Original Article

Muscle Weakness

A Progressive Late Complication in Diabetic Distal Symmetric Polyneuropathy

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The aim of the study was to determine the progression of muscle weakness in long-term diabetes and its relation to the neuropathic condition. Thirty patients were recruited from a cohort of 92 diabetic patients who participated in a study on muscular function 6–8 years earlier. Nine subjects were nonneuropathic, 9 had asymptomatic neuropathy, and 12 had symptomatic neuropathy. Thirty matched control subjects who participated in the initial studies were also included. At follow-up, isokinetic dynamometry at the ankle, electrophysiological studies, vibratory perception thresholds, and clinical examination (neuropathy symptom score and neurological disability score [NDS]) were repeated. The annual decline of strength at the ankle was 0.7 ± 1.7% in control subjects, 0.9 ± 1.9% in nonneuropathic patients, 0.7 ± 3.1% in asymptomatic neuropathic patients, and 3.2 ± 2.3% in symptomatic neuropathic patients. In the symptomatic patients, the decline of muscle strength at the ankle was significant when compared with matched control subjects ($P = 0.002$) and with the other diabetic groups ($P = 0.023$). Also, the annual decline of muscle strength at the ankle was related to the combined score of all measures of neuropathy ($r = -0.42$, $P = 0.03$) and to the NDS ($r = -0.52$, $P = 0.01$). In patients with symptomatic diabetic neuropathy, weakness of ankle plantar and dorsal flexors is progressive and related to the severity of neuropathy. *Diabetes* 55:806–812, 2006

Diabetic polyneuropathy presents with sensory disturbances. Later on, motor disturbances can occur in more severe conditions, leading to distal weakness and atrophy of the muscles of the lower leg and foot. Accordingly, inability to walk on heels is used to identify diabetic subjects with this more severe degree of diabetic polyneuropathy (1). Using quantitative techniques, we observed that muscle strength is reduced at the ankle and knee and is related to the presence and severity of diabetic polyneuropathy in cross-sectional studies of type 1 and 2 diabetic patients (2,3). Also, the muscle weakness is associated with atrophy of striated muscle, probably due to insufficient reinnervation (4,5).

Duration of diabetes and poor metabolic control are well-known risk factors for development of diabetic polyneuropathy (6,7). In cross-sectional and prospective studies, a number of other risk factors have been identified, including hypertension, height, smoking, retinopathy, and microalbuminuria (8,9). In a follow-up study, high HbA_{1c}, height, female sex, and cigarette smoking were independent risk factors for progression of diabetic polyneuropathy (10). Weakness evaluated by manual testing has been reported to be an independent risk factor for the development of foot ulcers (11,12), probably because muscle weakness at the ankle and knee in diabetic neuropathy leads to abnormal application of pressure at the sole of the foot during walking (2). This indicates that motor dysfunction is of importance for this severe neuropathic complication and is relevant to monitor in the clinic and in clinical trials.

In our initial studies, patients with symptomatic neuropathy had weakness of lower leg muscles, whereas diabetic patients with either asymptomatic neuropathy or no neuropathy had normal muscle strength (3,4). No follow-up study in diabetic neuropathy has been performed with special focus on muscle weakness, though motor function assessed as part of the clinical examination has been included in some studies (13,14). Since diabetic neuropathy is progressive, we hypothesized that distal muscular function deteriorates with time in patients with symptomatic neuropathy. Therefore, we have evaluated muscle strength at follow-up 6–8 years after the initial study in diabetic patients with symptomatic neuropathy, asymptomatic neuropathy, without neuropathy, and in control subjects using isokinetic dynamometry.

RESEARCH DESIGN AND METHODS

Ninety-two diabetic patients (56 type 1 and 36 type 2 diabetic subjects) who had participated in cross-sectional studies on motor function 6–8 years earlier were identified for follow-up (2,3). All patient files in the hospital were examined to identify any disorder that had developed since the first examination and that could interfere with motor performance apart from diabetic distal symmetric polyneuropathy. Such patients were excluded from follow-up. Furthermore, patients with neuropathies other than diabetic distal symmetric polyneuropathy, such as mononeuropathies, mononeuritis multiplex, and proximal diabetic neuropathy, were not included. The remaining patients and their individually matched control subjects were identified and invited to participate. Sixteen patients were excluded due to conditions possibly interfering with motor function, including stroke (2), intermittent claudication (2), renal dialysis (2), toe amputation (1), severe retinopathy (2), multiple sclerosis (1), prosthetic knee replacement (1), acute erysipelas (1), breast cancer (1), cervix cancer treated with radiotherapy (1), use of crutches for walking (1),

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Received for publication 21 September 2005 and accepted in revised form 14 December 2005.

MNCV, motor nerve conduction velocity; NDS, neurological disability score; NSS, neuropathy symptom score; SNCV, sensory nerve conduction velocity; VPT, vibratory perception threshold.

TABLE 1
Demographic data, clinical data, and laboratory findings in the diabetic patients and the matched control subjects at follow-up

	Control subjects	Diabetic subjects			
	All	All	No neuropathy	Asymptomatic neuropathy	Symptomatic neuropathy
n	30	30	9	9	12
Sex (male/female)	21/9	21/9	4/5	8/1	9/3
Age (years)	55 (39–76)	56 (39–73)	64 (43–73)	61 (39–73)	51 (39–62)
Weight (kg)	79 (58–103)	76 (55–101)	74 (55–88)	82 (71–98)	73 (58–101)
Height (cm)	175 (160–192)	177 (158–190)	166 (158–185)	177 (160–190)	179 (163–182)
Blood glucose (mmol/l)	—	10 (2.1–23.7)	11.7 (5.2–18.4)	9.3 (2.1–18.5)	10.4 (4.2–23.7)
HbA_{1c} (%)	—	8.5 (6.5–11.1)	9.1 (6.6–10.6)	8.2 (6.5–10.2)	8.7 (7.3–11.1)
Creatinine (μmol/l)	—	89 (62–295)	86 (66–295)	94 (62–116)	99 (63–155)
Duration of diabetes (years)	—	32.5 (12–45)	28 (12–43)	28 (13–45)	34.5 (29–44)

Data are median (range).

and severe head injury (1). Three patients could not be located and 10 patients had died, leaving 63 patients for follow-up. All patients received a written invitation, and if no answer was returned a new invitation was sent. Twenty-three patients did not want to participate and 10 patients did not reply, leaving 30 patients (22 type 1 and 8 type 2 diabetic subjects) for follow-up.

At the initial studies, patients were charaterized as symptomatic neuropathic, asymptomatic neuropathic, and nonneuropathic subjects according to the minimal criteria for diabetic neuropathy (2,3). The classification applied in the initial study was used for follow-up, also. In the previous studies, the symptomatic neuropathic patient group consisted of 35 patients, the asymptomatic group of 30 patients, and the nonneuropathic group of 27 patients. In the present study, the numbers were 12 (34%), 9 (30%), and 9 (33%) patients, respectively.

Care was taken to find the exact same healthy control subjects matched with the individual patients during the initial studies. For six patients, the initial control subjects could not be evaluated, as two control subjects had developed a disorder possibly interfering with motor performance, one control subject had died, and three control subjects could not be located. Instead, six control subjects who had participated in the initial studies and who had comparable antropometric data were included. All subjects gave informed consent to the study, which was approved by the local ethics committee.

Clinical examination. Each patient was examined by the same neurologist (J.J.) as in the initial studies and evaluated according to the same neurological disability score (NDS) (15) and neurological symptom score (NSS) as applied in the initial studies. The NDS is a combined score obtained from the neurological examination of muscle weakness, activity of tendon reflexes, and degree of sensation of the great toe and index finger. The NSS includes motor, sensory, and autonomic symptoms.

Isokinetic dynamometry. Maximal voluntary isokinetic muscle strength of the ankle dorsal and plantar flexion and wrist extension and flexion was determined using the same isokinetic dynamometer as in the initial studies (Lido Active Multijoint; Loredan Biomedical, West Sacramento, CA). The same testing procedures were applied as at the initial test for all patients and control subjects (2). The dominant arm and nondominant leg were tested. Maximal strength was measured as peak torque at slow movement velocities. The participants repeated the movements eight times with a resting period between each repetition. When measuring strength at the ankle, subjects were in a sitting position, and the foot was placed on a foot plate and secured by two straps, after which maximal flexion and extension was measured. Wrist test was performed with the subjects sitting in an upright position with the forearm pronated on an arm rest. Standardized verbal feedback was given during the procedures.

Biochemical examination, quantitative sensory examination, and nerve conduction studies. At the start, a blood sample was drawn for determination of blood glucose, HbA_{1c}, and creatinine levels in all patients using standard laboratory methods.

Nerve conduction was evaluated with standardized transcutaneous stimulation and recording techniques using an electromyograph (Keypoint; Medtronic, Skovlunde, Denmark) with standard filter settings. Motor nerve conduction velocity (MNCV) was measured in the dominant forearm segment of the median (elbow to wrist) nerve and in the nondominant leg segment of the peroneal (below capitulum to ankle) nerve. Sensory nerve conduction velocity (SNCV) was measured with antidromic activation of the nondominant sural nerve and the dominant median nerve (wrist to fingers II and III). Z-scores were calculated for all MNCVs.

Vibratory perception threshold (VPT) was determined by stimulating the pulp of the index finger of the dominant hand and the corresponding area of the nondominant great toe. As in the initial study, the 4, 2, 1 stepping algoritm and a CASE IV unit was used (WR Medical Electronics, Stillwater, MN), (16).

Definitions, calculations, and statistical analyses. Change in muscle strength was calculated and expressed as a percentage of the initial value. As the time elapsed between the two examinations was not completely identical for each patient, change was calculated and expressed as a percentage (%) per year. Therefore, annual loss of muscle strength does not refer to yearly examinations of the participants, as only two observations were conducted. Values obtained from diabetic patients and control subjects were compared using an unpaired *t* test. A Kruskal-Wallis test was applied when comparing nonneuropathic patients, asymptomatic neuropathic patients, and symptomatic neuropathic patients. To estimate the associations between muscle strength and neuropathy rank-sum score and the various biochemical findings, linear regression analyses were applied. For all statistical analyses, a 5% limit of significance was applied.

RESULTS

The follow-up interval was (means ± SD) 7.5 ± 0.8 years for all diabetic subjects and 7.6 ± 1.0 years for control subjects. Demographic and clinical data for all groups are

TABLE 2
NSS and NDS data for all diabetic patients and the three subgroups at the initial study (NSS_1 and NDS_1) and at follow-up (NSS_2 and NDS_2)

	All diabetic subjects	No neuropathy	Asymptomatic neuropathy	Symptomatic neuropathy
n	30	9	9	12
NSS_1	0 (0–5)	0	0	1 (1–7)
NSS_2	1 (0–8)	0 (0–1)	1 (0–2)	2 (0–8)
NDS_1	6 (0–36)	2 (0–6)	6 (0–23)	16 (4–39)
NDS_2	12 (0–48)	2 (1–18)*	11 (0–23)*	22 (3–48)*†‡

Data are median (range). *A Kruskal-Wallis test showed that the three subgroups varied significantly ($P = 0.002$). †$P < 0.005$ compared with the nonneuropathic group. ‡$P < 0.03$ compared with the asymptomatic neuropathic group.

TABLE 3
Electrophysiological and VPT data at the initial study ($_1$) and at follow-up ($_2$)

	All diabetic subjects	No neuropathy	Asymptomatic neuropathy	Symptomatic neuropathy
n	30	9	9	12
Median nerve (m/s)				
$MNCV_1$	51 (39.8–63.6)	53.1 (43.8–63.6)	50.2 (39.8–55.7)	49.3 (45.7–56.2)
$MNCV_2$	49.3 (31.1–57.4)	51.1 (44.5–56.6)	48.2 (41–57.4)	47.1 (31.1–55.8)
$SNCV_1$	47.2 (36.2–60.3)	54.1 (43.6–60.3)	43.1 (36.2–59.6)	47.2 (39.7–53.5)
$SNCV_2$	46.4 (36–61.4)	53.2 (43.3–61.4)	46.4 (39.3–50.6)*	42.8 (36–54.1)†
Deep peroneal nerve (m/s)				
$MNCV_1$	39.5 (27.1–49.4)	42.7 (37.4–49)	39.4 (30.6–48.9)	38.1 (27.1–49.4)
$MNCV_2$	38.3 (24.7–49.9)	40.5 (30.9–47.1)	37 (24.7–49.9)	36.3 (28.7–42.3)
Sural nerve (m/s)				
$SNCV_1$	43.6 (33.4–55.8)	42.9 (33.4–55.8)	43.7 (39.7–50.3)	44.8 (38.2–55.5)
$SNCV_2$	39.3 (21.9–54.6)	45.9 (36.8–53.8)	42 (27.8–54.6)	36.8 (21.9–36.8)
VPT (percentile)				
Index finger$_1$	98 (70–99)	97 (70–99)	98 (87–99)	98 (97–98)
Index finger$_2$	95 (25–99)	96 (40–99)	75 (25–99)	98.5 (40–99)
Great toe$_1$	94.5 (47–99)	92 (47–97)	95 (63–99)	98 (63–99)
Great toe$_2$	97 (1–99)	91 (50–99)	80 (40–99)	98.5 (1–99)

Data are median (range). *$P < 0.05$, †$P < 0.01$ compared with the nonneuropathic group. VPT data are expressed as percentile values, abnormal VPTs ≥98th percentile. Number of patients in whom results were not obtainable; median nerve $SNCV_1$ (1)/$SNCV_2$ (6) and $MNCV_2$ (3), peroneal nerve $MNCV_1$ (2)/$MNCV_2$ (7), and sural nerve $SNCV_1$ (15)/$SNCV_2$ (20).

shown in Table 1. The overall diabetes duration was [median (range)] 32.5 years (12–45). No difference was found when comparing age, weight, disease duration, and metabolic control for the three patient subgroups.

NSS and NDS. NDS at the initial study was similar for participating and nonparticipating diabetic patients at follow-up. Changes of the NSS and the NDS developed between the initial study and follow-up in the three diabetic groups are presented in Table 2. It appears that the NDS differs significantly between the three diabetic groups at follow-up. Four patients from the initial group with symptomatic neuropathy had a decrease of NSS from 1 to 0, whereas six patients with asymptomatic neuropathy and four patients without neuropathy developed symptoms of neuropathy. Seven patients reported muscular weakness, which was located to the lower legs in four subjects. Clinical signs of muscular weakness were found in 10 of the diabetic participants, of whom 8 had symptomatic neuropathy. In 7 of the 10 subjects with muscular weakness, the impairment occured at the ankle.

TABLE 4
Muscle strength measurements at the initial study ($_1$) and at follow-up ($_2$)

	Control subjects	Diabetic subjects			
Movement		All	No neuropathy	Asymptomatic neuropathy	Symptomatic neuropathy
n	27	27	8	7	12
Ankle					
Dorsal flexion					
Absolute values$_1$	29.6 ± 8.2	26.3 ± 7.7	26.3 ± 9.2	30.2 ± 4.9	23.1 ± 6.6
Absolute values$_2$	29.4 ± 9.4	23.3 ± 9.1*	24.6 ± 8.3	30.1 ± 6.6	18.3 ± 8.3
Annual change	−0.4 ± 2.2	−1.6 ± 2.7	−0.5 ± 2.1	−0.5 ± 3.0	−2.8 ± 2.4
Plantar flexion					
Absolute values$_1$	105.0 ± 29.7	91.6 ± 28.2	84 ± 31.2	97.2 ± 33.5	92.8 ± 24.2
Absolute values$_2$	97.4 ± 29.1	73.7 ± 24.1†	71.5 ± 21.0	89.3 ± 21.0	66.2 ± 25.1
Annual change	−1.0 ± 2.1	−2.2 ± 3.4	−1.2 ± 3.1	−0.8 ± 4.4	−3.6 ± 2.5‡
Annual change for both movements	−0.7 ± 1.7	−1.9 ± 2.6	−0.9 ± 1.9	−0.7 ± 3.1	−3.2 ± 2.3‡
n	26	26	7	8	11
Wrist extension					
Absolute values$_1$	9.1 ± 3.4	8.4 ± 2.4	6.6 ± 2.1	9.4 ± 3.4	10.5 ± 3.3
Absolute values$_2$	8.5 ± 2.9	8.2 ± 2.2	7.4 ± 2.7	9.5 ± 2.4	7.6 ± 1.0
Annual change	−0.6 ± 3.1	−0.4 ± 2.9	−0.02 ± 2.9	−0.5 ± 4.5	−0.5 ± 1.7
Flexion					
Absolute values$_1$	16.2 ± 5.6	15.2 ± 4.1	12.4 ± 3.3	18.0 ± 5.6	17.3 ± 6.0
Absolute values$_2$	16.9 ± 5.7	15.3 ± 4.6	15.3 ± 5.7	18.3 ± 4.2	13.0 ± 2.6
Annual change	0.7 ± 2.9	−0.3 ± 2.3	1.2 ± 2.1	−0.5 ± 2.9	1.2 ± 3.0
Annual change for both movements	0.03 ± 2.6	−0.3 ± 2.3	0.6 ± 2.4	−0.5 ± 3.1	0.1 ± 2.2

Data are means ± SD. Muscle strength measurements given as absolute values (Nm) and annual change (%/year). *$P < 0.02$, †$P < 0.005$ compared with control subjects; ‡$P < 0.05$ compared with diabetic subgroups.

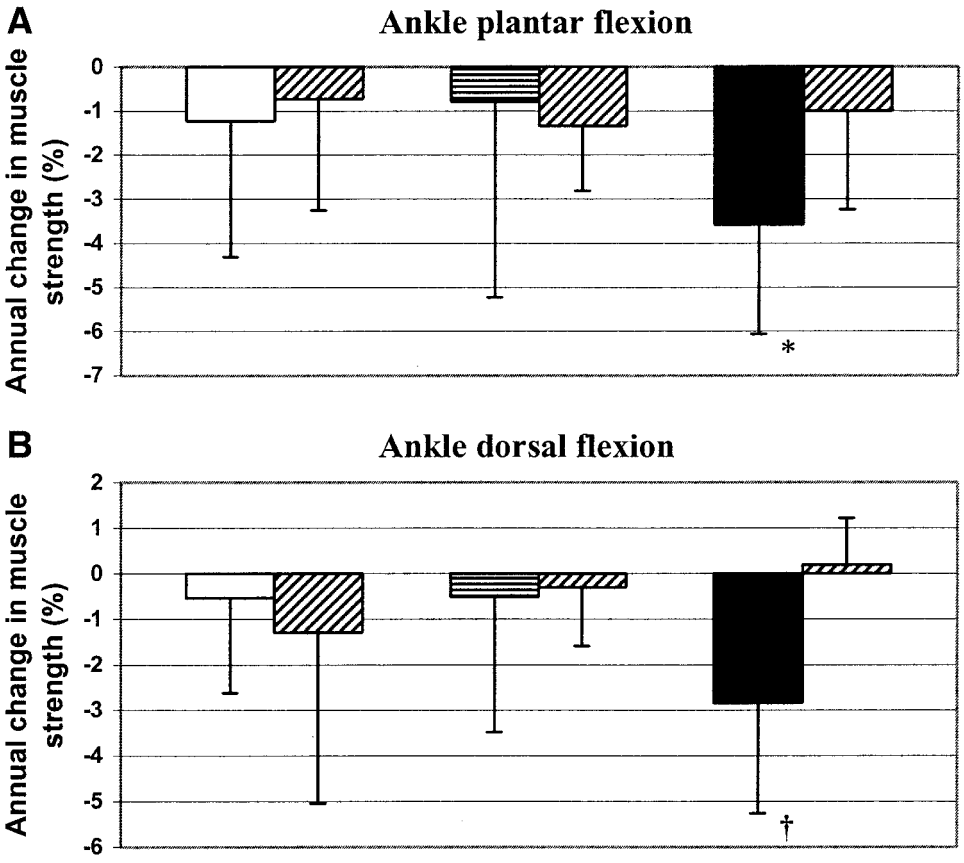

FIG. 1. Annual change in muscle strength of ankle plantar flexion (*A*) and of ankle dorsal flexion (*B*) for the three subgroups of diabetic patients and their matched control subjects. **P* < 0.02 when compared with the individually matched control subjects. †*P* < 0.002 when compared with the individually matched control subjects. □, nonneuropathic patients; ▤, asymptomatic neuropathic patients; ■, symptomatic neuropathic patients; ▨, individually matched control subjects for each patient subgroup.

Electrophysiology and vibratory perception. Electrophysiological data and VPTs are presented in Table 3. In general, functions were slightly impaired during the follow-up period. The overall annual decline of SNCV and MNCV in all diabetic patients was in the range of 0.3–0.4 m $\cdot s^{-1} \cdot year^{-1}$. Median nerve SNCV was reduced in patients with symptomatic neuropathy as well as in patients with asymptomatic neuropathy compared with patients without neuropathy. VPTs were abnormal (>98th percentile) at both the index finger and at the great toe in eight diabetic patients, of whom six had symptomatic neuropathy.

Muscle performance. In Table 4, it appears that muscle strength at the ankle of dorsal flexors and plantar flexors was reduced in the group of all diabetic patients compared with the group of all control subjects. Also, there was a tendency for impairment of the annual decline of combined muscle strength at the ankle ($P = 0.057$).

The annual decline of muscle strength at the ankle in each of the three groups of diabetic patients and in their matched control subjects are shown in Fig. 1. The decline of muscle strength was significant in the group of diabetic patients with symptomatic neuropathy, only. For plantar flexion, the annual decline was $-3.6 \pm 2.5\%$ vs. $-1.0 \pm 2.2\%$ in control subjects ($P = 0.02$) and for dorsal flexion $-2.8 \pm 2.4\%$ vs. $0.2 \pm 1.0\%$ ($P = 0.002$), respectively.

The statistical comparison of the annual decline of muscle strength at the ankle between the three diabetic patient groups is shown in Fig. 2. Plantar flexion ($P = 0.049$) and combined strength performance ($P = 0.023$) at the ankle were both significantly reduced in diabetic patients with symptomatic neuropathy compared with patients with asymptomatic neuropathy and patients without neuropathy (Kruskal-Wallis).

At the wrist, no significant differences occured neither when expressed as absolute values nor as annual decline (Table 4) of wrist extensors or flexors for the combined diabetic group. Neither were there any differences of change in muscle strength at the wrist between the three diabetic groups.

Correlations between muscle strength and other measures of neuropathy. There was a relationship between the annual decline of muscle strength at the ankle and the neuropathy rank-sum score in the combined group of all diabetic patients ($r = -0.42$, $P = 0.03$) (Fig. 3). Also, there was a relationship between the annual decline of muscle strength at the ankle and the NDS found in the initial study, in the combined group of all diabetic patients ($r = -0.52$, $P = 0.01$) (Fig. 4). There was no significant relationship between the annual decline of muscle strength at the ankle and VPT ($r = -0.14$), peroneal MNCV ($r = -0.20$), median MNCV ($r = -0.07$), or median SNCV ($r = -0.015$).

In control subjects, a relationship was established between annual decline of muscle strength and age ($r = -0.54$, $P = 0.005$), but such a relationship was not present in the diabetic patients.

DISCUSSION

In this follow-up study, we found that long-term diabetic patients with symptomatic neuropathy are subject to a progressive decline of muscle strength at the ankle, whereas diabetic patients with asymptomatic or no neuropathy preserve their muscle strength.

Several studies have documented a high prevalence of neuropathy in diabetic patients ranging from 28 to 66%, depending on the definition of the neuropathy applied (1,9,17,18). Only few studies have focused on the various types of neuropathy. In one study (1), polyneuropathy was

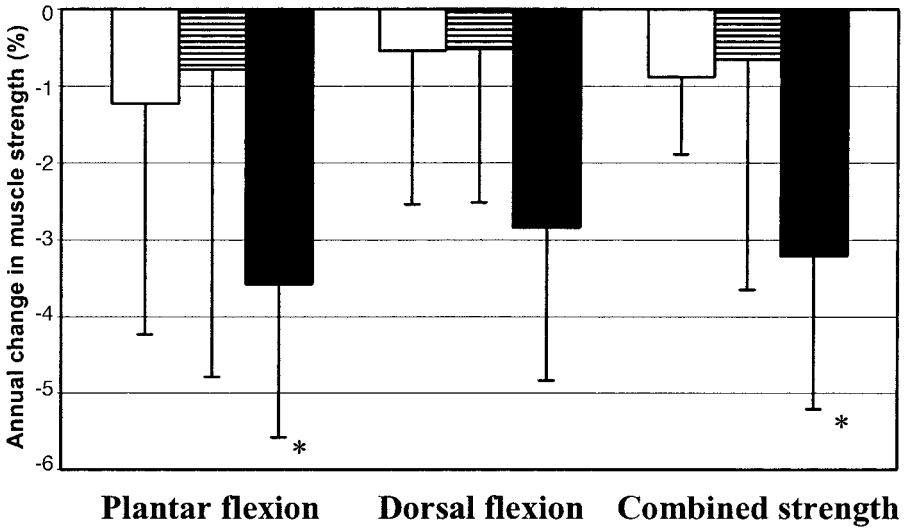

FIG. 2. Annual change in muscle strength at the ankle for three diabetic patient subgroups. *$P <$ 0.05 when comparing the diabetic patient subgroups. Data are means ± SD. □, nonneuropathic patients; ▤, asymtomatic neuropathic patients; ■, symptomatic neuropathic patients.

found in 54% of type 1 and 45% of type 2 diabetic patients and was symptomatic in 15 and 13% of the patients, respectively. Another study (18) documented a prevalence of mild autonomic neuropathy in 54 and 73% of type 1 and type 2 diabetic patients, respectively. In contrast, only 6% of the type 1 and 1% of type 2 diabetic patients had severe polyneuropathy leading to motor dysfunction with inability to walk on the heels (1). Our study indicates that motor dysfunction is an end-stage manifestation of severe polyneuropathy, with an annual decline of muscle strength of 3%.

Quantitative sensory tests and electrophysiological examinations reflect peripheral nerve function with high reproducibility (19). Therefore, these methods are well established and often used in follow-up studies (16,20–22). Quantitative muscle testing is infrequently applied in studies of diabetic neuropathy, which may be due to poor reproducibility as suggested earlier (23,24). However, in our laboratory maximal isokinetic muscle strength at the ankle can be determined with a day-to-day variation of only 3.5–5% in healthy control subjects and in patients with peripheral neuropathy (25).

When the three diabetic subgroups were combined, the annual decline in muscle strength at the ankle showed a tendency for significance, only. One female patient showed an annual increase in muscle strength of ~6% (the maximum value in Fig. 2), by far exceeding that seen in any other participant, including the control subjects. She had not changed her level of physical activity during the follow-up period, and her body weight was unchanged, indicating that the maximal strength determined at the initial study was falsely low. If this patient is excluded from the analyses, the annual decline in muscle strength at the ankle is significantly lower for the combined group of diabetic patients, also.

As only 30 patients from the original group of 92 diabetic patients participated in this follow-up study, a selection bias might have been introduced. No information was obtained from the 33 patients who did not wish to participate in this study; therefore, it remains unknown why they

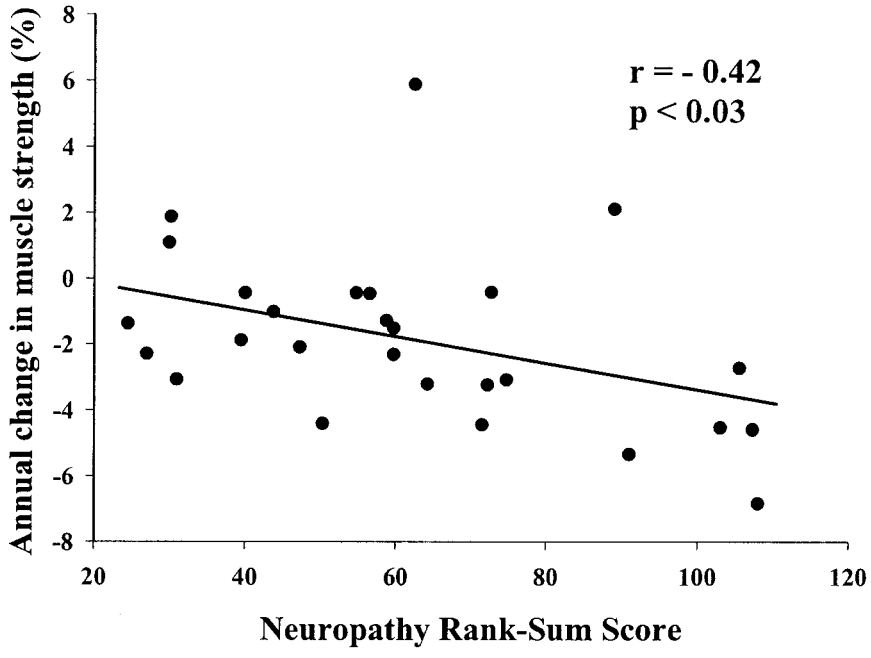

FIG. 3. Relationship between change of combined muscle strength of plantar and dorsal flexors at the ankle and the neuropathy rank-sum score in all diabetic patients.

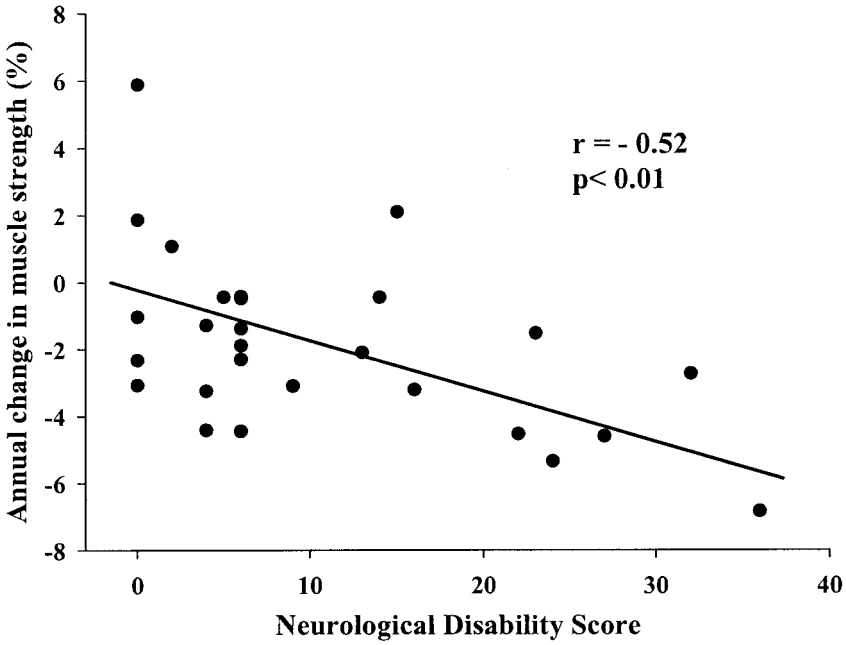

FIG. 4. Relationship between annual change of combined muscle strength of plantar and dorsal flexors at the ankle and the NDS at the initial studies in all diabetic patients.

declined to participate. However, nonparticipating and participating patients had the same NDS in the initial study. Therefore, it seems that a representative part of the patients were reevaluated. Further, approximately one-third of the patients in each of the three subgroups participated (Table 2). Long-term diabetes complications developed in a substantial number of patients during the follow-up period, and these patients were excluded. In addition, 10 patients had died during follow-up. There is reason to believe that many of these patients had severe diabetes complications, including severe neuropathy. It is possible, therefore, that the muscular decline in the group of diabetic patients with symptomatic neuropathy is underestimated.

Change in muscle strength was found to be related to age in the control subjects. This was not the case for the diabetic patients, indicating that other factors than aging are important for the loss of distal muscle strength found in symptomatic neuropathic diabetic patients.

Several studies have described impairment of gait (26–28), foot ulceration (29), and increased risk of falling (27) in neuropathic diabetic patients (30–32). Furthermore, reduced walking speed and impaired static and dynamic balance and dyscoordination in older diabetic patients with neuropathy has been observed (33). Confronted with demanding motor tasks in complex environments requiring high attention, neuropathic patients are more liable to have an unsteady gait, and, consequently, the risk of falling increases. Also, neuropathic patients produce higher forces during heel contact, which could result in an increased risk of foot ulcers (34), a feared complication in this patient group. Further, in patients with motor dysfunction, wasting of small foot muscles occurs, possibly contributing to the pathogenesis of foot ulcers (35). In addition to loss of muscle strength caused by diabetes, the patients are subject to an age-related loss of muscle mass found in healthy subjects (36). On average, healthy men and women in their 7th and 8th decades exihibit 20–40% less strength when compared with younger individuals. Also, the loss is more pronounced for even older age-groups. A qualified prediction of each individual patient's distal muscle strength followed by intervention during an early phase could prevent the accelerated loss of strength and improve quality of life in these patients.

Correlations were found between change in isokinetic muscle strength at the ankle and a standardized clinical examination for diabetic neuropathy (NDS) at the initial study. Quantitative sensory examinations and electrophysiological measurements, on the other hand, showed no correlation to change in muscle strength at the ankle. MNCVs did not correlate to loss of muscle strength, indicating that the neuropathic process involved is due to axonal loss rather than demyelination (37). This was also the case for HbA_{1c}, suggesting that a few measurements of the metabolic condition are not sufficient for prediction of loss of muscle strength at the ankle in diabetic patients. Other studies (2,38,39) have documented a relationship between neuropathy and muscle weakness, a finding that is supported by the present observation that clinical rating of neuropathy is useful for prediction of impairment of motor performance.

Isokinetic dynamometry is a sophisticated and time-consuming procedure performed in a few clinics, only. This study shows that the easily performed NDS test predicts the development of distal muscle weakness and can be used as a surrogate estimate of this complication.

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