studies using sonography for entrapment neuropathy such as carpal tunnel syndrome (CTS)[4–9] have been presented. However, there are few reports of DPN diagnosis using sonography. We showed previously that the cross-sectional area (CSA) of the median nerve in the carpal tunnel of patients with DPN is greater than that of controls and correlates with NCS.[10] The aim of this study was to assess the echo intensity of the peripheral nerve and to evaluate the relationship between NCS results and sonographic findings in diabetic patients.

Materials and Methods

Participants

Thirty patients with type 2 diabetes were enrolled in this study at the Gifu University Hospital from October 2007 to January 2009 (17 men and 13 women; age range, 36–83 years; mean ± SD, 59.8 ± 10.2 years). Our control group consisted of 32 healthy volunteers without diabetes mellitus or CTS (25 men and 7 women; age range, 24–72 years; mean, 53.7 ± 13.9 years). Patients' wrists with symptoms of CTS were not included in the study; those that were included had negative Phalen test results. Every participant was able to walk unaided, and none had received hemodialysis.

We studied a total of 95 peripheral nerves (including 62 median nerves and 33 tibial nerves) of 62 participants who received both sonography and NCS. This study was approved by the Institutional Review Board of Gifu University Hospital, and informed consent was obtained from all participants.

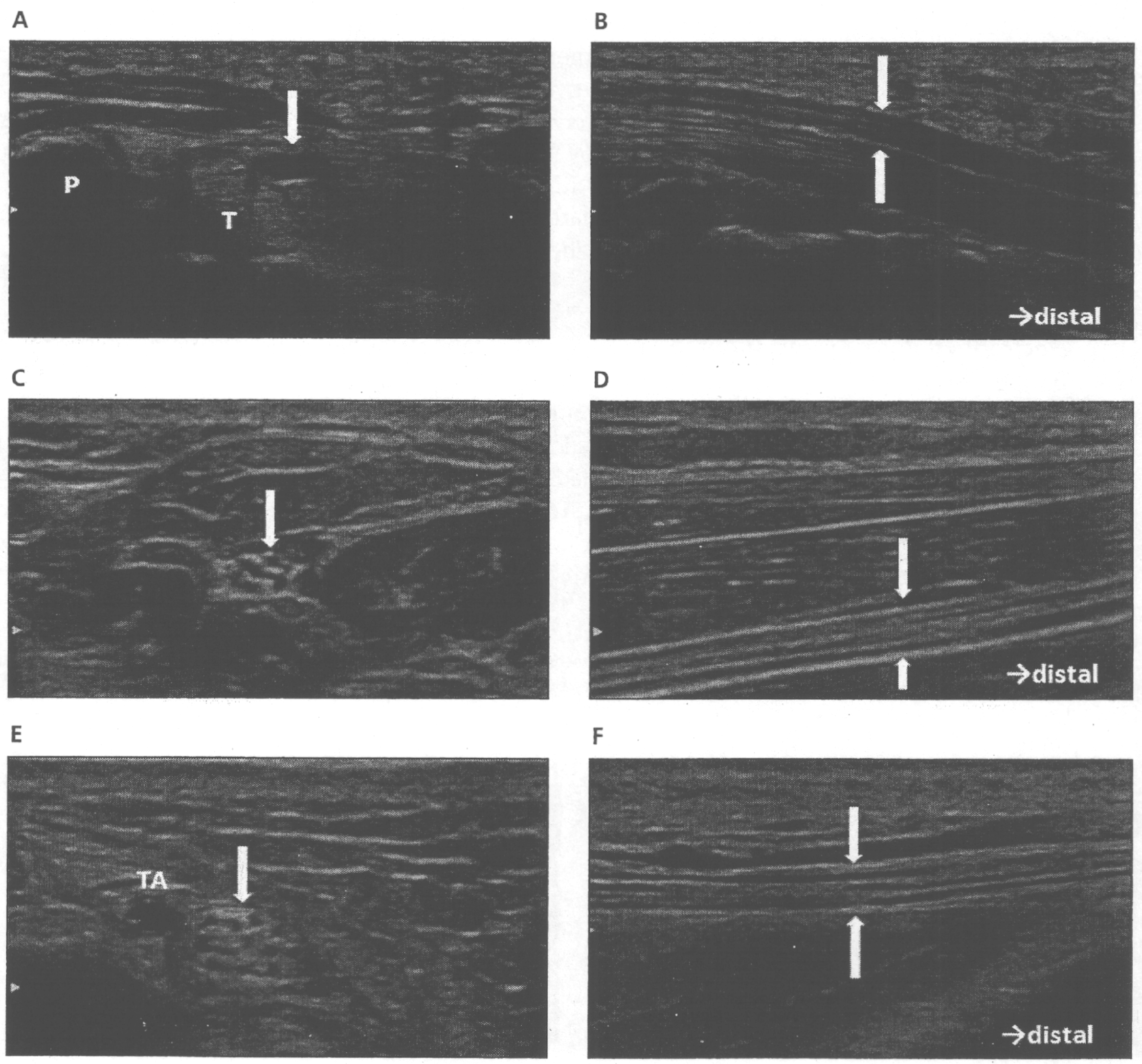
Sonographic Examinations

Sonographic examinations were performed by 1 of 2 experienced sonographers (with at least 10 years of ultrasound experience) using a 6.0- to 14.0-MHz linear array probe (portable real-time apparatus: EUB-7500; Hitachi Corporation, Tokyo, Japan; or ProSound Alpha 10; Aloka Co, Ltd, Tokyo, Japan). Sonograms were quantitatively analyzed using ImageJ software (National Institutes of Health, Bethesda, MD), and only the image obtained by a specific zoom setting was used. Computer analyses were performed by 2 other sonographers who did not have any knowledge of the electrodiagnostic results (observer A had 15 years of experience, and observer B had 6 years of experience). All participants were in the supine position on a table with fingers semiextended during examination of the median nerve and in the prone position during examination of the tibial nerve. The major axis, minor axis, and CSA of the median nerve were measured at the carpal tunnel and at 5 cm proximal to the wrist (wrist). The major axis, minor axis, and CSA of the tibial nerve were measured at the posterior medial malleolus (ankle). The CSA was calculated by the indirect method using the formula major axis × minor axis × π × 1/4 (square millimeters). There are 2 sonographic measurement methods of the nerve CSA: the indirect method (ellipsoid formula) and the direct method (tracing). Recently, Alemán et al[11] reported that median nerve CSA measurements are reproducible by either the direct or indirect method when a standardized sonographic examination protocol is applied. In addition, Sernik et al[12] also reported a high correlation (r = 0.99) between the areas calculated by the indirect and direct methods; consequently, we used the easier indirect method in our study. The volar wrist crease and pisiform bone or medial malleolus were used as initial external reference points and landmarks during scanning. Transverse and longitudinal sonograms of the nerve at each position were recorded (Figure 1). The peripheral nerve's speckled pattern on sonography enabled us to assess its size and echo intensity.

Of the 62 participants, 26 (42%; 13 diabetic patients and 13 controls) were recorded as specific zoom images on the Hitachi EUB-7500 ultrasound equipment. The stored images were further analyzed by 2 sonographers on a personal computer using ImageJ. Each observer received training specific to this study before initiation of the data collection. The images were saved as JPEG files and transferred to a personal computer for analysis. The monochrome sonogram was quantized to 8 bits (ie, 256 gray levels). Histogram analysis on sonography has been expected to offer an objective index for estimating echo intensity such as in diagnosis of fatty liver. The region of interest was set to cover the entire nerve, excluding its hyperechoic rim. The brightness of the pixels ranged from 0 (black) to 255 (white). We used the percentage of the hypoechoic area as the index after the effects of the gain shift on the echo intensity in the median nerve were confirmed (Figure 2).

The normal appearance of the peripheral nerve should be readily recognized. The nerve consists of multiple hypoechoic bands corresponding to neuronal fascicles, which are separated by hyperechoic lines that correspond to the epineurium. Thus, the mean echogenicity was used as a threshold level for the analysis of the percentage of the hypoechoic area because the echogenicity of the peripheral nerve was obtained as a graded echo density from black to white. The percentage of the hypoechoic area was studied using computer analysis. Using ImageJ, the amount of the hypoechoic area falling below the threshold echo intensity level was calculated (Figure 3). Each measurement was taken 5 times, and the mean value was used in the analysis.

Figure 1. Transverse and longitudinal sonograms of the median and tibial nerves at each level. **A**, **C**, and **E**, Transverse sonograms showing the median nerve in the carpal tunnel (**A**) and 5 cm proximal to the wrist (**C**) and the tibial nerve in the posterior medial malleolus (**E**). The nerve (arrows) shows speckled pattern. **B**, **D**, and **F**, Longitudinal sonograms showing the median nerve in the carpal tunnel (**B**) and 5 cm proximal to the wrist (**D**) and the tibial nerve in the posterior medial malleolus (**F**). P indicates pisiform bone; T, tendon; and TA, tibial artery.



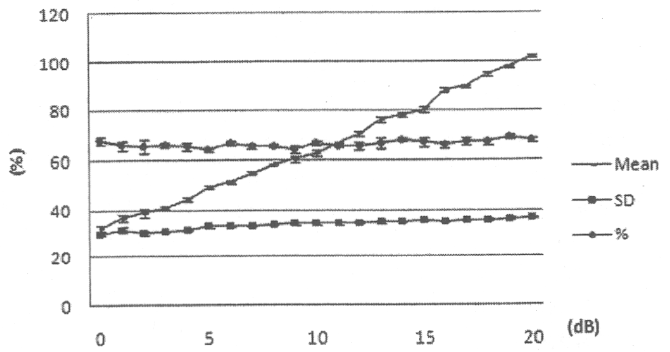


Figure 2. Effects of gain shift on the echo intensity in the median nerve. The line connecting rectangles shows a change of the mean; the line connecting squares shows a change of the SD; and the line connecting circles shows a change of the percentage according to the gain shift.

Intraobserver reproducibility was expressed as the difference between 2 repeated measurement results from the same observer. Interobserver reproducibility was expressed as the difference between 2 measurements obtained by 2 observers. Intraobserver reproducibility and interobserver reproducibility were estimated according to intraclass and interclass correlation coefficients.

Electrophysiologic Examinations

Routine NCS was performed using conventional procedures and standard electromyography (Neuropack MEB-2200; Nihon Kohden Corporation, Tokyo, Japan). All examinations were performed in a room with an ambient temperature of 25°C. The skin surface temperature in all cases was 31°C to 33°C. Motor nerve conduction velocity (MCV) was calculated from the distance of 2 stimulating points and the difference in each response time, and the compound muscle action potential (CMAP) was recorded from the abductor pollicis brevis muscle of the median nerve and the extensor digitorum brevis of the tibial nerve.

The rough reference ranges for the MCVs from the Gifu Laboratory are 50 m/s for the median motor nerve conduction velocity (MMCV) and 40 m/s for the tibial motor nerve conduction velocity (TMCV); therefore, we divided the patients into 4 groups (median nerve >50 and <50 m/s [high- and low-MMCV groups] and tibial nerve >40 and <40 m/s [high- and low-TMCV groups]) and compared them with the controls.

Statistical Analysis

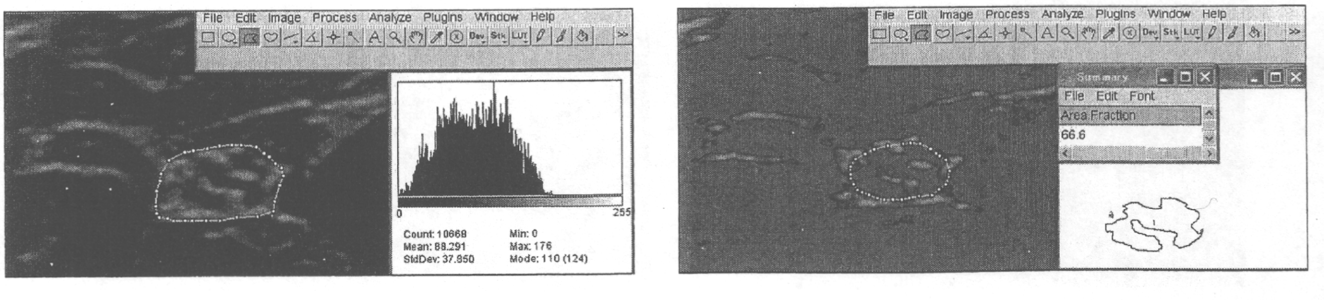
The Mann-Whitney *U* test was used to compare the data between 2 groups. Pearson correlation coefficients were used to investigate the correlation of the CSA and percentage of the hypoechoic area with clinical parameters. Results are given as mean ± SD, and statistical significance was assessed as $P < .05$.

A receiver operating characteristic (ROC) curve was fitted to sonographic measurements using clinical DPN criteria as the reference standards to determine the optimum cutoff point and to evaluate the diagnostic accuracy of sonographic measurements. Receiver operating characteristic curves are plots of the true-positive rate (sensitivity) against the false-positive rate (1.0 – specificity) for the different possible cutoff points of a diagnostic test. The cutoff value at the Younden index point indicates the optimum threshold. To see the change of diagnostic accuracy according

Figure 3. Method of quantitative analysis for echo intensity using ImageJ software. **A**, The region of interest was set to cover the entire nerve, including the hyperechoic rim surrounding the nerve. The mean pixel brightness value was used for further analysis as a threshold. **B**, The percentage was calculated using the Analyze Particles function on the hypoechoic area in the nerve after threshold input.

A

B



to reference standards, another ROC curve was fitted using MCV results, and the sensitivity and specificity of sonography and NCS were calculated and compared between 2 examinations.

Results

Detailed demographic data for the diabetic patients and controls are shown in Table 1. There were no significant differences in age, height, weight, or body mass index (BMI) between controls and diabetic patients. Intraobserver reproducibility was high for both observers (observer A, intraclass correlation coefficient = 0.998; observer B, intraclass correlation coefficient = 0.987); interobserver reproducibility was also high (interclass correlation coefficient = 0.995). Results of the sonographic examinations and NCS of the diabetic patients and controls are shown in Table 2. Cross-sectional areas in the high-MMCV group were 8.8 ± 2.1 mm^2 in the carpal tunnel and 6.7 ± 1.4 mm^2 in the wrist. Cross-sectional areas in the low-MMCV group were 14.0 ± 6.1 mm^2 in the carpal tunnel and 9.8 ± 3.7 mm^2 in the wrist. Cross-sectional areas in the controls were 8.3 ± 1.8 mm^2 in the carpal tunnel and 7.1 ± 2.0 mm^2 in the wrist. There was a significant increase in the median nerve CSA in the low-MMCV group compared with that in the controls (carpal tunnel, $P < .001$; wrist, $P < .05$) and the high-MMCV group (carpal tunnel, $P < .001$; wrist, $P < .01$). Cross-sectional areas in the ankle were 15.0 ± 6.1 mm^2 in the low-TMCV group, 8.8 ± 2.9 mm^2 in the high-TMCV group; and 8.9 ± 2.8 mm^2 in the controls. There was a significant increase in the tibial nerve CSA in the low-TMCV group compared with that in the controls ($P < .01$) and the high-TMCV group ($P < .05$).

The percentage of the hypoechoic area was significantly increased in the low-MMCV group compared with that in the controls ($P < .01$) and the high-MMCV group ($P < .05$). Sonograms and histograms of the diabetic patients and controls are shown in Figure 4.

The MCV and CMAP of both the median and tibial nerves in the low-MCV group showed a significant decrease compared with those in the controls and the high-MCV group. On the other hand, latency was significantly slower in the low-MCV group than in the controls and the high-MCV group.

Table 3 shows the correlation results between several sonographic findings and characteristics in the median nerve. The CSA in the carpal tunnel showed a significant correlation with age (r = 0.306; $P < .05$), MCV (r = –0.655; $P < .001$), latency (r = 0.552; $P < .001$), and CMAP (r = –0.311; $P < .05$). In the wrist, the CSA was also significantly correlated with age (r = 0.266; $P < .05$), body surface area (BSA; r = 0.271; $P < .05$), MCV (r = –0.502; $P < .001$), latency (r = 0.296; $P < .05$), and CMAP (r = –0.285; $P < .05$). The percentage of the hypoechoic area showed a significant correlation with MCV (r = –0.624; $P < .001$) and latency (r = 0.595; $P < .01$).

Table 4 shows the correlation results between several sonographic findings and characteristics in the tibial nerve. The CSA in the ankle showed a significant correlation with age (r = 0.493; $P < .01$), weight (r = 0.359; $P < .05$), BMI (r = 0.454; $P < .05$), MCV (r = –0.532; $P < .01$), latency (r = 0.525; $P < .01$), and CMAP (r = –0.414; $P < .05$). The percentage of the hypoechoic area showed a significant correlation with weight (r = 0.432; $P < .05$), BMI (r = 0.432; $P < .05$), BSA (r = 0.435; $P < .05$), MCV (r = –0.565; $P < .01$), and latency (r = 0.466; $P < .05$).

The latency period of the median nerve was divided into 3 groups: latency of less than 3.5 milliseconds, latency of 3.5 to 4.0 milliseconds, and latency of greater than 4.0 milliseconds. The MCV of the median nerve was also divided into 3 groups: MCV of less than 50 m/s, MCV of 50 to 55 m/s, and MCV of greater than 55 m/s.

Table 1. Characteristics of All Participants

Parameter	Controls	Diabetic Patients
n	32	30
Male/female	25/7	17/13
Age, y	53.7 ± 13.9	59.8 ± 10.2
Height, cm	164.9 ± 6.9	161.2 ± 7.7
Weight, kg	62.6 ± 9.5	62.6 ± 10.2
BMI, %	22.6 ± 2.8	24.1 ± 2.9
Duration, y	NA	15.4 ± 10.7
HbA1c, %	NA	8.9 ± 1.9
CVRR, %	NA	1.96 ± 1.19
Presence of sensory symptoms, n (%)	NA	47 (14/30)
Bilaterally decreased or absent Achilles tendon, n (%)	NA	66.7 (20/30)
Decreased vibratory sensation, n (%)	NA	66.7 (20/30)

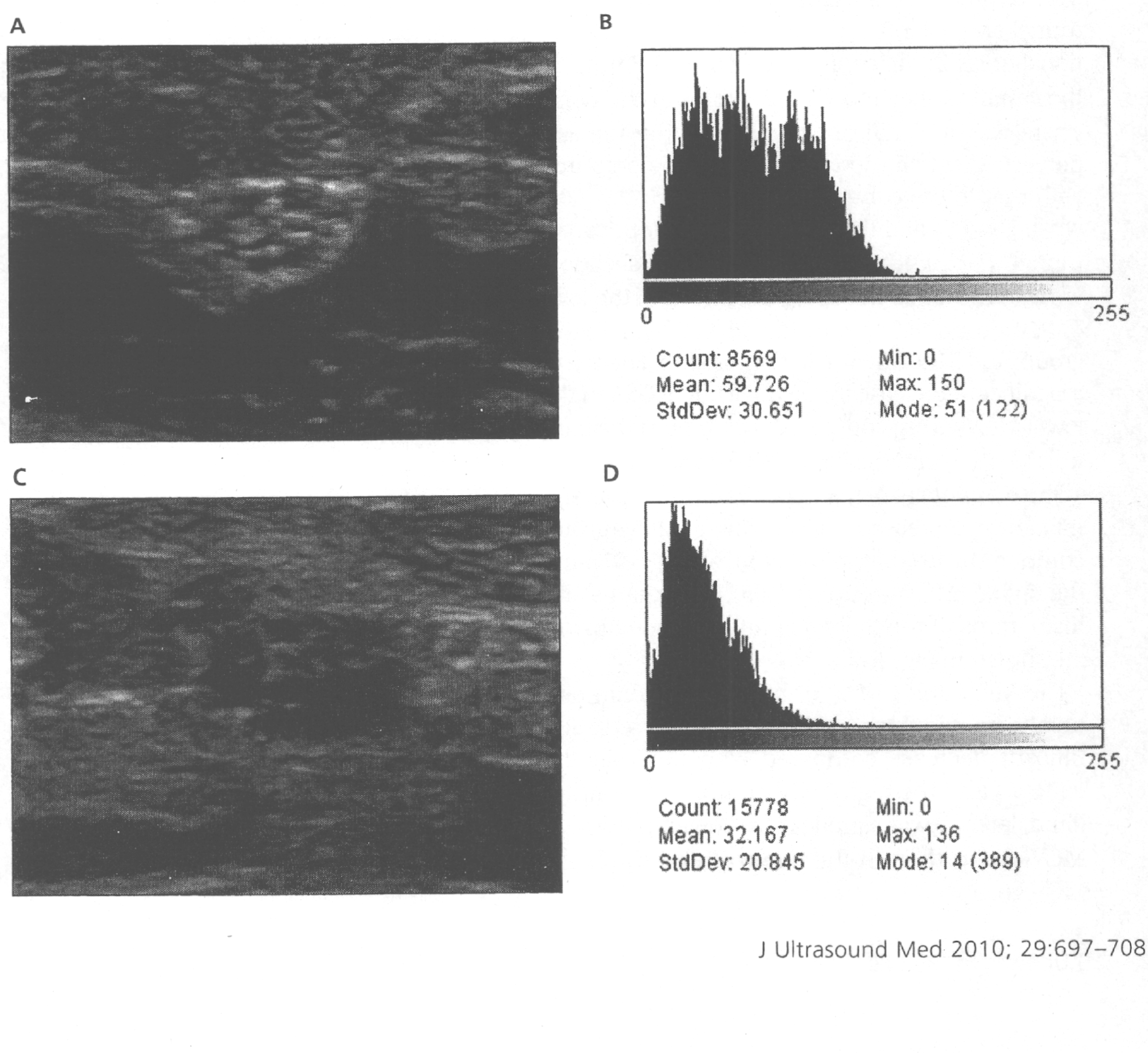
CVRR indicates coefficient of variation of R-R intervals; HbA1c, hemoglobin A1c; and NA, not applicable.

Table 2. Sonographic and Electrophysiologic Measurements of Patients With Diabetes Mellitus and Controls

	Median Nerve			Tibial Nerve		
		Diabetic Patients			Diabetic Patients	
Parameter	Controls (n = 32)	High MMCV (n = 16)	Low MMCV (n = 14)	Controls (n = 14)	High TMCV (n = 5)	Low TMCV (n = 14)
Sonographic measurements (CSA)						
Level of carpal tunnel, mm^2	8.3 ± 1.8	8.8 ± 2.1	14.0 ± 6.1[a,b]			
Level of 5 cm proximal to the wrist, mm^2	7.1 ± 2.0	6.7 ± 1.4	9.8 ± 3.7[c,d]			
Level of posterior medial malleolus, mm^2				8.9 ± 2.8	8.8 ± 2.9	15.0 ± 6.1[e,f]
Sonographic measurements (echo intensity)						
SD	31.3 ± 3.2	31.3 ± 4.5	26.0 ± 5.1[c,g]	28.3 ± 3.4	27.3 ± 1.2	26.5 ± 3.5
Hypoechoic area, %	62.3 ± 3.0	61.8 ± 5.0	72.3 ± 6.6[e,g]	57.6 ± 3.9	60.3 ± 2.7	61.4 ± 5.3
Electrophysiologic measurements						
MCV, m/s	54.9 ± 4.3	53.1 ± 2.8	45.3 ± 3.5[a,b]	50.1 ± 3.3	42.1 ± 1.9[e]	35.8 ± 2.4[a,h]
Latency, ms	3.7 ± 0.6	3.8 ± 0.5	4.7 ± 1.3[e,g]	4.1 ± 0.5	4.5 ± 0.8	5.6 ± 1.0[a,f]
CMAP, mV	13.7 ± 4.9	6.4 ± 3.2[a]	5.8 ± 3.2[a]	18.7 ± 6.8	10.3 ± 4.1[c]	5.9 ± 5.1[a]

Mann-Whitney *U* test: [a]$P < .001$ versus controls; [b]$P < .001$ versus high MMCV; [c]$P < .05$ versus controls; [d]$P < .01$ versus high MMCV; [e]$P < .01$ versus controls; [f]$P < .05$ versus high TMCV; [g]$P < .05$ versus high MMCV; [h]$P < .01$ versus high TMCV.

Figure 4. Transverse sonograms and histograms of the nerve at each level. **A**, Sonogram of the median nerve in a control participant's wrist. **B**, Histogram of the median nerve in a control participant's wrist. **C**, Sonogram of the median nerve in a diabetic patient's wrist. **D**, Histogram of the median nerve in a diabetic patient's wrist (continued).



Categorizing of participants into tertiles of latency yielded 3 separate groups. Compared with the first tertile, CSAs of the median nerve increased significantly with each tertile. Moreover, after combining tertiles of latency and the MCV, even more comprehensive CSA stratification was possible, with all CSAs ranging from 7.1 mm^2 in participants in the lowest tertile of both parameters to 14.6 mm^2 in participants in the highest tertile (Figure 5). The latency period of the tibial nerve was divided into 3 groups: latency of less than 4.5 milliseconds, latency of 4.5 to 5.0 milliseconds, and latency of greater than 5.0 milliseconds. The MCV of the tibial nerve was also divided into 3 groups: MCV of less than 40 m/s, MCV of 40 to 50 m/s, and MCV of greater than 50 m/s. The CSA of the tibial nerve stratification was 16.3 mm^2 in participants in the highest tertile for both parameters (Figure 6).

In the ROC analysis (Figure 7), the following cutoff values corresponded to the highest diagnostic accuracy: 11 mm^2 for the sonographic CSA of the carpal tunnel, 8 mm^2 for the sonographic CSA of the wrist, and 10 mm^2 for the sonographic CSA of the ankle; 62% for the hypoechoic area of the wrist and 66% for the hypoechoic area of the ankle; 52 m/s for the NCS MCV of the median nerve and 42 m/s for the NCS MCV of the tibial nerve; and 4.0 milliseconds for latency in the median nerve and 4.4 milliseconds for latency in the tibial nerve. According to the cutoff values derived from ROC analysis, the most effective sonographic parameter was the CSA of the carpal tunnel (68.2% sensitivity and 85% specificity), whereas the most effective NCS parameter was the tibial nerve MCV (87.5% sensitivity and 93.5% specificity). The sensitivity was lower with sonog-

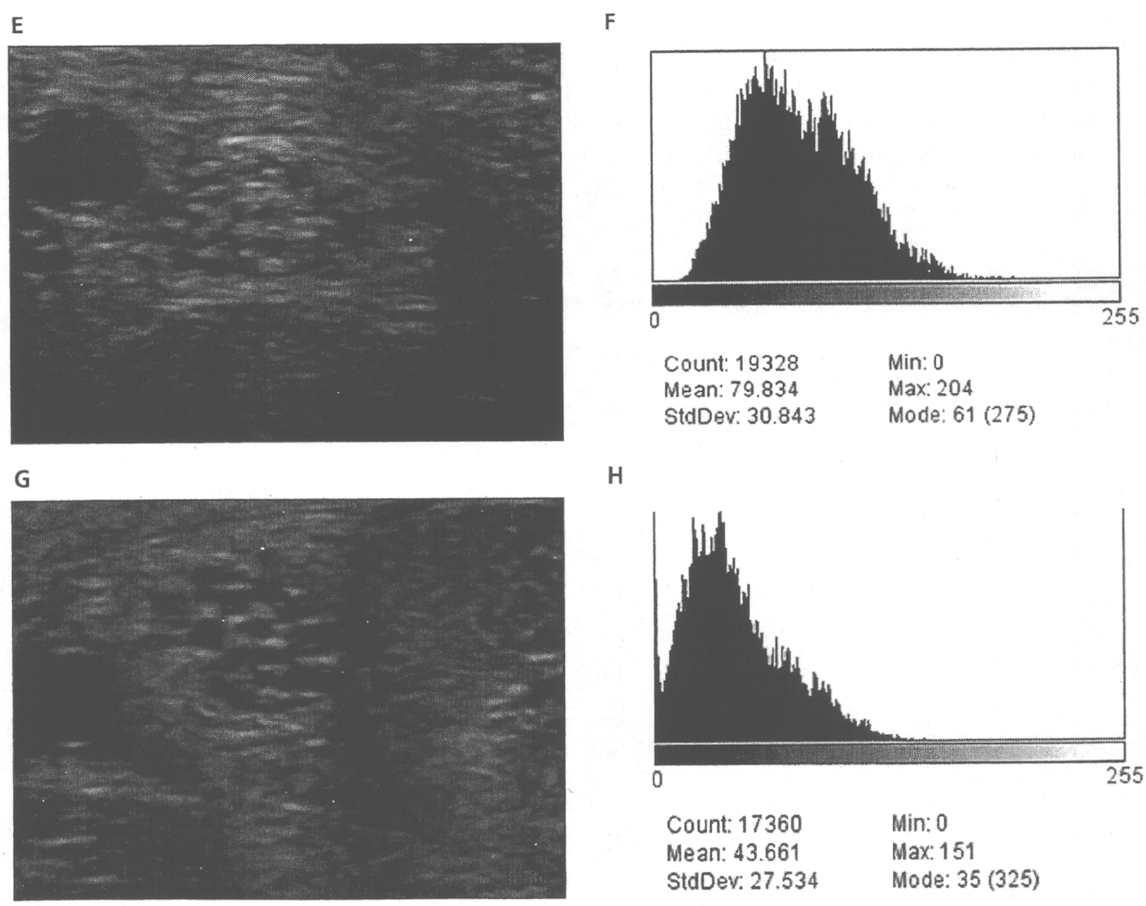


Figure 4. (continued) **E**, Sonogram of the tibial nerve in a control participant's ankle. **F**, Histogram of the tibial nerve in a control participant's ankle. **G**, Sonogram of the tibial nerve in a diabetic patient's ankle. **H**, Histogram of the tibial nerve in a diabetic patient's ankle.

Table 3. Correlation Between Several Sonographic Findings and Characteristics in the Median Nerve

	Correlation Coefficient		
	CSA		Percentage of
Parameter	Carpal Tunnel	Wrist	Hypoechoic Area
Age	0.306[a]	0.266[a]	0.358
Height	−0.041	0.187	−0.020
Weight	0.131	0.217	0.232
BMI	0.186	0.189	0.328
BSA	0.123	0.271[a]	0.182
CVRR	−0.050	0.125	0.101
HbA1c	−0.251	−0.098	0.301
Duration	0.298	0.173	−0.219
MCV	−0.655[b]	−0.502[b]	−0.624[b]
Latency	0.552[b]	0.296[a]	0.595[c]
CMAP	−0.311[a]	−0.285[a]	−0.336

The CSA and percentage of the hypoechoic area were compared with the participant's age, physical parameters, coefficient of variation of R-R intervals (CVRR), hemoglobin A1c (HbA1c) level, duration, and nerve conduction study by Pearson correlation coefficients.
[a]$P < .05$; [b]$P < .001$; [c]$P < .01$.

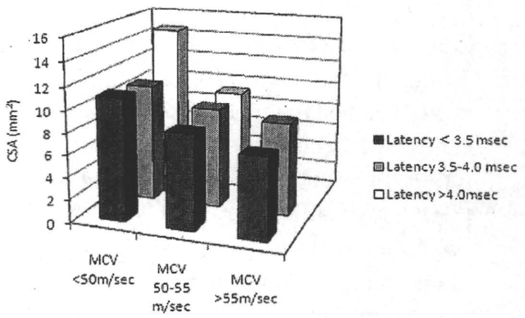


Figure 5. Cross-sectional area stratification in the median nerve by combining tertiles of latency and MCV. The CSA increased from 7.1 mm² in participants in the first tertiles of both nerve conduction study parameters to 14.6 mm² in participants in the third tertile of latency and MCV. The latency was divided into 3 groups: latency of less than 3.5 milliseconds, latency of 3.5 to 4.0 milliseconds, and latency of greater than 4.0 milliseconds. The MCV was also divided into 3 groups: MCV of less than 50 m/s, MCV of 50 to 55 m/s, and MCV of greater than 55 m/s.

raphy than NCS, but the specificity was similar between sonography and NCS (Table 5).

Discussion

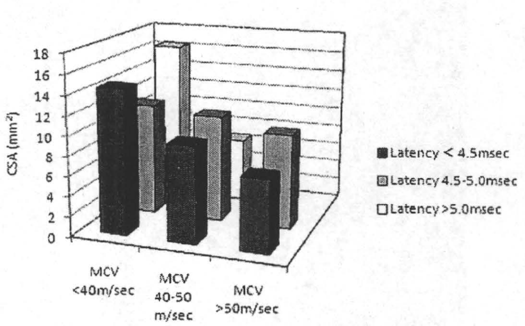
Diabetes mellitus is becoming a major cause of premature disability in Japan, and peripheral neuropathy is a common complication of diabetes.[13] The diagnosis of diabetic neuropathy is based on its characteristic symptoms and can be confirmed with NCS.[13–16] However, NCS is time-consuming, slightly invasive, and generally not well tolerated for repeated evaluations.[17] In contrast, sonographic examinations can be performed to assess peripheral nerves with less discomfort and have already been used for the evaluation of disorders of the peripheral nervous system.[4–10]

Table 4. Correlation Between Several Sonographic Findings and Characteristics in the Tibial Nerve

	Correlation Coefficient	
Parameter	CSA	Percentage of Hypoechoic Area
Age	0.493[a]	0.062
Height	−0.079	0.182
Weight	0.359[b]	0.432[b]
BMI	0.454[b]	0.432[b]
BSA	0.229	0.435[b]
CVRR	0.115	−0.038
HbA1c	0.241	0.156
Duration	0.018	−0.109
MCV	−0.532[a]	−0.565[a]
Latency	0.525[a]	0.466[b]
CMAP	−0.414[b]	−0.321

The CSA and percentage of the hypoechoic area were compared with the participant's age, physical parameters, coefficient of variation of R-R intervals (CVRR), hemoglobin A1c (HbA1c) level, duration, and nerve conduction study by Pearson correlation coefficients.
[a]$P < .01$; [b]$P < .05$.

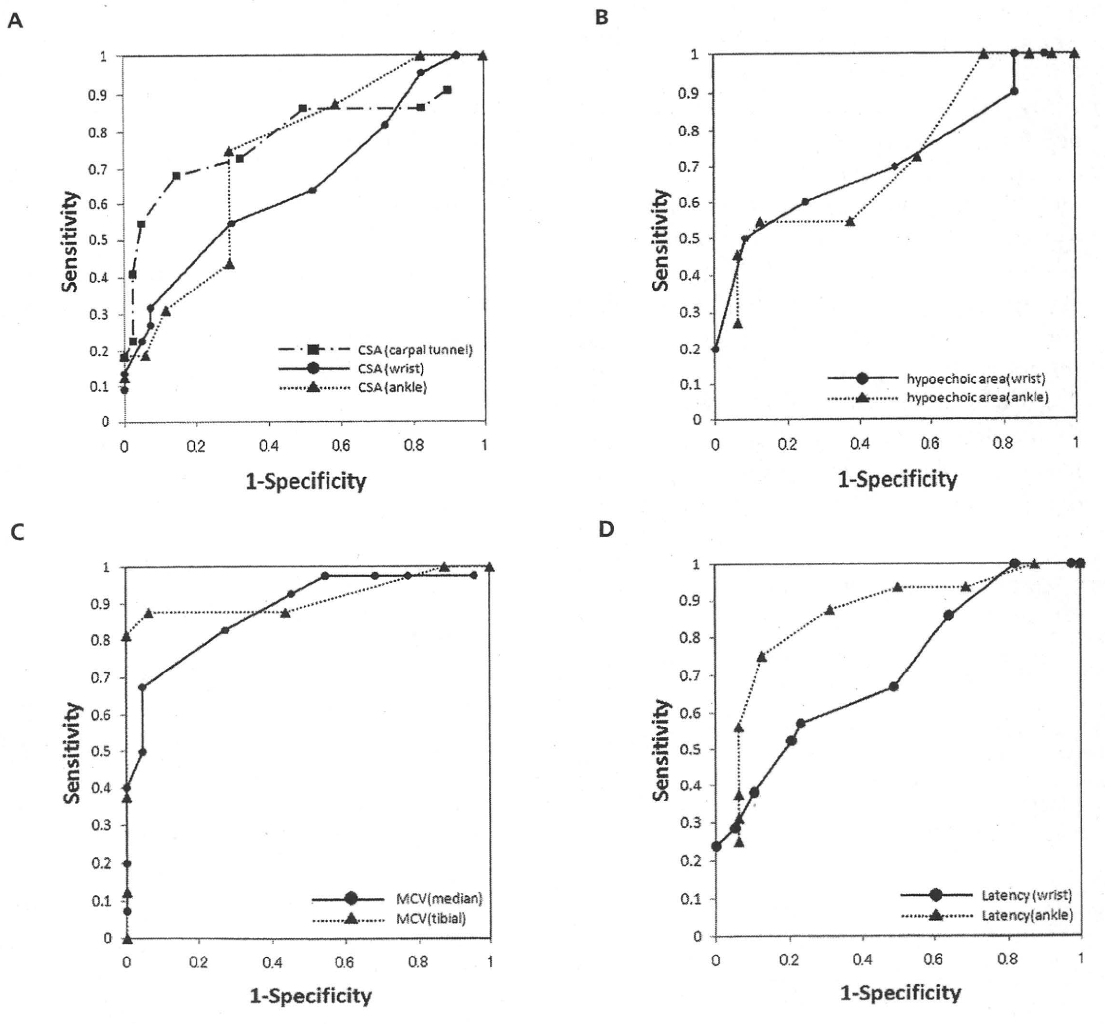
Figure 6. Cross-sectional area stratification in the tibial nerve by combining tertiles of latency and MCV. The CSA was 16.3 mm² in participants in the highest tertile of both latency and MCV. The latency was divided into 3 groups: latency of less than 4.5 milliseconds, latency of 4.5 to 5.0 milliseconds, and latency of greater than 5.0 milliseconds. The MCV was also divided into 3 groups: MCV of less than 40 m/s, MCV of 40 to 50 m/s, and MCV of greater than 50 m/s.



Conventional motor and sensory NCS has been widely used to diagnose DPN.[18–24] Symptoms of DPN appear bilaterally from the toes or the soles of the feet. Thus, NCS in the lower limbs should be more suitable to assess DPN severity. However, NCS in the lower limbs is time-consuming, and the action potential in the lower limbs sometimes cannot be evoked in cases of patients with advanced DPN. Some previous studies have reported that nerve conduction velocity slowing in the upper limbs is similar to that in the lower limbs of diabetic patients.[25,26] Skin temperature and humidity, however, easily affect the sensory nerve conduction velocity at the time of measurement. Mizumoto et al[27] reported that they chose instead to look at distal motor latency and the MCV because the sensory nerve conduction velocity was not measurable in many patients and appeared to be an unsuitable parameter. For the reasons above, we performed only the motor nerve conduction study.

Sonographic criteria for the diagnosis of neuropathy have been proposed by several studies. Cartwright et al[28] evaluated the CSA reference value studied for nerve sonography. In their study, the mean area of the tibial nerve at the

Figure 7. Receiver operating characteristic curves fitted for difference modality. **A**, When the ROC curve was fitted using sonographic CSA results, the CSA of the carpal tunnel was most effective. **B**, When the ROC curve was fitted using the sonographic hypoechoic area, the area of the tibial nerve was most effective. **C**, When the ROC curve was fitted using NCS MCV results, the MCV of the tibial nerve was most effective. **D**, When the ROC curve was fitted using NCS latency results, the latency of the tibial nerve was most effective.



ankle was 13.7 mm^2, which was greater than the value of 8.9 mm^2 that we obtained. They also reported that age and height showed weak correlations with the nerve CSA, whereas weight and BMI showed stronger correlations with the nerve CSA. Their study participants' mean BMI and weight were 26.5 and 74.5 kg, respectively, which were markedly greater than those of our participants, explaining the discrepancy with our findings. Mean normal median nerve CSA values cited in the literature vary between 6.1 and 10.4 mm^2; the difference between these normal values constitutes 51% of the normal median nerve CSA (8.4 mm^2), which is similar to our result of 8.3 mm^2.[29] The aim of our study was to evaluate whether the sonographic findings in the median and tibial nerves corresponded to the results of motor NCS in diabetic patients. We found that the CSA of both median and tibial nerves in diabetic patients were significantly larger than those in controls. Carpal tunnel syndrome and tarsal tunnel syndrome (TTS) are the most common entrapment neuropathies. A cross-sectional study of diabetic neuropathy reported by Dyck et al[16] found that polyneuropathy was the most common form of diabetic neuropathy, followed by CTS. It is well known that diabetic neuropathies are frequently asymptomatic. Kim et al[15] reported that 6.8% of diabetic patients had asymptomatic electrophysiologic CTS. The most common etiologies of TTS are mass lesions in the tunnel such as lipomas, ganglions, osteochondromas, varicosities, and synovitis because of rheumatoid arthritis or chronic uremia; however, to our knowledge, TTS is a rare complication of diabetes mellitus. Using sonography in the median nerve, Sernik et al[12] showed decreased echogenicity of the median nerve in symptomatic CTS wrists. Although sonography provides excellent detail of peripheral nerve parenchymal changes, there is currently a lack of quantitative examinations of peripheral nerve echogenicity. We therefore attempted to create a standardized quantitative analysis of sonographic images to allow a more objective assessment of nerve echogenicity in diabetic patients. This study was not designed to compare sonographic findings with histological changes; rather, the intent of this initial study was to develop a method of computer quantitation of echogenicity changes and to assess for a correlation with NCS. In our data, it appears that the percentage of the hypoechoic area of the peripheral nerve was significantly greater in lower-MCV patients with diabetes mellitus compared with controls and higher-MCV patients with diabetes mellitus. It is likely that these findings reflect pathologic changes, although the pathogenesis of nerve enlargement and an increasing percentage of the hypoechoic area in peripheral nerves are uncertain because affected median or tibial nerves have rarely been biopsied in patients with diabetes mellitus.

Table 5. Comparison of Sensitivity and Specificity Between Sonography and NCS

Parameter	Sensitivity, %	Specificity, %
Sonography		
CSA (median nerve, carpal tunnel)	68.2	85.0
CSA (median nerve, wrist)	54.5	70.0
CSA (tibial nerve, ankle)	75.0	70.6
Hypoechoic area (median nerve, wrist)	50.0	91.7
Hypoechoic area (tibial nerve, ankle)	54.5	87.5
NCS		
MCV (median nerve)	67.5	95.5
MCV (tibial nerve)	87.5	93.8
Latency (median nerve)	57.1	76.9
Latency (tibial nerve)	87.5	68.8

Diabetic neuropathy is characterized by axonal loss combined with demyelination, which is reflected in typical neuropathophysiologic findings, including reduced CMAP amplitudes combined with slowed nerve conduction. With regard to the relationship between sonography and NCS in this study, we found an increased CSA of the peripheral nerve in diabetic patients, especially those with a low MCV, compared with healthy controls. Moreover, the percentage of the hypoechoic area in the median nerve increased significantly compared with the controls and diabetic patients with a high MCV. According to ROC curve analysis, to investigate whether using sonography and NCS could judge the diagnostic accuracy for DPN, we compared the sensitivity and specificity of different modalities. Both the sensitivity and specificity were higher for NCS than sonography. These results are consistent with current widely accepted status of NCS as being more sensitive than sonography in the evaluation of polyneuropathy and CTS. However, although sonographic measurement had insufficient sensitivity, its specificity was similar to that of NCS. In addition, sonography was able to directly show morphologic change in the peripheral nerve. Compared with NCS, sonography caused less discomfort to patients and took less time. For these reasons, we have insisted on the possibility of using sonography to diagnose DPN.

Severinsen and Andersen[30] reported that the nerve conduction velocity may be reduced not only because of loss of the fastest conducting axons but also because of demyelination and acute metabolic dysregulation, which may cause lower nerve conduction velocity. Suzuki et al[31] reported that sorbitol itself and secondary sodium accumulation caused by an increase in sorbitol may be major contributors to the increase in intracellular hydration using a ^{1}H-nuclear magnetic resonance study. It has further been hypothesized that the peripheral nerve is swollen in individuals with diabetes mellitus because of increased water content related to increased aldose reductase conversion of glucose to sorbitol.[32] We hypothesize that an increased hypoechoic area of the peripheral nerve in diabetic patients may occur because of increased water content, which is also a cause of an enlarged peripheral nerve. Furthermore, our data showed that CSAs were negatively correlated with both a reduced MCV and delayed latency. Our findings may reveal that asymptomatic CTS or TTS exists in diabetic patients, and both entrapment and other factors such as metabolic or vascular causes affect DPN.

Finally, our study was an sonographic examination only; therefore, it remains unknown exactly what causes increased the hypoechoic area or CSA. In addition, there were some limitations of our study that warrant discussion because advanced sonographic techniques such as color and power Doppler imaging were not used. However, sonography is a noninvasive method that can be used to evaluate detailed nerve structures. Further studies are needed to confirm these findings in larger groups of diabetic patients and in other types of neuropathy.

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大学の禁煙推進の取り組みと学生の喫煙率変化
—10年の取り組みを経過して—

Changes in Student Smoking Rates and the Total Smoking Ban at the University:
a Follow-up of the Last 10 Years

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報　告

大学の禁煙推進の取り組みと学生の喫煙率変化 —10年の取り組みを経過して—

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Changes in Student Smoking Rates and the Total Smoking Ban at the University: a Follow-up of the Last 10 Years

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Gifu University has implemented a no-smoking policy since the last ten years. Since the annual smoking rate of students significantly increased in 1998, several measures have been taken to curb this rate. Open lectures on enlightenment were initiated. Gifu University Hospital prohibited smoking in all its buildings, and Gifu University established a working group for the promotion of the no-smoking policy in 2003. In addition, enlightenment books were provided to all the students and the faculty, and the president declared a no-smoking action in 2003. In April 2005, a total smoking ban was established in all the university-owned buildings and grounds. At the same time, an anti-smoking education program for freshmen, a quitting program for smokers, and a commendation for previous smokers who successfully quit smoking were also introduced. Owing to the abovementioned measures, the total smoking rate decreased from 15.8% in 1999 to 4.4% in 2007 in Gifu University. The smoking rates in men and women who entered the university in 1998 increased from 9.4% and 1.2% in 1998 to 32.2% and 6.4% in 2001, respectively, in the four years of under graduation. On the other hand, the smoking rates in men and women who entered the university in 2004 increased from 3.8% and 0.0% in 2004 to 13.3% and 1.1% in 2007, respectively. Such anti-smoking activities may accelerate the decrease in students' smoking rate. We report here as an example that the anti-smoking actions taken by the university had a positive effect on the health promotion of university students.

Key words：total smoking ban, smoking rate, university, support for quitting smoking
敷地内禁煙，喫煙率，大学，禁煙支援

Ⅰ．はじめに

大学生活は，下宿をしてひとり暮らしを始めたり，アルバイトやサークル活動と学業を両立させるなど，新しい生活環境の一歩を踏み出す時期である．同時に生活習慣が変化することとなるが，自分の生活習慣を親の監督下から自己管理していく能力を訓練する期間でもあると考えられる．この観点から，大学における健康増進活動は，極めて重要である．タバコ関連疾患である癌，虚血性心疾患，脳血管疾患は我が国の三大死因であり，大学時代という人生における早い時期に，喫煙を開始させないこと，喫煙学生には禁煙を促すことは生涯の健康を守るために重要である．とくに，成人する時に気軽に喫煙を開始することのないように阻止するためには，成人をむかえる年代をかかえる大学の環境は重要である．このような大学としての社会的責任ならびに学生教育における環境整備の重要性を自覚し，岐阜大学では1998年から様々な取り組みをすすめてきた．この10年間の学内敷地内禁煙をはじめとする様々な取り組みと学生喫煙率の減少結果は，学生のヘルスプロモーション向上を考える上で参考となる事例と思われる．

Ⅱ．本学の禁煙推進の取り組みについて

本学は，1998年より，学生の未成年からの喫煙開始ならびに喫煙者増加の問題に対して，保健管理センターと学生支援課が中心となって取り組んできた．同年より学生の喫煙率の調査を開始し，「タバコの害について」の啓発講演会を定期的に実施しはじめた．2001年からは保健管理センターから処方箋を発行する形でニコチン代替療法支援を開始した．しかし，ニコチンパッチ代は自己負担であったため，実際の処方数は年間数人であった．2002年からは健診の事後指導の一環として，喫煙者に個別保健指導を開始することとした．しかし，保健管理センターの呼びかけや，個別に呼び出して指導するだけでは年間２～３例にとどまり，大学全体の喫煙率には大きな効果がみられなかった．2003年からは各学会の取り組みの影響で，附属病院が建物内全面禁煙となり，これを機に全学の喫煙環境を考える動きが出てきた．病院評価の問題，禁煙外来開設，健康増進法（第25条受動喫煙の防止）の制定など多くの社会的変化の影響があり，全学的組織として学長を含む11名の委員からなる，学内禁煙推進ワーキンググループが設置された．保健管理センターでは禁煙に関する啓発冊子（学生8,000部，職員3,000部作成）を作成し全学生・職員に配布した．2004年には大学が禁煙宣言をし，喫煙学生には禁煙成功までニコチンパッチを無料提供し，保健管理センターで学生の禁煙指導を続けることとなった．このため，年間20～30例の禁煙成功者を生み，成功者には学長から表彰状を贈るようにした．2005年に大学敷地内全面禁煙を達成した．同年からは大学教育活性化経費により，全学共通教育の保健体育必修講義の１回を利用して，保健管理センターの医師が全新入学部生を対象に啓発教育を実施することとなった．年間８回開講し，保健体育の必修科目受講者が受講しやすいようにした．その結果，2005年の受講率は新入生の88.4％であった．敷地内全面禁煙後も学内で喫煙している学生は散見されており，職員が気軽に注意できるように，手渡すだけで注意を促すイエローカードを作成したり，敷地内禁煙を示す掲示板，旗を設置した．また，ホームページや保健管理センターニュースでの啓発記事の提供も続けている．以上の経緯を（表１）にまとめた．

表１　岐阜大学の禁煙対策取り組み

・1998年～2004年	：外部講師を招いての啓発講演会（２回/年）
・1998年～現　在	：喫煙率調査を実施した
・2001年～2003年	：ニコチン代替療法実施（自己負担料あり）
・2003年～2005年	：附属病院を建物内全面禁煙に
・2003年～現　在	：禁煙WG設置（学長含む11名）
・2003年	：啓発冊子を作成，全学生と職員に配布
・2004年	：禁煙宣言
・2004年～現　在	：ニコチンパッチを成功まで無料提供 成功者には学長から表彰 啓発チラシを全学生に配布
・2004年～現　在	：ホームページ上で禁煙チラシを公開
・2005年	：敷地内全面禁煙開始
・2006年～現　在	：喫煙者へイエローカードで啓発 全学共通教育必修講義で啓発
・2007年	：敷地内全面禁煙を知らせる旗を設置

Ⅲ．喫煙率調査の対象と方法

1998年度から2007年度までの10年間の定期健康診断受診時に学部学生全員に喫煙に関する質問紙調査を行ない，結果を解析した．定期健康診断は毎年２～４月に実施している．質問は「タバコについてお答え下さい」で，次の５つの選択肢の中からひとつのみ選んでもらった．即ち，①現在喫煙している（毎日，時々も含む），②禁煙にトライ中，③６ヶ月以上前に禁煙している，④過去に数本だけ吸ったが今は吸わない，⑤今まで一度も吸ったことがない，のうち①②の回答者を喫煙学生とした．喫煙学生数を受診者数で割った値を喫煙率とした．なお，回答率は回答数を在籍学生数で割った値で，図１の下部に示した．回答率は常に60％以上で，2001年以降は80％以上であった．全学生の喫煙率に加え，４年間在学中の喫煙率の変化を調べるために1998年入学，2001年入学，2004年入学学生の男女別喫煙率の変化を分析した．

Ⅳ．結　　果

1998年から調査を開始した全学生の喫煙率は，1999年の15.8％をピークに，以後，低下してきた．2004年４月の禁煙宣言，建物内全面禁煙，2005年４月の敷地内全面禁煙実施後も喫煙率は低下し，2007年には4.4％となった．入学後，学年を追うごとに学生の喫煙率の変化をみると，1998年入学者は男子で入学時の9.4％から４年生時の32.2％まで，女子で1.2％から6.4％まで増加していたが，2004年入学者は男子は入学時の3.8％から４年生時の13.3％まで，女子は0.0％から1.1％までの増加にとどまった．

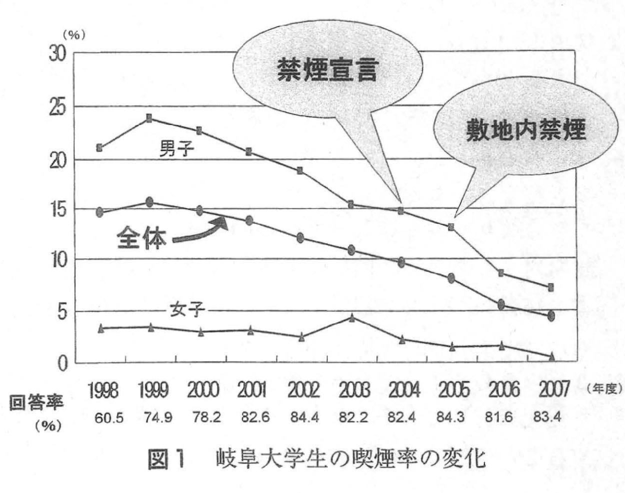

図１　岐阜大学生の喫煙率の変化

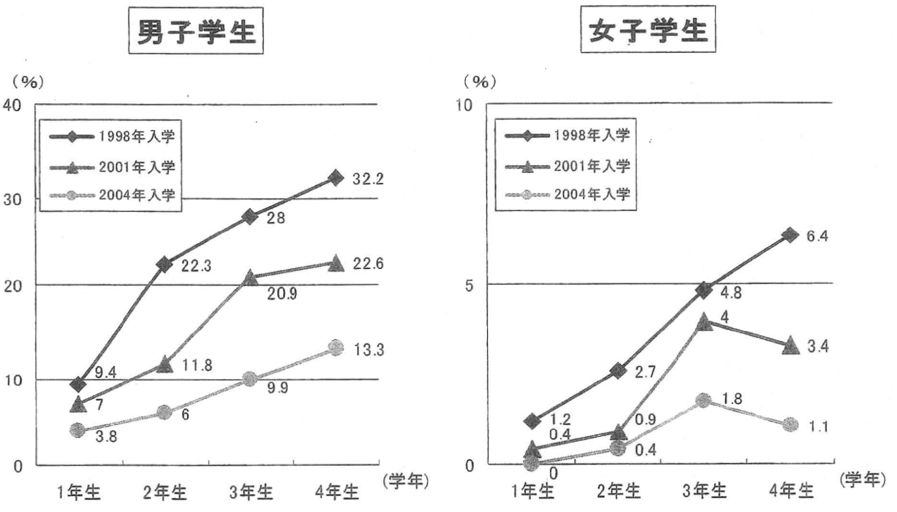

図2　1998年・2001年・2004年入学者の学年経過による喫煙率の変化

V．考　察

今回，1998年から2007年まで10年間にわたる岐阜大学の禁煙推進の取り組みと学部学生の喫煙率の変化を報告した．男女ともに年々喫煙率が低下していた（図1）上に，学年が上がるごとに増加していく喫煙率の増加程度も減少していた（図2）．学生の喫煙率の低下は，健康増進法の制定や社会啓発の進歩の影響もあり，大学環境改善だけの要因で低下したかどうかの判定は難しい．また，岐阜大学での禁煙推進のための個々の取り組みの効果，取り組みを行なわなかった場合の変化に関しては今回は検討していない．しかし，我々が大学職員に実施した調査では，喫煙者の8割が20歳代に喫煙習慣を獲得している[1]ので，大学の禁煙に対する意識改革は重要である．したがって，様々な学内の禁煙推進の取り組みと学生喫煙率の低下の事例は，他大学の学生禁煙推進の参考になるであろう．

日本の大学生の喫煙率を「学生の健康白書2005」[2]（学生の健康白書作成に関する特別委員会編集）から推察すると，2005年度の定期健診時，学部男子は，15.2%（15,539/15,539＋86,788），女子は，4.6%（2,983/2,983＋61,506）であった．これは，岐阜大学の2005年の男子喫煙率13.0%，女子喫煙率1.5%より高い値である．また，平成2004年11月に調査された「国立大学法人における喫煙対策調査報告書」[3]によると，学生喫煙率は平均16.7%であり，同年の岐阜大学は，9.6%であった．同調査報告書によると，84校からの回答のうち大学全体としての取り組みを行なっているのが53校であるものの，建物内の禁煙（建物内に喫煙場所はない）は，2004年9月で16校，「大学の敷地内禁煙（敷地内に喫煙場所はない）」は，2004年9月で2校であった．岐阜大学はこの2校のうちの1校であるので，比較的新しい取り組みをした大学として，その経過中の学生喫煙率の変化を報告することは他大学の参考になると考えた．清原と川村は，国立京都大学学部学生の喫煙率の推移を示している[4]．同大学も2000年の男子16.5%，女子3.3%から2006年の男子8.7%，女子1.2%に喫煙率は低下しており，岐阜大学と同じ傾向であった．同大学は敷地内禁煙ではないので，敷地内禁煙のみの効果で学生の喫煙率が減少したわけではなさそうである．社会要因も含め，様々な取り組みの効果が複合的に結果として表れたと考えるべきであろう．

ところで，Everett SAら[5]は，米国の大学生の調査において，70%の学生が「タバコを吸ってみたことがある」と答え，そのうち42%は喫煙者，19%は常習的喫煙者になってしまうことを報告している．常習的喫煙者の82%は禁煙を試みたことがあるものの，4人に3人は成功しなかったと報告している．この報告から常習的喫煙者の多くは，大学生の年代までに喫煙習慣を獲得していることが推察される．我々，大学の保健管理担当職は，大学内で吸ってみるということができないような環境づくりをめざすことで喫煙学生を増やさないというアプローチの実践ができるだろうと考える．環境を変化させるといかに学生の喫煙率に影響するかという科学的根拠は，現在我々の検索した限りでは明らかでなかった．ルブリン大学やカナダでの前向き検討[6,7]が進行中であるので，この結果を期待したい．我々の10年間の取り組みは比較検討が不十分であるが先進的な実践として報告価値があると考えた．

たとえ敷地内禁煙が完璧に達成されたとしても，学生にとって喫煙をはじめるきっかけは皆無ではないので，入学後にタバコを吸いはじめる学生は依然として存在する．大学内だけでなくアルバイト先など学外の影響もあるため，吸い出してしまった後の禁煙指導体制の強化も不可欠である．本学で実施した無料の支援体制やニコチン代替療法を無料で成功まで継続する体制は評価すべきと同時に，その有効性については今後の検討が必要と考えている．大学の禁煙プログラムの効果に関する先行研

究として，1994～1995年にCambridge大学とAnglia Polytechnic大学で実施されたポピュレーションスタディーがある[8]．学生たちへの聞き取りも含めた詳細な調査では，啓発ハンドブックを配布するだけでは学生の禁煙や喫煙をしはじめないというモチベーションを上げるには効果的でなく，テレビでのキャンペーンCMですら記憶はあるが考えを変えるには至らなかったことを報告している．しかし，①学内環境をすべて禁煙にすること，②喫煙者が禁煙することは難しいので支援を受けることが必要なことを学生に理解させること，③少なくとも１年以上の経験のある専門家が大学内で学生の禁煙支援を行なうこと，④安価または無料でニコチン代替治療を提供すること，のポイントが効果的であったと筆者は示している．特に，大学入学前から喫煙していた学生には，ニコチン代替療法が禁煙成功に効果的であることから，ニコチン代替療法支援にかかる費用は高価とはいえないとも述べている．禁煙環境とともに喫煙者対策の教育支援プログラムが大学では必要であることが提唱されていたので，本学の取り組みはひとつのモデルとして今回，紹介した．

敷地内禁煙措置に対する学内の反応についてであるが，我々が敷地内禁煙実施後２年目に行なった学内の調査では，７割以上の学生と職員が，「敷地内禁煙になって良かった」と回答した．１割強の学生と職員は，「かくれて吸う人がいる」「吸いがらが増えた」などの喫煙者に対する配慮の不足から，敷地内禁煙の問題点を指摘していた[9]．敷地内禁煙を含めた大学内の環境整備が学生の喫煙開始を予防する効果があると同時に，喫煙者への支援も充実させて，さらなる敷地内禁煙を達成させるという双方の取り組みを両輪のようによい関係で発展させることが重要と考えている．

Ⅵ．結　語

本学では，この10年間にわたる禁煙宣言，敷地内禁煙，無料禁煙支援体制の強化などの多様な取り組みと学生の喫煙率低下の結果事例は，大学生のヘルスプロモーションのための環境改善の事例として学校保健の参考になると考えられた．

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COLUMN

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Doctor's view

病気の"ゼロ次予防"の重要性
～新たな健診・保健指導について(第4回)～

「糖尿病予備軍の人がそのままにしていると1年に10%程度の割合で糖尿病を発症するが、積極的に生活習慣改善をすると、その発症を予防したり、時には正常に戻すぐらいの効果が期待できそうだ」という事を示した研究を前回は紹介しました。

「様々な病気の予備軍であるメタボリック症候群の人をみつけて、早くもとに戻す」のが、新たな特定健康診査・保健指導の目的ですが、本当は予備軍になることを予防することの方がもっと大切なはずです。「病気にならないよう予防すること」を"一次予防"といいます。健康診断をうけて適切な保健指導を受けたり、病気の早期発見・早期治療をすることを指します。将来、病気になって高額かつ長期の医療費が必要になることを考えると、健康診断の費用はこれよりとても少ないので、一次予防活動は国民の医療費削減のためにも効果的と考えられています。しかし、これはよく考えると、病気の予備軍になってから初めて予防を始めるようなことです。本当は「病気になりやすい状況を予防すること」がもっと大事なのです。この予防は一次予防の前段階ですから"ゼロ次予防"ともいわれます。この"ゼロ次予防"は、健康的な生活習慣を維持できるような社会全体の取り組みが重要です。たとえば、栄養バランスの良いヘルシーなメニューが身近に提供されることです。良質な外食産業は評価されるべきです。また、職員食堂ではヘルシーメニューが提供されてカロリー表示されるなど食事教育を兼ねるような社員への福利厚生も標準になってほしいものです。地域には、公園など体を動かすことのできる施設が整備されたり、職場の休憩時間にはバレーボールなどをして自然に体を動かす仲間がいるという環境づくりも"ゼロ次予防"として重要です。小学生・中学生に伝統的な和食のすばらしさを教え、健康的な生活の伝統を持つ日本人としての誇りを持ってもらう"食育"は、"ゼロ次予防"として、次世代につながる最も大事なことです。

このように考えてくると、"ゼロ次予防"の取り組みは、ごく当たり前のことのように聞こえるかもしれません。"バランスの良い食事とよく体を動かすこと"なんてあたりまえではないかと。しかし、最近はこのごくあたりまえのことを続ける事が難しい社会になっているのです。思い浮かべて下さい。以前は、"ごはん、おみそ汁、焼き魚、おひたし"が夕食の定番でした。"バターブレッド、ポタージュスープ、魚フライ、マヨネーズサラダ"と油の多い食事になっていませんか。行楽には、朝早く起きて"手作りおにぎり"を作ったものですが、便利だからと"ハンバーガーにフライドポテト"になっていませんか。お団子やおはぎなどのお菓子は年中行事などの機会を楽しみに、たまに食べたものですが、今は24時間コンビニでスイーツが手にはいる環境にあります。便利な社会になったが故に、年中いつでも油料理や甘い物など口当たりの良いものが食べられることになってしまったのです。戦後、わずか50年で日本人が1日に摂取する油の量は、3～5倍にもなったといわれています。以前は、バス停や電車の駅から歩いて帰宅したものですが、車社会となった今は、"歩く"という全身運動の時間が極端に減ってはいませんか。学校や塾にと忙しい中学生・高校生が車で送り迎えをうけているのもあたりまえの風景になってきました。

このような環境の中では、"ゼロ次予防"の取り組みが、より重要になります。たとえば、便利な外食や

特定健康診査・特定保健指導について

ファーストフード店には、野菜たっぷりのヘルシーメニューを定番にしてほしいですよね。せめてカロリーや栄養素の表示はしてほしいものです。油や砂糖がたっぷりの食品には、「これだけを食べ続けると脂肪肝・糖尿病・脂質異常症の危険が高まります」とか「これを毎日食べて肥満になっても個人責任で対応して下さい」ぐらいの警告も必要かもしれません。タバコのパッケージには肺がんや心臓病の危険について明記されているわけですから。あるいは、職場のラジオ体操の習慣やスポーツサークルの復活は自然に体を動かすチャンスをつくるという点で有用です。ノーカーデーを設定するのもエコ活動につながりますから一石二鳥ですね。

ところで、メタボリック症候群は様々な病気の"予備軍"であることを〈第2回〉でお話ししました。便利すぎる現代社会に生きる我々は、"予備軍の予備軍"といっても過言ではありません。岐阜大学の学部生約5500人に学生生活についてアンケート調査をしたところ、約50%が「運動不足だと思う」と回答しました。「食事が不規則である」「栄養が偏っていると思う」と回答したのは、自宅生で50%、下宿生は70%もいました。健康診断の結果では男子学生の14%が肥満で、これは近年 少しずつ増加しています。岐阜大学では新入生全員に採血検査を実施していますが、学生の中には、脂肪肝、脂質異常(中性脂肪やLDLコレステロール値が高い)、インスリン抵抗状態(血糖値を正常にするためにインスリンをたくさん出さざるを得ない状態)の者が少なからずおります。いずれも、肥満学生に多く、すでに生活習慣病予備軍が大学生に存在することが判明したのです。この世代は現在のメタボリック症候群世代より、もっと若いうちにメタボリック症候群ができあがってしまうかもしれません。ということは、この年代から生活習慣改善や、"ゼロ次予防"の取り組みを広げることがとても必要です。そのためには、社会全体の意識が変わることが大事です。「若いうちはいいだろう」ということはありません。"ゼロ次予防"の取り組みこそが、10年·20年…50年後の国民の健康度を変えることができるのです。みんなでがんばりましょう。

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