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EPIDEMIOLOGY/HEALTH SERVICES RESEARCH

OBJECTIVE

The relation between clinical complications and social network characteristics in type 2 diabetes mellitus (T2DM) has hardly been studied. Therefore, we examined the associations of social network characteristics with macro- and microvascular complications in T2DM and investigated whether these associations were independent of glycemic control, quality of life, and well-known cardiovascular risk factors.

RESEARCH DESIGN AND METHODS

Participants with T2DM originated from the Maastricht Study, a population-based cohort study (*n* = 797, mean age 62.7 ± 7.6 years, 31% female). Social network characteristics were assessed through a name generator questionnaire. Diabetes status was determined by an oral glucose tolerance test. Macro- and microvascular complications were defined as a history of cardiovascular disease and the presence of impaired vibratory sense and/or retinopathy and/or albuminuria, respectively. We assessed cross-sectional associations of social network characteristics with macro- and microvascular complications by use of logistic regression adjusted for age, HbA_{1c}, quality of life, and cardiovascular risk factors, stratified for sex.

RESULTS

A smaller network size, higher percentages of family members, and lower percentages of friends were independently associated with macrovascular complications in both men and women. A smaller network size and less informational support were independently associated with microvascular complications in women, but not in men.

CONCLUSIONS

This study shows that social network characteristics were associated with macro- and microvascular complications. Health care professionals should be aware of the association of the social network with T2DM outcomes. In the development of strategies to reduce the burden of disease, social network characteristics should be taken into account.

Macro- and microvascular complications of type 2 diabetes mellitus (T2DM) are associated with increased disability, reduced quality of life (QoL), reduced life expectancy, and substantial economic impact for society (1). Multiple studies have shown the beneficial effects of improved blood glucose levels, blood pressure,

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cholesterol levels, smoking cessation, and other lifestyle behaviors on the risk of complications (1–3). Recent data suggest that there may be an important influence of the social network on diabetes self-management and complications (4–12). Available studies in T2DM have either focused on functional network characteristics (4,5), which include measures on social support, such as emotional support, practical support, or informational support (13), or on structural network characteristics, which refer to network size, contact frequency, or the type of relationship within the social network (14,15). For instance, higher levels of social support, a functional network characteristic, have been associated with lower blood pressure, lower LDL cholesterol, better glycemic control, and improved lifestyle behaviors (4–6). In addition, low levels of social support have been associated with the prevalence of T2DM (16), as well as with lower QoL and higher mortality in T2DM (10,11). Data from the general population have convincingly shown that a lack of social support is associated with an increased cardiovascular disease (CVD) risk (17).

Structural characteristics, such as a smaller network size, have also been associated with the prevalence of T2DM (16). In the general population, a smaller network has been associated with the incidence of stroke (18) and mortality (19), whereas in patients with a chronic condition, a wider variety of social interactions was found to support physical health and emotional well-being (7). Furthermore, in patients with T2DM with complications, a smaller network size has been associated with the incidence of chronic kidney disease and mortality (12).

Previous studies highlight the potential of social network interventions to lower the risk of diabetes complications via improved glycemic control (20). However, evidence on the direct association of functional and structural network characteristics with T2DM complications is scarce.

In view of the above, we assessed the associations of functional and structural social network characteristics with macro- and microvascular complications in T2DM and investigated whether these associations were independent of glycemic control, QoL, and cardiovascular risk factors.

RESEARCH DESIGN AND METHODS

Study Population

We used data from the Maastricht Study, an observational, prospective, population-based cohort study. The rationale and methodology have been described previously (21). In brief, the study focuses on the etiology, pathophysiology, complications, and comorbidities of T2DM and is characterized by an extensive phenotyping approach. All individuals aged between 40 and 75 years and living in the southern part of the Netherlands were eligible for participation. Participants were recruited through mass media campaigns and from the municipal registries and the regional Diabetes Patient Registry via mailings. Recruitment was stratified according to known T2DM status, with an oversampling of individuals with T2DM, for reasons of efficiency. The present report includes cross-sectional data from the first 3,451 participants, who completed the baseline survey between November 2010 and September 2013. The examinations of each participant were performed within a time window of 3 months. The study has been approved by the institutional medical ethics committee (NL31329.068.10) and the Minister of Health, Welfare, and Sport of the Netherlands (permit 131088-105234-PG). All participants gave written informed consent. In the present report, all participants with T2DM (n = 975) were included. Complete data on social network, potential confounders, and macro- or microvascular complications were available in 797 participants. The reasons for missing data were incomplete questionnaires (n = 97) and missing data on covariates and macro- or microvascular complications (n = 81) (see Supplementary Fig. 1).

Measurements

Diabetes Status

To determine T2DM, all participants (except those who used insulin) underwent a standardized 75-g oral glucose tolerance test after an overnight fast (21). T2DM was defined according to the World Health Organization 2006 criteria (22). Individuals on diabetes medication, but without type 1 diabetes mellitus, were considered to have T2DM (21).

Macrovascular Complications

Macrovascular complications were defined as a self-reported history of myocardial infarction, and/or cerebrovascular infarction or hemorrhage, and/or percutaneous artery angioplasty of the coronary arteries, abdominal arteries, peripheral arteries, or carotid artery, and/or vascular surgery on the coronary, abdominal, peripheral, or carotid arteries.

Microvascular Complications

Microvascular complications were defined as the presence of diabetic retinopathy and/or impaired vibratory sense and/or albuminuria. To determine the presence of diabetic retinopathy, fundus photography of both eyes was performed. All fundus photographs were made with a nonmydriatic auto fundus camera (model AFC-230; Nidek, Gamagori, Japan) and evaluated by a trained and experienced grader in a masked fashion, and in case of any doubt or an abnormal finding, the fundus photograph was discussed with a medical retina specialist. Based on these fundus photographs, the presence of diabetic retinopathy was graded according to the Diabetic Retinopathy Disease Severity Scale and the International Clinical Diabetic Retinopathy Disease Severity Scale (23). Fundus photography was implemented some months after the start of the Maastricht Study. In 107 participants with T2DM without fundus photographs, data could be supplemented by data from the general practitioner. The highest grade of the left or right eye was counted to dichotomize the presence of retinopathy (21).

Vibration perception thresholds (VPTs) were tested with a Horwell Neurothesiometer (Scientific Laboratory Supplies, Nottingham, U.K.) in order to assess the presence of impaired vibratory sense. VPTs were tested three times at the distal phalanx of the hallux of the right and left foot (21). The mean of the three measurements for the least sensitive foot was used in further analyses (impaired vibratory sense was defined as VPT $>$ 25 V) (24).

To assess urinary albumin excretion (UAE), participants were requested to collect two 24-h urine samples. Urinary albumin concentration was measured with a standard immunoturbidimetric assay by an automatic analyzer (due to a change of supplier, by the Beckman Synchron LX20 and the Roche Cobas 6000) and multiplied by collection volume to obtain 24-h UAE. A urinary albumin concentration below the detection limit of the assay (2 mg/L for the Beckman Synchron

LX20 and 3 mg/L for the Roche Cobas 6000) was set at 1.5 mg/L before multiplying by collection volume. Only urine collections with a collection time between 20 and 28 h were considered valid. If needed, UAE was extrapolated to 24-h excretion. For this study, UAE was preferably based on the average of two 24-h urine collections (available in >90% of the participants) (21,25). Albuminuria was defined as an albumin excretion ≥30 mg/24 h (25).

General Measurements

Self-administered questionnaires were used to assess educational level, employment status, smoking status, alcohol consumption, and diabetes duration. BMI and hypertension were measured at the study center (21). Glycosylated hemoglobin A_{1c} (HbA_{1c}) and total/HDL cholesterol were determined as described elsewhere (21). Health-related QoL was assessed with the 36-item Short Form (SF-36) Health Survey, and transformed scale scores were calculated according to Ware et al. (26).

Social Network Data Collection

Data on individual social networks were collected through a questionnaire using a name generator method, one of the most widely used instruments for examining egocentric network data (27,28). An egocentric network refers to a network centered on a specific individual (i.e., the participant), called the ego. Each person who has a relationship with the participant (ego) was defined as a network member (called alter) (27,28). The name generator/interpreter is used to map the participants' social network and to collect information about the network members (27,28). The name generator included seven questions on different types of contacts; participants were asked to name a maximum of five network members per question. Questions concerned *1*) people who advised them on problems, *2*) people who could offer them practical help if they were sick, *3*) people who provided emotional support when they were feeling unwell, *4*) people who helped them with small and larger jobs around the house, *5*) people they visited for social purposes or that they could go out with sometimes, and *6*) people with whom they could discuss important matters, and, finally, *7*) participants were asked to name a maximum number of 10 additional people who were also important for them because of mutual activities. In total, participants could name a maximum number of 40 network members. After every question and for each network member named, they were asked to indicate their frequency of contact with this person over the last 6 months (daily or weekly, monthly, quarterly, and half-yearly). Moreover, the participants were asked to identify their relationship to this person (e.g., partner, sister, friend, neighbor, etc. [28 options]), how far away this person lived, and to indicate this person's sex and age.

Functional Characteristics of the Social Network (Social Support)

Participants were asked to indicate the names of contacts who provided informational support related to advice on any problems, emotional support related to discomfort, emotional support related to important decisions, practical support related to jobs, and practical support related to sickness. For every type of support, participants could name a maximum of five network members. This results in a possible range of zero to five for the functional network characteristics.

Structural Characteristics of the Social Network

The structural network characteristics were computed from the name generator data. We calculated the social network size, contact frequency, proximity, type of relationship, single household size, and participation in social activities. In brief, network size was defined as the total number of unique network members (alters) mentioned in the questionnaire. Total contacts per half year was defined as the sum of all contacts per half year. In addition, the percentage of network members that the participant (ego) had daily/weekly contact with, that were household members, and that lived within walking distance and the percentage of network members that were family members or friends were computed. Those social network constructs of percentages within the network were defined in steps of 10% (based on an average network size of 10 network members, a change in one network member corresponds to 10%).

Single household size (living alone) was defined as a person who lived alone in his household. Participation in social activities was defined as membership in, for instance, a religious group, volunteer organization, discussion group, self-support group, internet club, or other organization. A summary of all functional and structural network characteristics can also be found in Supplementary Table 1.

Statistical Analysis

Descriptive analyses were performed to examine the characteristics of the study population. To assess the differences between participants with and without complications, we performed χ^2, independent-sample Student *t* tests, and Kruskal-Wallis tests, as appropriate.

We conducted binary logistic regression analyses to examine the association of the social network variables with macro- and microvascular complications. In all analyses, associations were assessed for macrovascular versus no complications and microvascular versus no complications. For every network variable, odds ratios (ORs) and 95% CIs were reported. For descriptive purposes, network variables were reversed, i.e., multiplied by −1 (lower values on social network variables indicated as risk factor). Associations between network variables and complications were presented in four different models, adjusted for several confounders. In earlier studies glycemic control, QoL, and cardiovascular risk factors were often associated with diabetes complications (1–3), and also with social networks in other studies (4,7–9,11). Therefore, we considered these variables as potential confounders in our analyses. Model 1 was adjusted for age and sex as important covariates in the relation between social networks and health outcomes. Model 2 was additionally adjusted for HbA_{1c} to assess the hypothesis of whether the association is explained by the level of glycemic control. Model 3 was additionally adjusted for QoL to assess whether the association is explained by differences in QoL. Model 4 was additionally adjusted for cardiovascular risk factors as possible confounders (BMI, hypertension, total-to-HDL cholesterol ratio, smoking status, educational level, and employment status). As previous studies have shown sex differences in the associations between social networks and T2DM (29–31), we tested for statistical interactions (effect modification) between the network

variables and sex. The associations between social network variables and macrovascular complications showed no interaction with sex. The majority of the associations between social network variables and microvascular complications showed an interaction with sex ($P < 0.1$); therefore, we stratified these analyses by sex. All analyses were conducted using IBM SPSS software version 21.0 (IBM Corp., Armonk, NY). A *P* value <0.05 was considered statistically significant.

RESULTS

The study population consisted of 797 participants with T2DM with a mean age of 62.7 ± 7.7 years, of whom about one-third was women (31.4%). Table 1 presents the general characteristics for the population, stratified by macro- and microvascular complication status. In total, 411 participants (51.6%) had no complications, 217 participants (27.2%) had macrovascular complications, and 254 participants (31.9%) had microvascular complications (of whom 85 participants [10.7%] had both macro- and microvascular complications). Participants with macro- or microvascular complications were somewhat older and more often men, had a longer T2DM duration, a higher HbA_{1c}, an adverse CVD risk profile, and a lower educational level, and were less often employed compared with participants without complications.

Functional Network Characteristics and Macrovascular Complications

Table 2 shows that less informational support was associated with an 11% higher odds of macrovascular complications, adjusted for age, sex, and HbA_{1c} (model 2). Additional adjustment for QoL and cardiovascular risk factors attenuated this association (OR 1.07 [0.95–1.20]). Less emotional support on important decisions was associated with a 13% higher odds of macrovascular complications (model 2). Additional adjustment for QoL and cardiovascular risk factors attenuated this association (OR 1.04 [0.91–1.21]). Less practical support with jobs around the house was associated with a 14% higher odds of macrovascular complications (model 2). Additional adjustment slightly attenuated this association (OR 1.12 [0.98–1.29]).

Structural Network Characteristics and Macrovascular Complications

A smaller network size was associated with a 6% higher odds of macrovascular complications, compared with those without complications, in the fully adjusted model (Table 2, model 4). The average social network size according to complication status is presented in Fig. 1.

Every additional 10% of the network that was contacted daily or weekly was associated with a 6% higher odds of macrovascular complications (model 2). These associations were slightly attenuated after further adjustment for QoL and cardiovascular risk factors (OR 1.06 [0.99–1.13]). Every additional 10% of the network that was a family member was associated with a 8% higher odds of macrovascular complications, and each 10% drop in the number of friends was associated with a 12% higher odds of macrovascular complications, in fully adjusted models. Living alone was associated with a 53% higher odds of macrovascular complications (model 2). Additional adjustment for QoL and cardiovascular risk factors attenuated this association (OR 1.28 [0.82–2.01]).

Functional Network Characteristics and Microvascular Complications

Table 3 shows that in women, less informational support was associated with a 33% higher odds of microvascular complications, after full adjustment (model 4). Less emotional support when feeling unwell was associated with a 33% higher odds of microvascular complications (model 3). Additional adjustment for cardiovascular risk factors slightly attenuated this association (OR 1.27 [0.95–1.71]). Less emotional support with important decisions was associated with a 27% higher odds of microvascular complications (model 2). Additional adjustment for QoL and cardiovascular risk factors attenuated this association (OR 1.14 [0.84–1.53]). In women, less practical support with jobs around the house was associated with a 41% higher odds of microvascular complications, after adjustment for age (model 1). However, additional adjustment for glycemic control, QoL, and cardiovascular risk factors attenuated this association (OR 1.29 [0.94–1.77]).

No significant associations between functional characteristics of the social network and microvascular complications were observed in men (Table 3).

Structural Network Characteristics and Microvascular Complications

In women, each fewer network member reported (smaller network size) was associated with a 15% higher odds of microvascular complications, compared with those without complications, in the fully adjusted model (Table 3, model 4). Other structural social network characteristics were not associated with microvascular complications in women. In men, living alone was associated with a 72% higher odds of microvascular complications (Table 3, model 2); this association attenuated to borderline significance after adjustment for cardiovascular risk factors (OR 1.56 [0.93–2.64], $P = 0.093$). Further, no significant associations between other structural characteristics of the social network were observed in men.

CONCLUSIONS

To the best of our knowledge, this study is the first to specifically assess the association of functional and structural characteristics of the social network with clinical complications of T2DM. A smaller social network size was associated with macrovascular complications in both men and women with T2DM. Moreover, the type of relationship in terms of family members and friends was associated with macrovascular complications; participants with higher percentages of family members or lower percentages of friends had a significantly higher OR of macrovascular complications. These associations appeared to be independent of glycemic control, QoL, and other cardiovascular risk factors. Further, a smaller social network size and less informational support was associated with microvascular complications only in women with T2DM. In men, living alone was associated with microvascular complications; however, this association was explained by QoL and CVD risk factors.

Macrovascular Complications

Functional characteristics of the social network (lower levels of informational, emotional, and practical support) were significantly associated with macrovascular complications in the models adjusted for sex, age, and HbA_{1c}. These observations are similar to previous findings by Orth-Gomér et al. (17), demonstrating that a lack of social support is a risk factor for coronary heart disease. Moreover, our findings complement

Table 1—General and social network characteristics of the study population (n = 797) stratified for the presence of macro- and microvascular complications

	No complications (n = 411)[1]	Macrovascular complications (n = 217)	P value[2]	Microvascular complications (n = 254)	P value[3]
Demographic characteristics					
Age (years)	61.5 ± 7.8	64.1 ± 7.1	<0.001	64.2 ± 7.2	<0.001
Male sex (%)	60.8	75.6	<0.001	80.7	<0.001
Educational level, low/intermediate/high (%)[4]	43.1/29.2/27.7	51.2/27.6/21.2	0.104	47.67/27.2/25.2	0.512
Employment status, employed/retired/no paid job/unknown (%)	33.1/35.5/21.4/10.0	22.1/42.9/19.8/15.2	0.010	23.6/42.5/16.9/16.9	0.002
Smoking status, never/former/current (%)	32.6/54.7/12.7	21.2/61.3/17.5	0.007	24.8/56.7/18.5	0.031
Alcohol consumption, none/low/high (%)[5]	28.0/54.6/17.3	36.1/46.3/17.6	0.087	29.1/48.8/22.0	0.233
QoL, physical component	49.3 ± 8.1	47.7 ± 10.3	<0.001	45.1 ± 10.4	<0.001
QoL, mental component	53.46 ± 8.40	51.39 ± 9.97	0.010	52.37 ± 9.55	0.135
Clinical characteristics					
BMI (kg/m^2)	29.09 ± 5.00	30.61 ± 4.72	<0.001	30.31 ± 5.03	0.002
Diabetes duration (years), median (IQR)	5.0 (3–10)[6]	7 (3–12)[7]	0.007	9 (4–17)[8]	<0.001
HbA_{1c} (mmol/mol)	49.8 ± 8.9	53.8 ± 12.3	<0.001	55.1 ± 14.3	<0.001
HbA_{1c} (%)	6.7 ± 0.8	7.1 ± 1.1	<0.001	7.2 ± 1.3	<0.001
Systolic blood pressure (mmHg)	140.0 ± 15.8	143.0 ± 18.9	0.045	145.7 ± 19.0	<0.001
Diastolic blood pressure (mmHg)	77.8 ± 9.4	75.5 ± 10.0	0.003	77.3 ± 9.5	0.505
Hypertension (%)[9]	75.2	93.1	<0.001	90.2	<0.001
Total/HDL cholesterol (mmol/L)	3.7 ± 1.2	3.7 ± 1.1	0.974	3.7 ± 1.1	0.980
Functional characteristics of the social network[10]					
Informational support	2.93 ± 1.70	2.51 ± 1.61	0.003	2.59 ± 1.70	0.013
Emotional support (discomfort)	2.32 ± 1.52	1.99 ± 1.42	0.008	2.04 ± 1.42	0.019
Emotional support (important decisions)	2.61 ± 1.58	2.19 ± 1.47	0.001	2.33 ± 1.44	0.018
Practical support (jobs)	2.55 ± 1.43	2.18 ± 1.38	0.002	2.22 ± 1.37	0.004
Practical support (sickness)	1.99 ± 1.35	1.71 ± 1.21	0.014	1.87 ± 1.25	0.283
Structural characteristics of the social network					
Network size	8.19 ± 4.58	6.59 ± 3.67	<0.001	7.12 ± 4.16	0.003
Contact frequency					
Total contacts per half year	203.0 ± 123.7	186.0 ± 125.4	0.108	182.4 ± 125.1	0.040
Percentage of daily-weekly contact	51.87 ± 27.09	56.71 ± 29.40	0.040	51.89 ± 30.28	0.994
Proximity					
Percentage of network members living within walking distance	27.23 ± 23.01	29.74 ± 27.41	0.250	28.34 ± 24.67	0.556
Type of relationship					
Percentage household members	16.82 ± 16.36	18.22 ± 19.41	0.365	17.97 ± 19.03	0.426
Percentage family members	61.97 ± 25.48	67.77 ± 28.70	0.013	63.09 ± 27.54	0.595
Percentage friends	23.86 ± 21.90	16.77 ± 20.22	<0.001	20.47 ± 22.52	0.056
Single household size (living alone) (%)	19.2	26.7	0.141	24.0	0.141
Participation in social activities (%)	43.1	42.9	0.946	42.5	0.946

Data are shown as mean ± SD, unless stated otherwise. IQR, interquartile range. [1]"No complications" was defined as absence of both macro- and microvascular complications. [2]No complications vs. macrovascular complications. [3]No complications vs. microvascular complications. [4]Low educational level was defined as no education, primary education, and lower vocational education. Intermediate educational level was defined as intermediate vocational education, higher secondary education, and vocational education. High educational level was defined as higher professional education and university. [5]Low alcohol consumption was defined as ≤7 glasses per week for women and ≤14 glasses per week for men, and high alcohol consumption was defined as >7 glasses per week for women and >14 glasses per week for men. [6]Data on diabetes duration were available in n = 286 participants. [7]Data on diabetes duration were available in n = 167 participants. [8]Data on diabetes duration were available in n = 197 participants. [9]Hypertension was defined as an office systolic blood pressure ≥140 mmHg, an office diastolic blood pressure ≥90 mmHg, and/or the use of antihypertensive medication. [10]Functional characteristics of the social network range from zero to five.

existing literature on the beneficial effects of social support on cardiometabolic control (4,5), health-related QoL (10), and mortality (11) in patients with T2DM.

A smaller social network size was independently associated with macrovascular complications in both men and women. Our results mirror previous findings in the general population, where a smaller social network has been associated with an increased risk for CVD (18). In addition, another study has shown an association of a smaller social network with poor diabetes self-management skills (9).

Further, we observed that in terms of network composition, participants with higher percentages of family members or lower percentages of friends had a significantly higher OR of macrovascular complications. The results may indicate that participants with a smaller social network that is centralized to family

Table 2—Associations of social network characteristics with macrovascular complications

	Macrovascular complications			
	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)
	Model 1	Model 2	Model 3	Model 4
Functional characteristics of the social network§				
Less informational support	1.11* (1.00–1.22)	1.11* (1.00–1.23)	1.07 (0.96–1.20)	1.07 (0.95–1.20)
Less emotional support (discomfort)	1.09 (0.97–1.23)	1.09 (0.97–1.23)	1.06 (0.93–1.20)	1.06 (0.93–1.21)
Less emotional support (important decisions)	1.13* (1.00–1.26)	1.13* (1.01–1.27)	1.07 (0.95–1.21)	1.04 (0.91–1.19)
Less practical support (jobs)	1.15* (1.01–1.30)	1.14* (1.01–1.30)	1.11 (0.97–1.27)	1.12 (0.98–1.29)
Less practical support (sickness)	1.13 (0.99–1.30)	1.13 (0.99–1.30)	1.09 (0.94–1.25)	1.08 (0.93–1.25)
Structural characteristics of the social network				
Smaller social network size (for every fewer network member)	1.08*** (1.03–1.13)	1.07** (1.03–1.12)	1.05* (1.00–1.10)	1.06* (1.00–1.1)
Contact frequency				
Total contacts per half year (for every 10 additional contacts)	1.00 (0.98–1.01)	1.00 (0.98–1.01)	1.00 (0.99–1.02)	1.00 (0.99–1.02)
Percentage of daily-weekly contact (for every additional 10%)	1.07* (1.01–1.13)	1.06* (1.00–1.13)	1.06 (0.99–1.13)	1.06 (0.99–1.13)
Proximity				
Percentage of network members living within walking distance (for every fewer 10%)	0.97 (0.91–1.04)	0.97 (0.90–1.04)	0.96 (0.89–1.03)	0.96 (0.90–1.04)
Type of relationship				
Percentage family members (for every additional 10%)	1.08* (1.01–1.15)	1.08* (1.01–1.15)	1.08* (1.01–1.15)	1.08* (1.01–1.16)
Percentage friends (for every 10% less)	1.14** (1.05–1.24)	1.15** (1.05–1.25)	1.12* (1.03–1.22)	1.12* (1.02–1.22)
Single household size (living alone) (%)	1.48 (0.99–2.21)	1.53* (1.02–2.31)	1.35 (0.88–2.08)	1.28 (0.82–2.01)
Participation in social activities (%)	0.96 (0.68–1.36)	0.96 (0.68–1.36)	1.10 (0.76–1.58)	1.11 (0.76–1.62)

Macrovascular complications $n = 217$; the reference category was no complications ($n = 411$). Model 1 was adjusted for sex and age. Model 2 was adjusted for sex, age, and HbA_{1c}. Model 3 was adjusted for sex, age, HbA_{1c}, and QoL. Model 4 was adjusted for sex, age, HbA_{1c}, QoL, hypertension, BMI, total/HDL cholesterol, smoking status, educational level, and employment status. §Functional characteristics of the social network have a range from zero to five. *$P \leq 0.05$, **$P \leq 0.01$, ***$P \leq 0.001$.

members were at higher risk to develop macrovascular complications. However, as our study was of cross-sectional nature, the order of events could also occur vice versa. Patients with macrovascular complications could lose friends and may be in need of informal care of their family members, which leads to a smaller network that is mainly composed of family members. This is similar to results from Conway et al. (32), which demonstrated that compositional changes in social networks across the life span due to illness was greatest among nonfamily members, whereas addition of network members was more likely among family members. Further (longitudinal) studies are needed to confirm our findings and address the order of events.

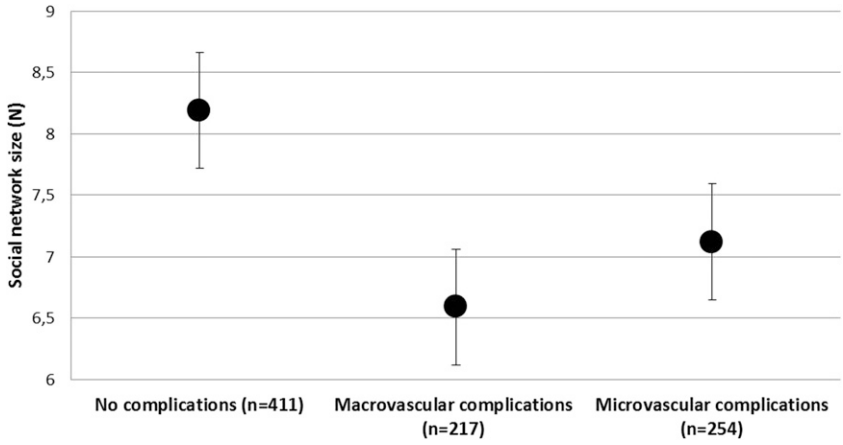

Figure 1—The average social network size according to complication status.

Microvascular Complications

In our analyses, informational, emotional, and practical support were associated with microvascular complications in women when adjusted for age. After adjustment for glycemic control, QoL, and other cardiovascular risk factors, this association was no longer significant for emotional and practical support, but the odds remained increased in the fully adjusted models. Therefore, the attenuation due to adjustment may be attributable to a lack of power, as we had a relatively small sample of women with microvascular complications ($n = 49$). In addition, the odds presented are conservative estimates, as we adjusted the associations for a broad range of potential confounders, which may be an overcorrection. Our findings on the association of social support with microvascular complications complement existing evidence on the beneficial effects of social support on glycemic control and blood pressure in T2DM (4,5), both risk factors for microvascular complications (2,3).

A smaller social network size was independently associated with higher odds of microvascular complications in women.

Table 3—Associations of social network characteristics with microvascular complications

	Microvascular complications			
	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)
	Model 1	Model 2	Model 3	Model 4
In women				
Functional characteristics of the social network§				
Less informational support	1.36** (1.10–1.68)	1.31* (1.05–1.63)	1.31* (1.04–1.65)	1.33* (1.03–1.71)
Less emotional support (discomfort)	1.45** (1.13–1.86)	1.37* (1.06–1.77)	1.33* (1.02–1.73)	1.27 (0.95–1.71)
Less emotional support (important decisions)	1.27* (1.01–1.59)	1.27* (1.00–1.62)	1.21 (0.93–1.56)	1.14 (0.84–1.53)
Less practical support (jobs)	1.41* (1.08–1.85)	1.31 (0.99–1.74)	1.26 (0.95–1.68)	1.29 (0.94–1.77)
Less practical support (sickness)	1.32 (0.96–1.81)	1.36 (0.96–1.91)	1.29 (0.92–1.83)	1.26 (0.87–1.83)
Structural characteristics of the social network				
Smaller network size (for every fewer network member)	1.15** (1.05–1.27)	1.13* (1.02–1.24)	1.10 (0.99–1.22)	1.15* (1.02–1.29)
Contact frequency				
Total contacts per half year (for every 10 additional contacts)	0.97 (0.94–1.00)	0.97 (0.94–1.01)	0.97 (0.94–1.01)	0.97 (0.93–1.00)
Percentage of daily-weekly contact (for every additional 10%)	1.09 (0.97–1.23)	1.06 (0.93–1.21)	1.01 (0.88–1.16)	1.04 (0.89–1.21)
Proximity				
Percentage of network members living within walking distance (for every fewer 10%)	0.98 (0.86–1.13)	0.99 (0.85–1.14)	0.97 (0.83–1.13)	1.01 (0.84–1.20)
Type of relationship				
Percentage family members (for every additional 10%)	1.06 (0.92–1.21)	1.02 (0.89–1.18)	0.97 (0.83–1.12)	1.05 (0.89–1.25)
Percentage friends (for every 10% less)	1.14 (0.97–1.35)	1.10 (0.93–1.31)	1.02 (0.85–1.22	1.05 (0.87–1.28)
Single household size (living alone) (%)	0.83 (0.38–1.82)	0.88 (0.39–1.90)	0.86 (0.35–2.11)	0.73 (0.27–2.00)
Participation in social activities (%)	0.88 (0.61–1.30)	0.90 (0.61–1.32)	0.95 (0.63–1.41)	0.94 (0.62–1.41)
In men				
Functional characteristics of the social network§				
Less informational support	1.01 (0.90–1.12)	1.00 (0.90–1.12)	0.96 (0.86–1.08)	0.96 (0.85–1.09)
Less emotional support (discomfort)	0.95 (0.83–1.09)	0.94 (0.82–1.08)	0.93 (0.81–1.06)	0.93 (0.81–1.07)
Less emotional support (important decisions)	0.98 (0.86–1.12)	0.98 (0.86–1.12)	0.94 (0.83–1.08)	0.93 (0.80–1.07)
Less practical support (jobs)	1.07 (0.93–1.22)	1.06 (0.93–1.22)	1.04 (0.90–1.19)	1.05 (0.91–1.21)
Less practical support (sickness)	0.98 (0.85–1.13)	0.97 (0.84–1.13)	0.92 (0.79–1.07)	0.92 (0.79–1.08)
Structural characteristics of the social network				
Smaller network size (for every fewer network member)	1.01 (0.97–1.06)	1.01 (0.96–1.05)	0.99 (0.95–1.04)	0.99 (0.94–1.05)
Contact frequency				
Total contacts per half year (for every 10 additional contacts)	1.00 (0.98–1.01)	1.00 (0.98–1.01)	1.00 (0.99–1.02)	1.00 (0.99–1.02)
Percentage of daily-weekly contact (for every additional 10%)	0.98 (0.92–1.05)	0.97 (0.91–1.04)	0.97 (0.91–1.04)	0.97 (0.91–1.04)
Proximity				
Percentage of network members living within walking distance (for every fewer 10%)	1.00 (0.93–1.09)	0.98 (0.90–1.06)	0.97 (0.90–1.06)	0.97 (0.89–1.05)
Type of relationship				
Percentage family members (for every additional 10%)	0.99 (0.93–1.07)	0.99 (0.92–1.06)	1.00 (0.93–1.08)	1.01 (0.93–1.09)
Percentage friends (for every 10% less)	1.02 (0.93–1.10)	1.01 (0.93–1.10)	1.01 (0.92–1.10)	1.01 (0.92–1.11)
Single household size (living alone) (%)	1.64* (1.02–2.62)	1.72* (1.06–2.78)	1.49 (0.91–2.45)	1.56 (0.93–2.64)
Participation in social activities (%)	0.90 (0.46–1.75)	0.98 (0.49–1.97)	1.04 (0.50–2.18)	1.41 (0.60–3.32)

In women, microvascular complications $n = 49$; the reference category was no complications ($n = 161$). In men, microvascular complications $n = 205$; the reference category was no complications ($n = 250$). Model 1 was adjusted for age. Model 2 was adjusted for sex, age, and HbA_{1c}. Model 3 was adjusted for sex, age, HbA_{1c}, and QoL. Model 4 was adjusted for sex, age, HbA_{1c}, QoL, hypertension, BMI, total/HDL cholesterol, smoking status, educational level, and employment status. §Functional characteristics of the social network have a range from zero to five. *$P \leq 0.05$, **$P \leq 0.01$.

Our results mirror the study performed by Dunkler et al. (12), which demonstrated that a smaller social network size was an independent risk factor for chronic kidney disease in patients with T2DM with end-organ damage. However, this study did not report on any sex differences. Our results extend their findings as we used a population-based sample of individuals with T2DM. Moreover, we used a more detailed investigation of the social network size with a name generator, one of the most widely used instruments for examining egocentric network data (27,28). In men, living alone was associated with microvascular complications; however, this association attenuated to a borderline significant association in the fully adjusted model. Nonetheless, we did not find any other significant associations of structural or functional social network characteristics with microvascular complications in men.

Discrepant findings between men and women have previously been found in several studies that examined the association of social network characteristics

and the development of T2DM (29–31) or metabolic control in patients with T2DM (5,33). A possible explanation is that these discrepancies may be attributable to different coping strategies among men and women, as men more frequently use problem-solving coping strategies and seek less social support, whereas women integrate social and emotional aspects more frequently into their coping strategies (34–36). This suggests that preventive strategies based on social network characteristics aiming to reduce microvascular complications should primarily be tailored to women. Yet, further research is needed to corroborate our findings in women with T2DM. In addition, the underlying mechanisms for sex-specific differences in microvascular complications should be investigated.

Strengths and Limitations

The strengths of this study include its population-based design and the comprehensive assessment of functional and structural network characteristics and macro- and microvascular T2DM complications. In addition, we used a name generator, one of the best-known, most detailed, and most widely used instruments to examine egocentric network data (27,28). Furthermore, study participants were well characterized, allowing adjustment for an extensive series of potential confounders, which makes residual confounding unlikely, and therefore conservative estimates of the actual associations are presented.

Some limitations should also be mentioned. This study was cross-sectional in nature, and therefore, causality could not be examined. In addition, nonsignificant findings in women with microvascular complications may be attributable to low power, as we had a relatively low number of women with microvascular complications in our study population.

Conclusion and Recommendations

To conclude, the current study shows that social network characteristics were associated with macro- and microvascular T2DM complications, in part independent of glycemic control, QoL, and cardiovascular risk factors.

The current study highlights the importance of social support and social network members for patients with T2DM. Health care professionals should be aware of the relation of the social network with T2DM outcomes. Knowledge of a patient's network and social support may render treatment strategies and lifestyle interventions more effective when tailored to the specific needs and network characteristics of a patient with diabetic complications. Further studies are needed to determine the potential role of network characteristics in the development of diabetic complications and their interaction with treatment. Social network characteristics may be an independent target in nonpharmaceutical and nonmedical interventions that aim to prevent the development of clinical complications in T2DM. Our findings support the efforts to develop effective interventions that tailor social network characteristics (13,37,38); however, it is important to assess whether these interventions meet the needs of patients with T2DM with complications. Based on the results of our study, we would suggest that social network size and the type of relationships and social support should be addressed in future interventions aiming to reduce the burden of disease in T2DM. For example, broadening the social network should be encouraged, as reinforcement of social networking has been shown to improve HbA_{1c} and blood glucose (37). Moreover, interventions aiming to generate behavioral change (e.g., physical activity) may also tailor to the social network of the participant, as it has been shown that network targeting can be used to increase the adoption of specific public health interventions (38). Finally, when designing such interventions, potential differences in social network characteristics between males and females should be taken into account.

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