and $P = 0.006$, 0.001, 0.011, <0.001, and <0.001, respectively). In addition, smoking habits were significantly associated with S-OC ($r = 0.27$; $P = 0.002$) and U-DPD ($r = 0.47$; $P<0.001$). In contrast, there was no significant relationship between smoking habits and creatinine clearance or volume of urine per 24 hours. Table 3 shows the differences in the distribution of renal function, bone metabolism, oral health markers, and social markers according to the percentage of sites with ≥6-mm CAL per person. Creatinine clearance per 24 hours and percentage of smokers were significantly higher in the third tertile than in the first or second tertiles ($P = 0.017$, ANOVA for creatinine clearance; $P<0.001$, χ^2 test, for smoking). In contrast, subjects in the third tertile had a lower volume of urine per 24 hours than subjects in the first or second tertile, although differences were not statistically significant ($P = 0.053$, ANOVA). S-OC, U-DPD, and the percentage of subjects using interdental brushes or dental floss were significantly lower in the third tertile than in the first or second tertiles ($P = 0.008$, ANOVA for S-OC; $P = 0.016$, ANOVA for U-DPD; $P = 0.011$, χ^2 test for use of interdental brushes or dental floss, respectively). The values of S-OC and U-DPD at the third tertile were significant by Scheffe multiple comparison test with the first tertile as the post hoc procedure ($P = 0.010$ for S-OC; $P = 0.016$ for U-DPD).

To evaluate the relationship between the percentage of sites with ≥6-mm CAL and renal function markers such as volume of urine and creatinine clearance or between the percentage of sites with ≥6-mm CAL and bone metabolism markers such as U-DPD and S-OC, multiple regression analysis was performed. According to the results of the Pearson correlation coefficients (Table 2), ANOVA, or χ^2 test (Table 3) among renal function, bone metabolism, periodontal disease and social markers, we selected the number

‖ STATA software package, STATA, College Station, TX.

Table 2.

Statistical Correlation Coefficients and *P* Values Among Renal Function, Bone Metabolism Markers, Smoking Habits, and Periodontal Disease Markers

Variables	% Sites With ≥6-mm CAL	Creatinine Clearance per 24 Hours (l/day)*	Volume of Urine per 24 Hours (ml/day)	S-OC (ng/ml)	U-DPD (nM/nM × Cr)	N Remaining Teeth	Smoking Habits
% sites with ≥6-mm CAL							
r	1.00						
P	–						
Creatinine clearance per 24 hours (l/day)*							
r	0.30	1.00					
P	<0.001	–					
Volume of urine per 24 hours (ml/day)							
r	−0.23	−0.71	1.00				
P	0.006	<0.001	–				
S-OC (ng/ml)							
r	−0.29	−0.27	0.11	1.00			
P	0.001	0.001	0.167	–			
U-DPD (nM/nM × Cr)							
r	−0.22	0.04	−0.08	0.56	1.00		
P	0.011	0.632	0.344	<0.001	–		
N remaining teeth							
r	−0.46	−0.07	0.13	0.06	0.07	1.00	
P	<0.001	0.359	0.090	0.484	0.419	–	
Smoking habits							
r	−0.22	−0.11	−0.01	0.27	0.47	0.02	1.00
P	<0.001	0.174	0.906	0.002	<0.001	0.750	–

* Creatinine (g/day) in urine per 24 hours/creatinine (g/l) in serum.

of remaining teeth, smoking habits (0: no; 1: current or past), use of interdental brushes or dental floss (0: no; 1: yes), and gender (0: male; 1: female) as confounding independent factors in the final models.

Results of multiple regression analysis between the percentage of sites with ≥6-mm CAL and renal function markers after controlling for confounding factors are shown in Table 4. Creatine clearance for 24 hours was positively associated with the percentage of sites with ≥6-mm CAL (standardized coefficient = 0.26; $P = 0.015$). Furthermore, S-OC was a negatively independent variable for the percentage of sites with ≥6-mm CAL, followed by the confounding factors by multiple regression analysis (standardized coefficient = −0.27; $P = 0.006$; Table 5).

DISCUSSION

We confirmed a weak but clear relationship between chronic renal failure in elderly Japanese subjects and periodontal disease. Although adjustment for demographic variables attenuated the strength of the association, the percentage of sites with ≥6-mm CAL remained significantly associated with renal function and bone metabolism markers.

S-OC or U-DPD can be measured in blood or urine, and they indicate the condition of bone turnover. Low bone mass and architectural deterioration of bone tissue are caused by an imbalance of skeletal turnover maintained by the two opposite but normally balanced processes of bone formation and resorption.[21] Chronic renal failure is associated with marked disturbances of bone structure and metabolism. A significant decrease in bone mineral density after kidney transplantation is a serious finding.[22] In addition, the validity of serum and urinary biochemical markers of bone turnover shows clinical use in relation to other important risk factors for the development of osteoporosis and chronic renal failure.[23] Osteoporosis can develop in patients with chronic kidney disease.[24,25] Furthermore, we recognized a significant relationship between bone mineral density and periodontal disease progression.[8] There is a growing body of evidence

Table 3.

Renal Function, Bone Metabolism, Oral Health Markers, and Social Markers of Subjects by Tertiles of Attachment Level

	% Sites With ≥6-mm CAL			
	First Tertile* 0.2 (0.3)	Second Tertile* 3.0 (1.5)	Third Tertile* 21.8 (13.5)	*P* Value
Mean (SD) creatinine clearance per 24 hours (l/day)†	67.7 (24.1)	76.3 (35.7)	87.7 (44.2)	0.017‡
Mean (SD) volume of urine per 24 hours (ml/day)	1,704.6 (477.6)	1,676.1 (466.6)	1,496.3 (558.0)	0.053‡
Mean (SD) S-OC (ng/ml)	9.1 (3.3)	8.2 (3.5)	7.0 (2.8)§	0.008‡
Mean (SD) U-DPD (nM/nM x Cr)	5.9 (1.5)	5.3 (1.7)	4.9 (1.7)‖	0.016‡
Subjects with past or current smoking habits (%)	26.1	51.7	62.2	<0.001¶
Subjects who experienced dental treatment during the past year (%)	31.4	29.8	37.1	0.455¶
Mean (SD) educational level (years)	9.9 (2.3)	10.3 (2.7)	10.3 (2.6)	0.373¶
Subjects who used interdental brushes or dental floss (%)	56.6	52.8	38.3	0.011¶

* The one-third and two-thirds percentiles were computed. We categorized the subjects by three tertiles according to the percentage of sites with ≥6-mm CAL; mean (SD).
† Creatinine (g/day) in urine per 24 hours/creatinine (g/l) in serum.
‡ ANOVA.
§ $P = 0.010$ by Scheffé multiple comparison test for first tertile as the post hoc procedure.
‖ $P = 0.016$ by Scheffé multiple comparison test for first tertile as the post hoc procedure.
¶ χ^2 test.

Table 4.

Relationship Between Percentage of Sites With ≥6-mm CAL and Renal Function Markers Controlling for Confounding Factors by Multiple Regression Analysis

	Dependent Variable (% sites with ≥6-mm CAL)					
Independent Variables	Coefficient	SE	*P* Value	95% Confidence Interval		Standardized Coefficient
N remaining teeth	−0.75	0.12	<0.001	−1.00	−0.51	−0.46
Creatinine clearance for 24 hours (l/day)*	0.09	0.04	0.015	0.02	0.16	0.26
Volume of urine for 24 hours (ml/day)	1.90E-04	2.80E-03	0.956	−0.01	0.01	0.01
Smoking habits	2.11	3.08	0.500	−3.98	8.20	0.08
Gender	−4.75	3.05	0.121	−10.78	1.28	−0.17
Use of interdental brushes or dental floss	−0.27	2.02	0.893	−4.26	3.72	−0.01
Constant	15.26	8.48	0.074	−1.52	32.03	

$R^2 = 0.321$; $P < 0.001$.
* Creatinine (g/day) in urine per 24 hours/creatinine (g/l) in serum.

indicating that chronic kidney disease is associated with disrupted regulation of the vitamin D–parathyroid hormone axis, which contributes to hyperparathyroidism and the high rate of bone disease in chronic kidney disease.[26] Vitamin D has proven successful in the prevention and amelioration of renal bone disorders in patients with mild to moderate renal insufficiency.[27] These findings show the probability that periodontal disease is influenced by chronic renal failure because of insufficient bone metabolism.

Table 5.

Relationship Between Percentage of Sites With ≥6-mm CAL and Bone Metabolism Markers Controlling for Confounding Factors by Multiple Regression Analysis

	Dependent Variable (% sites with ≥6-mm CAL)					
Independent Variables	Coefficient	SE	*P* Value	95% Confidence Interval		Standardized Coefficient
N remaining teeth	−0.74	0.12	<0.001	−0.99	−0.49	−0.47
S-OC (ng/ml)	−1.06	0.38	0.006	−1.82	−0.31	−0.27
U-DPD (nM/nM × Cr)	−0.34	0.85	0.688	−2.03	1.34	−0.04
Smoking habits	−2.70	3.24	0.406	−9.12	3.72	−0.10
Gender	2.70	3.83	0.481	−4.88	10.28	0.10
Use of interdental brushes or dental floss	−0.37	2.11	0.861	−4.55	3.81	−0.01
Constant	36.98	6.16	<0.001	24.79	49.18	

$R^2 = 0.316$; $P < 0.001$.

On the other hand, creatinine clearance showed higher levels in subjects with a higher percentage of sites with ≥6-mm CAL in our study. Diabetes mellitus is a major reason for chronic renal failure, and creatinine clearance increases in the early phase of renal involvement in patients with diabetes mellitus.[28] At a glomerular level, it is thought that hyperfiltration is caused by increases in the glomerular capillary plasma flow rate and mean glomerular capillary hydraulic pressure, which in turn are caused by changes in systemic arterial pressure and/or changes in efferent and afferent arteriolar resistances.[29] The attention has focused on evidence that infections of the oral cavity might be associated with diabetes mellitus and atherothrombosis, including heart infection, stroke, and peripheral vascular disease.[30,31] In addition, some studies[32,33] have been conducted to evaluate the relationship between lipopolysaccharides, such as cholesterol and triglycerides, and periodontal disease. However, it was impossible to show concrete connections based on the findings of our study. Because of our study limitations and the potential for residual confounding, these preliminary findings must be interpreted with caution.

Comparisons to the literature are difficult. We know of few published studies examining an association between chronic infections, such as periodontal disease, with kidney function. Overall, all published studies are case-control studies and are limited to other markers or causes of inflammation and kidney disease. Only one large-scale study[20] was conducted. Initial and severe periodontal disease were associated with estimated glomerular filtration rate. More studies, including prospective trials, are necessary to understand the exact nature of the relationship of periodontal disease and kidney disease.

One limitation of our study is that we could not confirm a clear cause–effect relationship between renal functional markers and periodontal conditions in the elderly because of our cross-sectional design. Furthermore, 83% of men smoked, and one-half of the subjects (49% to 54%) used interdental devices. We did not have detailed information on the percentage of male smokers or the percentage of use of interdental brushes or floss, and thus we could not determine whether these factors were common in the older general population of Japan. However, according to The Citizen Health Care Medical Treatment Welfare Consciousness Survey in Niigata City,[34] the percentage of subjects who use interdental brushes or floss was 47.5% for those 40 to 49 years of age and 41.8% for those 50 to 59 years of age.

Progressive bone loss consistently complicates renal transplantation in patients with immunosuppression.[35,36] In terms of the immune system, chronic renal failure is known to be associated with polymorphonuclear leukocyte impairment and is often complicated by multiple infections.[37,38] A chronic inflammatory response may lead to the development of conditions known to cause and predispose patients to periodontal disease.[31,39,40]

CONCLUSIONS

The present study suggests that there is a significant relationship between renal functional and bone metabolism markers, as well as periodontal disease. Consequently, the increasing incidence of chronic renal failure that occurs with age increases the probability

of severe periodontal disease in the community-dwelling older Japanese population.

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Serum markers of chronic dehydration are associated with saliva spinability

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SUMMARY Findings of a relationship between saliva and dehydration have been observed, but the precise nature of these relationships is unclear and no evidence of a direct link has been found. In particular, no study reports a relationship between chronic dehydration and saliva conditions in community-dwelling older adults. This study aimed to identify whether salivary conditions are sensitive to body hydration markers in an elderly population. A total of 403 subjects aged 76 years participated in the study. Stimulated saliva flow rate and spinability of saliva were measured. In addition, determinations of serum levels of uric acid, blood urea nitrogen (BUN), creatinine, sodium and potassium were made. Dehydration was defined as uric acid ≥ 7 mg dL^{-1} according to the standard value. The salivary spinability were significantly associated with the concentration of uric acid (OR = 2·06, $P = 0·044$) according to multiple logistic regression analysis. In addition, after adjusting for gender, the uric acid concentration and the salivary spinability was significantly associated with BUN, potassium and creatinine levels. The subjects with high uric acid levels (≥ 7 mg dL^{-1}) had the most elastic saliva. Both BUN and serum creatinine are the most commonly used indicators of renal function. Therefore, our findings might demonstrate that older adults who are dehydrated showed highly elastic saliva, which was associated with renal function. In conclusion, this study suggests that there is a significant relationship between chronic dehydration status and salivary spinability level.

KEYWORDS: chronic dehydration, elderly, saliva spinability

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Introduction

Dehydration in older adults has been shown to be a reliable predictor of increasing frailty, progressive deterioration in cognitive function, and an overall reduction in quality of life (1). Teach *et al.* and Popowski *et al.* have reported that increases in concentrations of plasma protein, serum uric acid and some minerals are related to dehydration in their previous studies (2, 3).

Uric acid is the final oxidation product of purine metabolism in the human body (4). It is produced either by accelerated generation of uric acid through purine metabolism or by impaired excretion in the kidney (5). Gout in humans is associated with abnormal levels of elevated uric acid in the body. Unlike urea and ammonia, uric acid can be excreted as a dry solid (2). It is therefore commonly found in the excretions of animals that live in dry environments (6). In addition, serum uric acid level is considered to be one criterion for the diagnosis of dehydration (7, 8).

Saliva is essential for the maintenance of oral health. The primary constituent of saliva is water and, traditionally, decreased body water homeostasis has been linked to salivary dysfunction. Dry mouth is common in the elderly population, and makes eating more difficult and increases the cariogenic

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potential of food (9). Salivary diminution is a known major risk factor for caries among people of any age (10).

Acute dehydration induced by a 24-h period without food and water was shown to reduce parotid saliva flow rate. This evidence suggests that there is a relationship between whole body hydration status and saliva flow rate (11). Findings of a relationship between saliva and dehydration have been observed, but the precise nature of these relationships is unclear and no evidence of a direct link has been found (12). In particular, no study reports a relationship between chronic dehydration and saliva conditions in community-dwelling older adults.

Accordingly, this study was carried out to identify whether saliva flow rate and salivary spinability measurements are sensitive to body hydration markers in a community-dwelling elderly population.

Materials and methods

Subjects

A total of 422 subjects, aged 76 years, participated in this study, out of a screened cohort of 600, who turned 70 in 1998 and since then have received annual examinations. All subjects were Japanese, in good general health, and did not require special care for their daily activities. All the subjects ($n = 422$) underwent medical and dental examination.

The examination protocol that was used in the examination for all subjects was reviewed and approved by the Ethics Committee of the Faculty of Dentistry, Niigata University.

Blood hydration markers

Determinations of serum concentrations of uric acid were used as a marker of dehydration. Dehydration was defined as uric acid ≥ 7 mg dL^{-1} according to the standard value (13). In addition, serum concentrations of blood urea nitrogen, creatinine, sodium and potassium as markers of kidney function were measured at a commercial laboratory.* The blood was taken at same time as saliva collection. During the day that the examination was conducted, usual food, fluid intake and smoking were encouraged.

*BML, Inc., Tokyo, Japan.

Saliva collection and measurement

Stimulated whole saliva was collected at the same time as other examinations. The mean times of day that the saliva was collected were 11:48 ± 2:03 for the subjects with ≥ 7 mg dL^{-1} uric acid and 11:49 ± 2:00 for the subjects with <7 mg dL^{-1} uric acid. There was statistically no significant difference in the time ($P = 0{\cdot}916$, *t*-test). The subjects chewed a 1-g piece of paraffin wax, and they expectorated secreted saliva into a test tube. Collection time was 3 min and flow rate per minute was calculated from one occasion of saliva collection. During the day that the saliva collection was conducted, usual food, fluid intake and smoking were encouraged.

After stimulated whole saliva was collected, salivary spinability was immediately measured using the Neva Meter.† The Neva Meter has been shown to be able to measure spinability of saliva objectively with acceptable reproducibility (14). The meter is based on the principle that electrical resistance reaches infinity at the breaking point of the spinability. After a saliva sample is introduced to the bottom reservoir of the device, it is automatically stretched at a constant rate of 5 mm s^{-1}. Next, application of an electrical current (5 V) to the liquid induces a microcurrent, which stops at the moment the thread breaks. The device detects the point at which the current stops and then measures the maximum length (in mm) of the thread, that is, the spinability. Measurements were taken five times consecutively and spinability was calculated by averaging three of five values, excluding the highest and lowest readings.

We also counted the number of remaining teeth. A personal interview was performed to obtain the bulk of information regarding sensation of dry mouth (no, sometimes and always) and smoking habits (no, past or current).

Data interpretation

A total of 403 subjects was included in our analysis after 19 subjects who did not complete the interview were excluded. Using analysis of variance, we compared smoking habits, the number of remaining teeth, stimulated salivary flow rate per minute (mL min^{-1}), and salivary spinability (mm) according to the sensation of dry mouth (no, sometimes and always). We compared

†IMI-001 Ishikawa Ironworks Co. Ltd, Kitakyusyu, Japan.

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Table 1. Smoking habit, the number of remaining teeth and saliva characteristics of subjects according to sensation of dry mouth

	Sensation of dry mouth			
	No ($n = 211$)	Sometimes ($n = 152$)	Always ($n = 40$)	P-value
Male/female	117/94	77/75	22/18	0·619
Smoking habit (current or experience) (%)	36·2	37·2	37·9	0·875
Number of remaining teeth	15·33 (SD = 0·22)	16·82 (SD = 9·02)	17·55 (SD = 9·25)	0·221
Stimulated salivary flow rate (mL min^{-1})	1·51 (SD = 0·86)	1·39 (SD = 0·77)	1·27 (SD = 0·90)	0·040
Salivary spinability (mm)	1·94 (SD = 0·44)	1·88 (SD = 0·31)	1·97 (SD = 0·42)	0·300

the salivary spinability and stimulated salivary flow rate among those with high (≥7 mg dL^{-1}) and low (<7 mg dL^{-1}) uric acid concentrations using the student's t-test with two-sided P-values. We used multiple logistic regression analysis to evaluate the relationship between serum uric acid concentration and saliva condition. The concentration of serum uric acid (0, <7 mg dL^{-1}; 1, ≥7 mg dL^{-1}) was selected as the dependent variable. Five variables [gender (1, male; 2, female), the number of remaining teeth, smoking habit (0, no; 1, past or current), salivary spinability, and stimulated salivary flow rate] were used as independent variables in the model. Finally, multiple linear regression analysis was performed to evaluate the relationship between the salivary or dehydration markers (stimulated saliva flow rate, salivary spinability and serum uric acid concentration) and kidney function markers (serum concentrations of blood urea nitrogen, sodium, potassium and creatinine). Each salivary or dehydration marker was used as a dependent variable. The kidney function markers as well as gender were used as independent variables. All calculation and statistical analyses were performed using the STATA® software package.[‡] A P-value <0·05 was considered statistically significant.

Results

Table 1 shows the relationship between gender, smoking habits, the number of remaining teeth and saliva characteristics of subjects according to the sensation of dry mouth. There was a significant difference by analysis of variance in stimulated saliva flow rates between the subject groups with the three different reported sensations of dry mouth. The values were lowest in subjects who reported they always had the sensation of a dry mouth. However, there was no significant relationship between sensation of dry mouth and other variables such as gender, smoking habit, number of remaining teeth and salivary spinability.

In addition, we evaluated the difference in the salivary spinability or stimulated salivary flow rate between those with high (≥7 mg dL^{-1}) and low (<7 mg dL^{-1}) uric acid concentrations. The salivary spinability was significantly lower for those with uric acid levels <7 mg dL^{-1} [1·90 (SD = 0·37) mm] compared with those with uric acid levels ≥7 mg dL^{-1} [2·11 (SD = 0·62) mm; $P = 0·004$, Fig. 1]. On the other hand, we could not find a significant relationship between uric acid levels and stimulated salivary flow rate (Fig. 1).

The results of multiple logistic regression analysis are presented in Table 2. Gender [odds ratio (OR) = 0·03; $P = 0·002$] and salivary spinability (OR = 2·06; $P = 0·044$) were significantly associated with the concentration of serum uric acid (Pseudo $R^2 = 0·19$; $P < 0·001$). The findings demonstrate that the males with higher salivary spinability showed higher serum uric acid levels. Especially, the change in salivary spinability per a unit (1 mm) was 2·06 times more likely to exhibit dehydration status (serum uric acid level ≥7 mg dL^{-1}).

As shown in Table 3, after adjusting for gender, the salivary spinability was significantly associated with serum concentrations of blood urea nitrogen (standard coefficient = 0·15, $P = 0·002$), potassium (standard coefficient = 0·12, $P = 0·012$), and creatinine (standard coefficient = 0·29, $P < 0·001$). In addition, the serum uric acid concentration was significantly associated with serum concentrations of blood urea nitrogen (standard coefficient = 0·26, $P < 0·001$), sodium (standard coefficient = 0·11, $P = 0·015$), potassium (standard coefficient = 0·20, $P < 0·001$), and creatinine (standard coefficient = 0·29, $P < 0·001$).

[‡]StataCorp, College Station, TX, USA.

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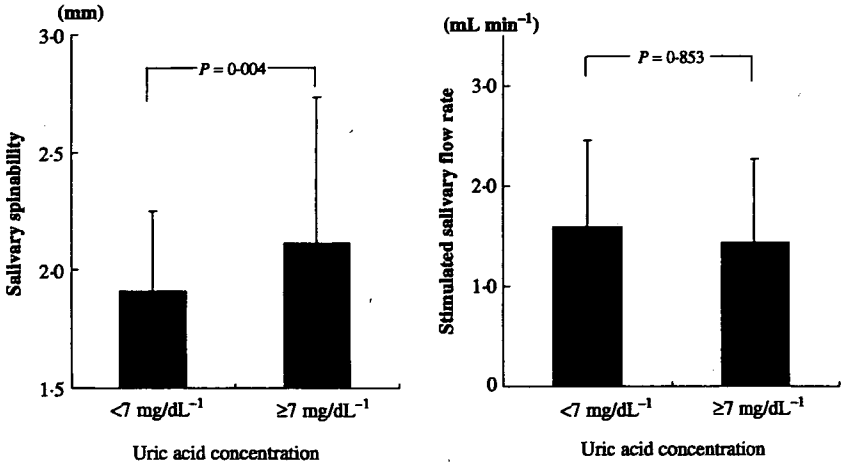

Fig. 1. Salivary spinability and stimulated salivary flow rate according to serum uric acid concentration.

Table 2. Odds ratio of saliva conditions for serum uric acid concentration

Independent variables	Dependent variable Serum uric acid concentration (0, <7 mg dL^{-1}; 1, ≥7 mg dL^{-1}) Odds	SE	*P*-value	95% CI
Gender (1, male; 2, female)	0·03	0·04	0·002	0·00, 0·29
Number of remaining teeth	1·04	0·02	0·063	1·00, 1·08
Smoking habit (0, never; 1, current or experience)	0·93	0·49	0·885	0·32, 2·64
Salivary spinability (mm)	2·06	0·74	0·044	1·02, 4·16
Stimulated salivary flow rate (mL min^{-1})	0·99	0·07	0·843	0·86, 1·13

Pseudo $R^2 = 0{\cdot}19$, $P < 0{\cdot}001$.

Table 3. The relationship between stimulated salivary flow rate, salivary spinability, uric acid and kidney function markers

	Stimulated salivary flow rate		Salivary spinability		Uric acid	
Independent variable	Standard coefficient*	*P*-value	Standard coefficient*	*P*-value	Standard coefficient*	*P*-value
Blood urea nitrogen	−0·08	0·095	0·15	0·002	0·26	<0·001
Sodium	−0·05	0·334	−0·04	0·425	0·11	0·015
Potassium	0·03	0·516	0·12	0·012	0·20	<0·001
Creatinine	−0·08	0·099	0·29	<0·001	0·29	<0·001

*Standardized coefficient adjusted by gender.

Discussion

In this study, serum uric acid concentrations, used as a marker of dehydration, were significantly associated with salivary spinability. Subjects with high uric acid concentrations showed highly elastic saliva. In addition, both the serum uric acid concentration and salivary spinability were significantly associated with serum blood urea nitrogen, serum potassium and serum creatinine concentrations.

Serum blood urea nitrogen and serum creatinine concentrations are the most commonly used indicators of renal function. A rise in blood creatinine levels is observed with marked damage to functioning nephrons (15). Furthermore, the most common cause of an elevated blood urea nitrogen concentration is due to a condition such as dehydration or malnutrition (16, 17). Therefore, our findings might demonstrate that older adults who are dehydrated showed highly elastic saliva, which was associated with renal function.

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Spinability is the thread-forming capacity of mucus under the influence of large-amplitude elastic deformation and it gives information about the internal cohesion forces of the mucus (18). Factors that control mucus spinability are the concentration of mucous glycoproteins, the degree of intermolecular and intramolecular cross-linkings, and the hydration of mucus (19, 20). To establish the reproducibility of the analysis of spinability using the Neva Meter, Gohara *et al.* (14) used polyvinyl alcohol in water, which is a well-known viscoelastic solution that displays unique properties (21). There was a significant correlation ($r = 0{\cdot}55$–$0{\cdot}59$, $P = 0{\cdot}05$) between spinability and viscosity.

According to our findings, salivary spinabilities were 1·90 (SD = 0·37) mm for the subjects with uric acid levels <7 mg dL^{-1} and 2·11 (SD = 0·62) mm for those with uric acid levels ≥7 mg dL^{-1}. Even if the difference in uric acid levels between the subjects with uric acid levels <7 mg dL^{-1} and those with uric acid levels ≥7 mg dL^{-1} was small, this difference was meaningful because the salivary spinability was classified as either >2·00 mm (high) or ≤2·00 mm (normal) according to previous report (22). In the report, the subjects with salivary spinability >2·00 mm showed significantly higher periodontal attachment level than those with ≤2·00 mm.

In terms of the relationship between serum uric acid concentration and salivary spinability, an increase in saliva total protein concentration and osmolality during dehydration has been seen to occur (23). The changes in saliva total protein concentration that are related to salivary spinability appear to be more sensitive to changes in whole body hydration status (23). However, we could not obtain more information from the present study on whether chronic renal failure influenced the concentration of mucous glycoproteins. Further studies are needed to confirm this possibility.

On the other hand, there was no significant relationship between serum uric acid concentration and stimulated salivary flow rate. However, subjects with the subjective sensation of dry mouth showed a significantly lower salivary flow rate than subjects without this sensation. Even if the evidence suggests that there is a relationship between whole body hydration status and saliva flow rate (11), there might be no relationship between chronic dehydration and saliva flow rate in this study. This shows that a low salivary flow rate was the cause for dry mouth. However, the subjects with dry mouth were not always in a state of chronic dehydration. In our study, only one subject out of 40 in the always dry mouth group had a high serum uric acid level (≥7 mg dL^{-1}).

One limitation of this study was that we investigated stimulated saliva as opposed to unstimulated saliva. Unstimulated salivary flow is a measure of the amount of saliva that is constantly secreted in the oral cavity, whereas stimulated salivary flow is a measure of the functional capacity of the gland (24). Selecting the stimulated saliva could be the reason for the lack of an association between uric acid levels and salivary flow rate. Resting salivary flow rate also should be measured in addressing the research question.

In conclusion, this study suggests that there is a significant relationship between chronic dehydration status and salivary spinability level.

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RESEARCH REPORTS
Clinical

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Longitudinal Relationship between Root Caries and Serum Albumin

ABSTRACT

Serum albumin levels are a practical marker of general health status in the elderly and have been used to determine the severity of an underlying disease and the risk for death. This longitudinal study evaluated the relationship between serum albumin levels and root caries. A total of 266 persons with at least 1 tooth at baseline underwent a baseline examination and then annual investigations for 6 years. Multiple linear regression analysis was used to assess the relationship between changes in serum albumin levels and the number of root caries lesions over 6 years, after adjustment for confounding factors. Change in the number of root caries lesions was significantly associated with change in serum albumin concentrations. The standardized coefficient was -0.148 (p = 0.024). We can confirm that serum albumin concentration correlates with root caries events. From these data, we conclude that persons with hypoalbuminemia are at high risk for root caries.

KEY WORDS: root caries, geriatric dentistry, serum albumin.

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INTRODUCTION

Serum albumin levels are a practical marker of general health status in the elderly and have been used to determine the severity of an underlying disease and the risk for death (Phillips *et al.*, 1989; Shibata *et al.*, 1991). Many conditions, such as inflammatory states, liver diseases, and renal diseases, lead to decreased serum albumin levels (Herrmann *et al.*, 1992; Rigaud *et al.*, 2000; Walrand *et al.*, 2000). Moreover, malnutrition can be monitored by the examination of serum albumin levels (Magagnotti *et al.*, 2000; Giordano *et al.*, 2001; Don and Kaysen, 2004). Recently, studies have shown that serum albumin levels are associated with general health status among the elderly (Corti *et al.*, 1994; Baumgartner *et al.*, 1996). Hypoalbuminemia occurs in a variety of diseases, and is associated with an increased rate of complications during hospitalization. In addition, serum albumin is a possible index of intrinsic aging (Shibata *et al.*, 1991).

In contrast, aging is known to lead to an increase in some oral conditions, such as gingival recession and root caries. Several risk factors for the development of root caries have been identified, including past caries, periodontal status, and salivary levels of cariogenic bacteria (Scheinin *et al.*, 1994; Lawrence *et al.*, 1995; Locker *et al.*, 1996; Powell *et al.*, 1998). Furthermore, some reports indicate a link between general health and dental caries. For example, the composite dental index, which combines caries, periodontitis, and edentulousness, has been linked to ischemic events in persons with coronary heart disease (Mattila *et al.*, 1995). Furthermore, it has been shown that increased dental caries may be associated with an increased immune response (Tenovuo *et al.*, 1990).

Previously, we showed an association between serum albumin levels and root caries in a cross-sectional study of elderly persons (Yoshihara *et al.*, 2003). However, because of the cross-sectional design, we could not confirm a clear relationship between serum albumin concentrations and root caries. This longitudinal study evaluated the relationship between serum albumin concentrations and root caries in elderly persons, after adjustment for confounding factors.

MATERIALS & METHODS

Participants

A longitudinal study was conducted in older adults residing in Niigata City, Japan. Initially, questionnaires were sent to all 4542 residents aged 70 years (born in 1927). Of these, 600 people were randomly selected, to provide approximately the same number of each gender for the baseline survey. Participants were asked to sign consent forms regarding the protocol, which was approved by the Ethics Committee of Niigata University School of Dentistry.

Participants were assessed according to the TMIG-Index of Competence subscale questionnaires. The TMIG-Index of Competence is used to assess functional capacity in older persons. The ability to perform a given function is

indicated by 'Yes' or 'No'. The highest score on the TMIG-Index subscales is 13 (Koyano *et al.*, 1991). The mean score of the TMIG-Index subscales of participants in this study was 11.9 ± 1.4. The results of this assessment pointed to a high level of competence among participants in this study.

Dental examinations were carried out at baseline and once a year for 6 yrs (1998-2004), that is, 7 times in 6 yrs.

Measurements

Root Caries Events

Four trained and experienced dentists assessed dental caries, including root caries. The examinations were conducted with the use of mirrors and ball-point periodontal probes under artificial light, without bite-wing radiographs. Root caries was diagnosed based on the criteria of the World Health Organization (1997). First, it was determined whether a given surface was exposed or not. An exposed root surface was defined as having at least 1 mm of visible root surface between the gingival crest and the cemento-enamel junction or the restoration margin. All exposed root surfaces were examined and recorded. Root decay was defined as a lesion detected on an exposed root surface that felt soft or leathery when probed. For a single instance of decay affecting both the crown and the root, the likely site of origin of the lesion was recorded as "decayed". When it was not possible to judge the site of origin, both the crown and the root were recorded as "decayed".

We tracked root caries incidence only on surfaces that were neither decayed nor filled at baseline examination. Whenever root decay was detected on a root surface that had previously been sound or non-exposed, it was counted as a disease event. Disease events were counted each year. Surfaces where disease events occurred once were excluded from additional-year evaluations. Finally, the number of surfaces on which a disease event occurred over the 6 yrs was converted into the number of teeth on which a disease event occurred in a given participant.

Interexaminer reliability for surfaces was assessed for the four examiners using 18 volunteer patients in the University Hospital before and during the survey. We calculated a kappa score using 5 codes (Sound, Filled, Decayed, Filled [with decay], and Bridge abutment: Special crown or Veneer/implant). The kappa values between each pair of examiners were 0.84-0.97.

Periodontal Disease Events

The periodontal examination included the assessment of attachment level at 6 sites around each tooth. Probing was performed with the use of a pressure-constant probe (Vivacare TPS Probe®, Schaan, Liechtenstein) and a probing force of 20 *g*. The periodontal examination was carried out by four trained dentists under sufficient illumination using artificial light. At first, the difference between attachment level at baseline and at follow-up for each site was calculated with site-level data. If the difference was ≥ 3 mm, it was counted as a periodontal disease event. Surfaces where disease events occurred once were excluded from additional-year assessments. Data were rounded off from site-level to tooth-level. Finally, the number of teeth with an event per person was calculated.

Interexaminer reliability for attachment was assessed for the four examiners using 18 volunteer patients in the University Hospital before and during the survey. As determined by replicate examinations of attachment level, the percent agreement (± 1 mm) ranged from 70.0% to 100%. The kappa (± 1 mm) ranged from 0.62 to 1.00.

Composition and Blood Measurements

Anthropometric evaluation included measurements of weight and height for the calculation of body mass index (BMI). BMI is defined as the individual's body weight divided by the square of his/her height. In addition, serum albumin and immunoglobulin G (IgG) concentrations were measured at a commercial laboratory (BML, Inc., Tokyo, Japan). Serum albumin concentration ≤ 4.0 g/dL was defined as low according to a previous report (Phillips *et al.*, 1989).

Statistical Analysis

For descriptive data (BMI, serum IgG levels, and the number of periodontal disease events), statistical differences between the number of root caries events were evaluated by analysis of variance (ANOVA) and Scheffé's multiple comparison test for the individuals with instances with zero root caries. Means and standard deviations were used to characterize continuous variables. In addition, we compared the number of root caries events over 6 yrs between persons with serum albumin concentrations ≤ 4.0 g/dL at baseline and those of persons with serum albumin concentrations > 4.0 g/dL at baseline, using the paired Student's *t* test. Subsequently, we selected persons with serum albumin concentrations > 4.0 g/dL at baseline and divided them into two groups: those with serum albumin concentrations ≤ 4.0 g/dL after 6 yrs and those with serum albumin concentrations > 4.0 g/dL after 6 yrs. We then compared the number of root caries events between these two groups.

Finally, we performed multiple linear regression analysis to assess the relationship between changes in serum albumin concentrations and the number of root caries events over 6 yrs, after controlling for periodontal disease events over 6 yrs, changes in BMI over 6 yrs, changes in serum IgG concentrations over 6 yrs, gender, the remaining number of teeth at baseline, the number of sites with ≥ 4 mm attachment level at baseline, and the number of decayed and filled surfaces at baseline. The level of significance was set at $p < 0.05$ for these tests. All calculations and statistical analyses were performed with the STATA™ software package (Stata Corp., College Station, TX, USA).

RESULTS

In this study, 334 people dropped out during the study. Serum albumin concentrations at baseline were 4.3 ± 0.2 g/dL for study participants and 4.3 ± 0.3 g/dL for the group who dropped out during the study. There was no significant difference between the two groups ($p = 0.168$; Student's *t* test). In addition, 36 people died during the study. Serum albumin concentrations at baseline for these persons were 4.1 ± 0.3 g/dL. The difference in serum albumin concentrations at baseline between study participants and those who died during the study was statistically significant ($p < 0.001$; Student's *t* test).

Of 600 participants, 266 persons who had at least 1 tooth at baseline and participated in all annual investigations (7 times in total), from baseline to 6 yrs, were included in the analysis. Baseline characteristics of the participants were: serum albumin levels, 4.3 ± 0.2 g/dL; serum IgG levels, 1483.9 ± 288.2 mg/dL; BMI, 22.4 ± 2.9 kg/m^2; the number of remaining teeth, 19.4 ± 8.2; the number of untreated and treated surfaces, 2.3 ± 3.2; and the number of sites with ≥ 4 mm attachment levels, 29.1 ± 25.7. Root caries developed in 52.3% of the participants over the six-year study. Serum IgG concentrations and

periodontal disease events showed significantly high values, with an increase in root caries events assessed by ANOVA ($p = 0.013$ for serum IgG; $p = 0.007$ for periodontal disease events). However, these differences were not significant according to the Scheffé multiple comparison test for the participants with instances with zero root caries (Table 1).

Table 1. Distribution of Root Caries Events and Association with Changes in BMI, IgG, and Periodontal Disease Events over 6 yrs (1998-2004)

Root Caries Event[a]	n	%	Changes from 1998-2004 [mean (SD)] BMI[d]	IgG	Periodontal Disease Event[a]
0	127	47.7	0.4 (1.4)	-209.3 (134.3)	8.6 (6.4)
1-2	96	36.1	0.1 (1.4) NS[c]	-196.6 (130.5) NS[c]	10.7 (6.6) NS[c]
3-4	27	10.2	0.4 (1.1) NS	-146.3 (184.4) NS	10.7 (6.2) NS
5-6	11	4.1	0.1 (0.9) NS	- 28.7 (201.1) NS	13.9 (7.0) NS
>7	5	1.9	0.6 (1.1) NS	- 24.5 (104.6) NS	13.2 (6.8) NS
			$p = 0.520$[b]	$p = 0.007$[b]	$p = 0.013$[b]

[a] A root caries or periodontal disease event was defined as the number of teeth on which a disease event occurred in a given person during the follow-up period.
[b] p values by ANOVA.
[c] Scheffé's multiple comparison test for the participants with instances with zero root caries.
[d] BMI is defined as the individual's body weight divided by the square of his/her height.

In addition, persons with lower serum albumin concentrations (≤ 4.0 g/dL) at baseline had a significantly higher number of root caries events over 6 yrs compared with persons with high serum albumin concentrations (> 4.0 g/dL) at baseline (1.8 ± 2.2 *vs.* 1.1 ± 1.6, respectively; $p = 0.031$, Student's t test) (Fig. 1). We divided persons with serum albumin concentrations > 4.0 g/dL at baseline into two groups: those with serum albumin concentrations ≤ 4.0 g/dL after 6 yrs and those with serum albumin concentrations > 4.0 g/dL after 6 yrs. The mean number of root caries events for 6 yrs was 1.6 ± 2.1 for the persons with serum albumin concentrations ≤ 4.0 g/dL after 6 yrs, compared with 1.0 ± 1.4 for those with serum albumin concentrations > 4.0 g/dL after 6 yrs ($p = 0.009$, Student's t test) (Fig. 2).

According to the results of multiple regression analysis, the number of root caries events, the change in BMI, serum IgG concentrations over 6 yrs, gender, and the number of sites with ≥ 4 mm attachment level at baseline were significantly associated with the change in serum albumin concentrations over 6 yrs (Table 2).

DISCUSSION

There was no significant difference in serum albumin concentrations at baseline between the study participants and those who dropped out. Therefore, we thought that the participants in this study were representative of the community. In addition, serum albumin concentrations ≤ 4.0 g/dL were defined as low according to Phillips' report (Phillips *et al.*, 1989). In the latter report, serum albumin concentrations were divided into 6 categories (< 4.0, 4.0-, 4.2-, 4.4-, 4.6-, 4.8-). There was a gradual increase in mortality rate with decreasing serum albumin concentrations. Persons with serum albumin levels < 4.0 g/dL had a crude all-cause mortality rate 6 times that of persons with a serum albumin concentration of 4.8 g/dL or higher. Therefore, we designated serum albumin concentrations as low (≤ 4.0 g/dL) and high (> 4.0 g/dL) in this study.

To our knowledge, this is the first longitudinal study to clarify the relationship between root caries and serum albumin levels in elderly persons. In this study, the number of root caries events over 6 yrs was significantly associated with the

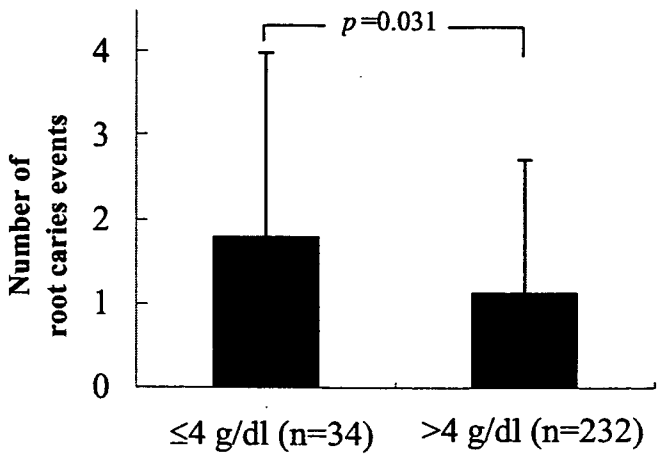

Figure 1. Number of root caries events based on serum albumin concentrations at baseline.

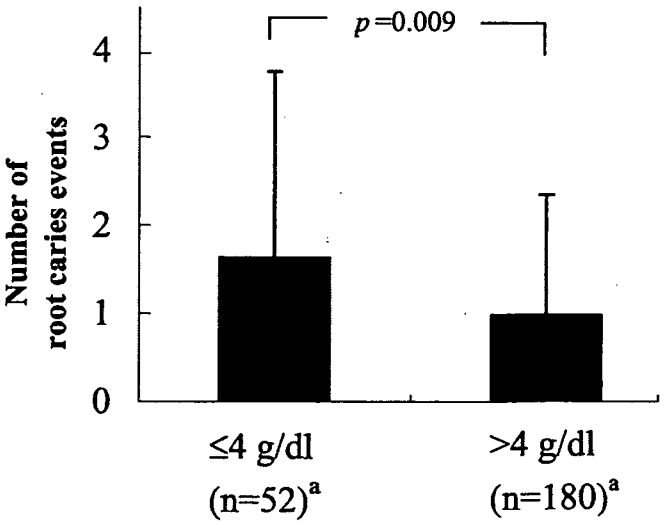

Figure 2. Number of root caries events based on serum albumin concentrations after 6 yrs. Subjects with serum albumin concentrations > 4.0 g/dL at baseline and with serum albumin concentrations ≤ 4.0 g/dL after 6 yrs: n = 52. Subjects with serum albumin concentrations > 4.0 g/dL at baseline and with serum albumin concentrations > 4.0 g/dL after 6 yrs: n = 180. Subjects with serum albumin concentrations ≤ 4.0 g/dL at baseline and with serum albumin concentrations ≤ 4.0 g/dL after 6 yrs: n = 20. Subjects with serum albumin concentrations ≤ 4.0 g/dL at baseline and with serum albumin concentrations > 4.0 g/dL after 6 yrs: n = 14.

Table 2. Relationship between the Number of Root Caries Events and Change in Serum Albumin Concentration over 6 yrs by Multiple Regression Analysis[e]

	Dependent Variable: Change in Serum Albumin Concentrations over 6 yrs				
Independent Variables	Coeff.	Std. Err.	*p* Value	[95% CFI]	Std. Coeff.[a]
Number of root caries events	-0.024	0.011	0.024	-0.045 - -0.003	-0.148
Number of periodontal disease events	0.003	0.003	0.372	-0.003 - 0.009	0.068
Change in BMI[b] over 6 yrs	0.034	0.012	0.004	0.011 - 0.058	0.177
Change in serum IgG levels over 6 yrs	2.980×10^{-4}	1.132×10^{-4}	0.009	< 0.001 - 0.001	0.163
Gender	0.096	0.036	0.008	0.025 - 0.168	0.178
Number of remaining teeth at baseline	0.002	0.002	0.394	-0.003 - 0.007	0.064
Number of sites with ≥ 4 mm LA[c] at baseline	0.002	0.001	0.002	0.001 - 0.004	0.219
Number of surfaces with DF[d] at baseline	-0.006	0.005	0.280	-0.016 - 0.005	-0.070
Constant	-0.337	0.078	< 0.001	-0.490 - -0.184	

$R^2 = 0.13$, $p < 0.001$

[a] Standardized coefficients.
[b] BMI is defined as the individual's body weight divided by the square of his/her height.
[c] Attachment level.
[d] The number of untreated and treated surfaces.
[e] The relationship was evaluated after adjustment for number of root caries events, number of periodontal disease events, change in BMI over 6 yrs, change in serum IgG levels over 6 yrs, gender, number of remaining teeth at baseline, number of sites with ≥ 4 mm LA at baseline, and number of surfaces with DF at baseline.

change in serum albumin concentrations over this period, after adjustment for confounding factors by multiple regression analysis. The standardized coefficient of the number of root caries events was -0.148 (p = 0.024). We can confirm that serum albumin concentration correlates with root caries events. Accordingly, these longitudinal findings support the results of a previous cross-sectional study indicating an association between oral health status and serum albumin levels (Yoshihara *et al.*, 2003).

Serum albumin levels provide an index of the severity of an underlying disease. Many conditions, such as malnutrition, inflammatory disorders, liver disease, and renal diseases, reduce serum albumin levels. In these cases, persons with hypoalbuminemia and malnutrition are likely to have decreased immunocompetence, with an increased risk of infection (Goubran Botros *et al.*, 1996).

In our study, the root caries events showed a direct relationship with increasing levels of IgG. In addition, a statistically significant association was found between IgG and serum albumin. Serum albumin concentrations fall as a result of a variety of infections. According to previous reports, serum IgG levels increase with the presence of dental caries (Parkash *et al.*, 1994; de Soet *et al.*, 2003). The nature of the human immune response to dental caries suggests that *Streptococcus mutans* and serum antibodies may play a major role in the pathogenesis of dental caries (Chia *et al.*, 2000). Furthermore, there was a significant relationship between serum albumin and serum IgG levels (Goubran Botros *et al.*, 1996).

Individuals with high root caries experience (> 7) had more periodontal disease events in our study than those with zero root caries, even if it was not significant by Scheffé's multiple comparison test. According to our previous study, having 1 or more instances of root caries was significantly associated with a mean loss of attachment (Takano *et al.*, 2003). Gingival recession or pocket depth was reported as a risk predictor or risk marker for root caries (Lawrence *et al.*, 1995; Mack *et al.*, 2004). Most lesions occurred on exposed root surfaces.

In this study, BMI was a significant factor associated with serum albumin levels (standardized coefficient, 0.177; p = 0.004) by multiple regression analysis, though there was no significant relation between root caries events and changes in BMI. According to a previous report, even if BMI or albumin levels were lower in the edentulous than in the dentate group, caries was not related to malnutrition (Mojon *et al.*, 1999). Our results support this previous finding.

We conclude that persons with hypoalbuminemia are at high risk for root caries. Furthermore, it is possible that root caries may influence the immune response in the elderly.

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体力科学 (2008) 57, 151～162

地方都市在住高齢者における日常生活での歩数と体力との関係

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RELATIONSHIP BETWEEN DAILY STEPS AND PHYSICAL FITNESS IN COMMUNITY-DWELLING ELDERY

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Abstract

The purpose of this study was to examine the association between the pedometer-determined steps per day and physical fitness in order to evaluate the usefulness of the pedometer-determined physical activity to help individuals meet the recommended exercise target level of the Ministry of Health, Labour and Welfare (MHLW). The subjects consisted of 222 men and 172 women aged 71 years in community-dwelling elderly. The subjects wore a pedometer for 7 consecutive days to measure daily steps. The functional capacity was assessed based on the Tokyo Metropolitan Institute of Gerontology Index of Competence (TMIG-IC) and self-reported performance of tasks (stair-climbing and chair-rising). Physical fitness tests included handgrip strength, knee extensor strength, leg extensor power, stepping, one-leg standing time with eyes open and maximal walking speed at 10 m. The men and women took on average 6,561±2,907 and 6,329±2,451 steps/day, respectively. Our subjects seemed to be highly functioning elderly, because the total scores of TMIG-IC (maximum : 13 scores) were on average 12 for men and women. The average of steps/day was significantly correlated with stair-climbing, chair-rising and knee extensor strength in men and women, and with body weight, body mass index (BMI), percent body fat (%Fat) and leg extensor power in women.

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The BMI and %Fat levels were significantly lower while the handgrip strength and knee extensor strength were significantly higher in women who attained to the level of the pedometer-determined physical activity as recommended by the MHLW.

The present study suggests that both men and women who take a lot of steps on a daily basis tend to demonstrate excellent leg strength and thus have a good ability to perform the tasks of daily living. In addition, the degree of obesity tends to be lower in women who regularly take a lot of steps. In addition, the number of daily steps taken has been recognized to be linked to gender, and such a link has also been suggested to be stronger in women than in men.

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key word：pedometer, daily steps, leg strength, functional performance, body composition

Ⅰ．緒　　言

我が国においては，後期高齢者の増大に伴う虚弱高齢者，特に要介護高齢者の増大が危惧されており，介護予防などの健康づくり対策が重要な課題となっている．最近，高齢者の健康の指標として生活機能の自立性が用いられており[1]，これには下肢筋力が重要な役割を果たす[2]．また，高齢者の健康寿命の長さや死亡前の要介護期間の短さにもっとも強い影響を及ぼす生活習慣因子として身体活動が挙げられている[3]．このようなことから，厚生労働省は健康日本21において高齢者の身体活動を増加させることを目標としている．また，高齢者の日常生活動作障害に対する初期予防活動として日常生活における積極的な歩行運動を推奨しており，その目安として１日の歩数の目標値を示している[4]．しかしながら，実際により多くの歩数を獲得している者，健康日本21の目標値を達成している者の体力や生活機能が高レベルであるかどうかについては検討されていない．

これまでの研究では，１日の総歩数と下肢筋力との間に関連ありとする報告[5]と関連なしとする報告[6,7]がある．また，歩数と下肢筋力との関係は男女間で異なる結果も報告されており[5]，歩数と下肢筋力との関連性については必ずしも一致した見解は得られていない．これら研究においては対象者に中年者を含んでいたり，高齢者においても対象者の年齢幅が広かったりしていること，また，対象者数が少ないことが挙げられる．体力や生活機能レベルは年齢によって大きく異なるため[8,9]，高齢者の日常生活での歩数と下肢筋力などの体力との関連性について検討するには，同一年齢の大集団を対象とする必要があると考えられる．

このようなことから，本研究では十分な対象者数を確保し，年齢の要因を除くために同一年齢の高齢者集団394名(男性222名，女性172名)を対象とし，歩数と体力との関連性について検討するとともに，健康日本21の目標値を基準として，達成している者とそうでない者との体力の比較について検討することを目的とした．

Ⅱ．方　　法

A．対象者

対象者は71歳の新潟市在住の高齢者394名(男性222名，女性172名)であった．各対象者に対して本研究の趣旨，手順，測定の危険性などについて詳細な説明を行い，自署による書面にて研究への参加の同意を得た上で実施した．同意の得られた対象者には質問紙票を郵送し，自宅で記入してもらった後，調査当日に会場で記入内容のチェックを行った．また，体力測定は医師のメディカルチェック，安静時心電図検査にて支障がないことを確認し，その後に実施した．

なお本研究は新潟大学大学院医歯学総合研究科倫理委員会による承認を得た．

B．測定項目および測定方法

1．生活機能調査

生活機能調査は下記の老研式活動能力指標と日常生活動作遂行能力である．

1）老研式活動能力指標[9]

老研式活動能力指標は13項目の設問について「はい」，「いいえ」の２つの選択肢から１つを選択させ，「はい」に１点，「いいえ」に０点を与え，これらの合計得点を算出した．

2）日常生活動作遂行能力

日常生活動作遂行能力の指標として，高齢者の日常生活動作の中でもっとも身体への負担度の高い動作である，階段昇降動作および椅子からの立ち上がり動作遂行能力[10]を用いた．階段昇降動作につい