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Research Article

Healthy Behaviors, Leisure Activities, and Social Network Prolong Disability-Free Survival in Older Adults With Diabetes

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Abstract

Background: Diabetes has been related to disability and excess mortality. We estimated the extent to which diabetes shortens disability-free survival and identified modifiable factors that may prolong disability-free survival in older adults with diabetes.
Methods: Disability-free older adults (n = 2 216, mean age: 71 years, female: 61%) were followed for up to 15 years. Diabetes was ascertained through medical examinations, medication use, or glycated hemoglobin ≥6.5% (48 mmol/mol). Disability-free survival was defined as survival until the occurrence of disability. A favorable (vs unfavorable) lifestyle profile was defined as the presence of at least 1 of the following: healthy (vs unhealthy) behaviors, active (vs inactive) engagement in leisure activities, or moderate-to-rich (vs poor) social network. Data were analyzed using Cox regression and Laplace regression.
Results: During the follow-up, 1 345 (60.7%) participants developed disability or died. Diabetes, but not prediabetes, was related to the outcome (hazard ratio [HR] 1.29, 95% CI 1.06–1.57), and 2.15 (1.02–3.27) years shorter median disability-free survival. In joint exposure analysis, disability-free survival was shortened by 3.29 (1.21–5.36), 3.92 (2.08–5.76), and 1.66 (0.06–3.28) years for participants with diabetes plus unhealthy behaviors, inactive engagement in leisure activities, or poor social network. Among participants with diabetes, a favorable profile led to a nonsignificant HR of 1.19 (0.93–1.56) for disability/death and prolonged disability-free survival by 3.26 (2.33–4.18) years compared to those with an unfavorable profile.
Conclusions: A healthy and socially active lifestyle may attenuate the risk of diabetes on disability or death and prolong disability-free survival among people with diabetes.

Keywords: Disability, Lifestyle profile, Survival, Type 2 diabetes mellitus

Type 2 diabetes mellitus (T2DM) affects 135.6 million people aged ≥65 years worldwide, and this number is projected to reach 276.2 million in 2045 (1). T2DM is associated with a higher risk of disability (2) and excess mortality (3), which have imposed a considerable economic affect on our society (1). Given population aging and the high prevalence of T2DM, identifying preventative strategies against these adverse health outcomes and prolonging survival with independence among older adults with T2DM has become a public health priority.

Accumulating evidence has shown that diabetes is associated with a 1.5- to1.8-fold increased risk of disability (2), and a 1.1- to 1.9-fold higher risk for excess mortality (3), depending on age, glycemic control, and the presence of complications. Several epidemiological studies have demonstrated the benefits of a healthy lifestyle including behaviors (such as alcohol consumption and smoking) and leisure activities, individually and jointly, on health outcomes among people with T2DM (4–7). In addition, having a moderate to rich social network has been inversely associated with physical function impairment (8), disability (9), and mortality (10). As a rich social network may decrease the risk of T2DM (11), a beneficial effect of social network on long-term outcomes secondary to T2DM could be expected. However, evidence on the association between social network and adverse health outcomes in people with T2DM is scarce.

Although lifestyle factors have been individually associated with T2DM and its complications, uncertainty remains regarding the effect of multiple lifestyle factors in combination. Because these lifestyle factors often cluster together, their synergistic effect on health may likely be greater than the effects of individual factors alone. However, the extent to which lifestyle profile can help older people with T2DM live longer without dependence is unclear. We have previously reported that participation in leisure activities and a moderate-to-rich social network may reduce the risk of dementia among people with T2DM (4). In the present study, we aimed to (a) estimate the extent to which T2DM shortens disability-free survival and (b) explore whether and to what extent a healthy lifestyle profile (including healthy behaviors, active leisure activities, and moderate-to-rich social network) can extend disability-free survival among older adults with T2DM.

Method

Study Population

The study population was derived from the Swedish National Study on Aging and Care-Kungsholmen (SNAC-K), an ongoing population-based cohort study of older adults aged ≥60 years living at home or in institutions in the Kungsholmen district of central Stockholm, Sweden. Information on data collection has been previously reported in detail (12). Briefly, 3 363 individuals were recruited to participate in the baseline examination (March 2001–June 2004). The younger old cohorts (60, 66, and 72 years) have been reexamined every 6 years and the older old cohorts (78, 81, 84, 87, 90, 93, 96, and 99+ years) every 3 years to capture more rapid changes in health status in older age.

For the current study, we included up to 15 years of follow-up data from March 2001 to December 2016. From a total population of 3 363 participants, we excluded 781 individuals with prevalent disability and 21 with type 1 diabetes at baseline. We further excluded 112 with missing information on glucose status and 412 who refused to participate in the follow-up examination, leading to a final sample of 2 216 individuals (Supplementary Figure 1).

SNAC-K was approved by the Ethics Committee at Karolinska Institutet and by the Regional Ethical Review Board in Stockholm. Written informed consent was obtained from all participants (or a proxy).

Data Collection

Information on demographics, lifestyle factors, current drug use, and medical conditions was collected based on structured assessments by trained nurses, and physicians (http://www.snac-k.se/). Peripheral blood samples were taken from all participants for laboratory tests.

Ascertainment of Prediabetes and Diabetes

Glycated hemoglobin A1c (HbA1c) was measured with Swedish Mono S filament high-performance liquid chromatography, and 1.1% was added to HbA1c values to equalize with international values based on the National Glycohemoglobin Standardization Program (13). T2DM was ascertained based on medical examination, diagnosis from the National Patient Register (NPR) (ICD-10 code E11), use of any antidiabetic medications, or HbA1c ≥ 48 mmol/mol (6.5%). Among diabetes-free participants, prediabetes was defined as HbA1c of 39–46 mmol/mol (≥5.7%–6.4%) and normoglycemia as HbA1c < 5.7% (14).

T2DM status was further categorized into controlled T2DM (HbA1c < 58 mmol/mol, 7.5%) and uncontrolled T2DM (HbA1c ≥ 58mmol/mol, 7.5%) according to the recommended glycemic targets for older adults (15).

Definition of Disability-Free Survival

Disability-free survival was defined as survival without the presence of disability during the follow-up period. Therefore, the outcome was the first occurrence of disability or death.

Participants reported their capacity to independently carry out activities of daily living (ADL) and instrumental ADL (IADL) at baseline and follow-up examinations. Caregivers were also asked to confirm these reports. Disability was considered to occur when a participant reported dependent on others for at least 1 of the 6 basic ADLs (dressing, bathing, eating, continence, toileting, and transferring) or 1 of the 8 IADLs (meal preparation, grocery shopping, housekeeping, laundry, handling money, using the telephone, using transportation, and managing medications) (16). People living in institutions were assumed to be dependent for grocery shopping, meal preparation, housekeeping, and laundry.

Information on vital status as of January 1, 2017 was obtained from the National Cause of Death Register by Statistics Sweden.

Healthy Behaviors

Behaviors included smoking status and alcohol consumption. Smoking status was categorized as never, former, or current smoking. Alcohol consumption was defined as the number of standard drinks per week, with a standard drink having roughly 12 g of alcohol. Alcohol consumption was categorized as heavy (weekly >14 standard drinks [168 g of alcohol] for men or >7 standard drinks [84 g of alcohol] for women), light-to-moderate (weekly 1–14 standard drinks [12–168 g of alcohol] for men or 1–7 standard drinks [12–84 g of alcohol] for women), and no/occasional drinking (17). Behaviors were categorized as “healthy” in the absence of current smoking and heavy drinking and “unhealthy” if either of these behaviors was present.

Leisure Activities

Information on leisure activities was collected with a self-administrated questionnaire. Participants were asked about their engagement over the last 12 months in a list of 26 predefined activities (4). As previously reported, these activities involved physical, mental, and social components (4).

Physical activities were activities that predominately have physical exercise involved, independent of mental or social engagement. Participants were asked about the types and frequency of physical exercises. A high level of activity was defined as engagement in any intense exercise (ie, jogging, long power walks, heavy-duty gardening, long bicycle rides, high-intensity aerobic, long distance ice skating, swimming, and ball sports) ≥2 times/week. A moderate level of activity was defined as moderate exercise (ie, walking along roads or in parks, walking in the woods, short bicycle rides, light aerobics, and golf) 1 time/week or engagement in a form of leisure that involves physical activity (ie, gardening, picking mushrooms/berries, hunting/fishing, home repairs, and car mechanics). A low level of physical activity was defined as engagement in any kind of aforementioned physical activity <1 time/week.

Mental activities included 6 items that primarily required cognitive stimulation and little or no social engagement, namely reading books, playing a musical instrument, listening to music, using the Internet or playing computer games, playing cards/chess, and painting/drawing/working with clay. The number of activities was summed and mental activity level was coded as low (0–1 activity), moderate (2–3 activities), or high (≥4 activities).

Social activities were those primarily involving social interactions, namely going to sports events, cinema/theater/concerts/, restaurants/bar/cafes, museum/art gallery, dancing, bingo, traveling, attending church meetings, study circle or courses, volunteering, and other social meetings. Level of engagement in social activities was defined as low, moderate, or high if participants reported 0, 1, or ≥2 activities, respectively.

Finally, for each component (physical, mental, and social), participants were given a score of 0, 1, or 2 for low, moderate, or high levels of engagement, respectively. A final leisure activities index was created by summing the mental, physical, and social activities component scores (range: 0–6). Overall leisure activity level was further coded as low (score 0–1), moderate (score 2–3), or high (score 4–6) (4). The latter 2 groups were similarly related to the outcomes, and were therefore combined as "active" (moderate/high) versus "inactive" (low) in subsequent analysis.

Social Network

Data on social network was collected at baseline in a self-administered questionnaire focused on social connections and social support (18). Social connections were measured by asking participants about marital status, cohabitation status, parenthood, friendships, and the frequency of direct or remote contact with friends, children, relatives, and neighbors. Social support was measured by asking participants about their satisfaction with these aforementioned contacts, perceived material and psychological support, sense of affinity with association members, relatives, and residence area, and being part of a group of friends.

Scores for social connection (5 items) and social support (5 items) were standardized based on baseline means and standard deviations (z scores), and a social network index was computed by averaging these 2 measures. Social network index was further divided by distribution into tertiles and interpreted as poor (≤ −0.14), moderate (−0.13 to 0.30), and rich (>0.30). The latter 2 groups were similarly associated with the outcomes, and thus were merged as "moderate-to-rich" versus "poor" in subsequent analysis.

Finally, a "favorable lifestyle profile" was defined as the presence of at least 1 of the following: healthy behaviors, active leisure activities, and moderate-to-rich social network (vs "unfavorable" otherwise). This dichotomization into a favorable and unfavorable group is due to small sample size in some subgroups of participants and for ease of interpretation. In addition, there was a tendency for those with presence of at least 1 optimal factor to be associated with a reduced risk of disability or death.

Covariates

Age at baseline was categorized into 4 age groups (60–69, 70–79, 80–89, and 90+ years). Education level was measured as the maximum level of formal schooling and classified as elementary school, high school, or university (19). Participants were asked if they lived alone in their household.

Weight and height were measured in participants without shoes and heavy clothes, and body mass index (BMI) was calculated as weight divided by the square of height. Arterial blood pressure was measured twice from the left arm with a sphygmomanometer at a minimum 5-minute interval. Systolic and diastolic blood pressure (SBP and DBP) were determined by the average of the 2 readings. Hypertension was defined as SBP ≥140 mm Hg, DBP ≥90 mm Hg, or the use of antihypertensive drugs. High total cholesterol was defined as a nonfasting total cholesterol of ≥6.22 mmol/L or the use of cholesterol-lowering agents.

Information on chronic diseases such as cardiovascular diseases (including atrial fibrillation, ischemic heart disease, heart failure, cardiac valve disease, bradycardias, and conduction diseases), cerebrovascular diseases, and depression was obtained through clinical examinations, medication use, and records from the NPR (20). Global cognitive function was tested using the Mini-Mental State Examination (MMSE) (4).

Statistical Analysis

Baseline characteristics by glycemic status were compared using chi-square tests for categorical variables and one-way ANOVA tests with Bonferroni correction for continuous variables.

Incidence rates (IRs, per 1 000 person-years) and 95% confidence intervals (CIs) of the composite outcome of disability or death were calculated as the number of the events divided by person-years at risk during the follow-up. Participants were considered at risk until the occurrence of disability, death, or end of follow-up. Cox proportional hazard models with age as the timescale were used to estimate hazard ratios (HRs) and 95% CIs for the composite endpoint associated with glycaemic status and modifiable factors, separately. Basic-adjusted models controlled for age group, sex, and education level (Model 1), and multi-adjusted models additionally controlled for living arrangement, BMI, and the presence of cardiovascular diseases, cerebrovascular diseases, hypertension, and depression (Model 2).

Statistical interactions between behaviors, leisure activities, social network, and glycaemic status for the risk of the outcome were assessed in 3 separate Cox regression models. First, we examined whether behaviors, leisure activities, or social network play a role in the association between T2DM and disability or death. Second, we performed joint exposure analysis to examine whether these factors could modify the association of T2DM with the composite endpoint. This is done by creating an indicator variable with the cross-product of T2DM status (yes vs no) and the level of behaviors (unhealthy vs healthy), leisure activities (active vs inactive) or social network (moderate-to-rich vs poor). Finally, based on the combination of the lifestyle profiles (favorable vs unfavorable) and T2DM status, 4 groups were created: (a) T2DM-free with favorable profile; (b) T2DM-free with unfavorable profile; (c) T2DM with favorable profile; and (d) T2DM with unfavorable profile. Statistical interactions were examined by creating an indicator variable with the cross-product of the exposure and the level of lifestyle factors. The proportional hazard assumption was tested by Schoenfeld residuals and no violation of proportionality was shown.

In order to quantify absolute differences in survival, we used Laplace regression to model the median age at the composite endpoint (21). During the study period, 60% of participants developed the outcome, and we therefore assessed the adjusted survival percentiles in the observed range (1st–60th). We estimated differences in the median age by which the first 50% of the population developed the outcome, herein referred to as median disability-free survival. These models were adjusted for the same set of covariates as mentioned above. Analyses were carried out using Stata, version 15 (College Station, TX, Stata Press, Stata Corp, 2015) with a 2-sided p value of <0.05 indicating statistical significance.

Results

Among the 2 216 participants, the mean (standard deviation [*SD*]) age was 71.3 (9.4) years, and 1 354 (61.1%) were female. Of all participants, 746 (33.6%) had prediabetes and 176 (7.9%) had T2DM at baseline. Compared to participants with normoglycemia, those with prediabetes or T2DM were more likely to be older and less educated, to have higher BMI, hypertension, cerebrovascular diseases, and cardiovascular diseases, to consume less alcohol, and to be less likely to engage in leisure activities and have a moderate-to-rich social network (Table 1).

Of 2 216 participants at baseline, 746 had prediabetes and 176 had T2DM. During a mean (*SD*) follow-up of 9.4 (4.6) years, 1 347 participants developed the outcome, including 789 with incident disability and 558 who died. In Cox regression analysis, participants with T2DM had almost 30% (HR 1.29, 95% CI 1.06–1.57) higher risk of disability or death compared to those with normoglycemia after adjustment for sociodemographic factors, BMI, SBP, depression, cerebrovascular diseases, and cardiovascular diseases. Prediabetes was not significantly related to the outcome.

In multivariable-adjusted Laplace regression models, relative to normoglycemia, the median age at disability or death was 2.1 years younger among those with T2DM (−2.15, 95% CI −3.27 to −1.02), and 2.5 years younger for those with uncontrolled T2DM (−2.53, 95% CI −4.82 to −0.24). Moreover, participants who had healthy behaviors had a lower risk (HR 0.68, 95% CI 0.60–0.78) of developing the outcome, and did so at an older median age (2.38, 95% CI 1.53–3.22) compared to those who had unhealthy behaviors. A lower risk and an older median age of developing the composite outcome was also observed in those with active engagement in leisure activities (HR 0.78, 95% CI 0.67–0.90; 1.91 years, 95%

Table 1. Baseline Characteristics of Participants by Glycemic Status (n = 2 216)

	Normoglycemia (n = 1 293)	Prediabetes (n = 746)	T2DM (n = 176)	p Value
Age (years)	70 (±9.0)	73 (±9.8)*	73 (±8.9)*	<.001
60–69	708 (54.7)	297 (39.8)	66 (37.5)	<.001
70–79	380 (29.4)	255 (34.2)	66 (37.5)	
80–89	159 (12.3)	145 (19.4)	36 (20.5)	
90+	47 (3.6)	49 (6.6)	8 (4.6)	
Female sex	798 (61.7)	475 (63.7)	81 (46.0)	<.001
Education level				
Elementary	146 (11.3)	102 (13.7)	30 (17.1)	<.001
High school	599 (46.4)	392 (52.6)	97 (55.1)	
University	546 (42.3)	252 (33.8)	49 (27.8)	
Living alone	638 (49.6)	411 (55.2)	93 (53.5)	.047
Body mass index (kg/m^2)	25 (±3.7)	26 (±3.9)*	28 (±4.3)*	<.001
Hypertension	917 (70.8)	560 (75.1)	153 (86.9)	<.001
High total cholesterol	641 (51.4)	414 (55.7)	90 (51.7)	.182
Depression	93 (7.2)	48 (6.4)	13 (7.4)	.790
Cerebrovascular diseases	42 (3.3)	38 (5.1)	12 (6.8)	.024
Heart diseases	182 (14.1)	156 (20.9)	64 (36.4)	<.001
Smoking status				.073
Never smoker	602 (46.8)	312 (42.1)	77 (44.5)	
Ever smoker	513 (39.8)	301 (40.5)	74 (42.8)	
Current smoker	171 (13.3)	129 (17.4)	22 (12.7)	
Alcohol consumption				<.001
No or occasional	292 (22.7)	246 (33.2)	65 (37.4)	
Light to moderate	741 (57.5)	365 (49.2)	86 (49.4)	
Heavy	255 (19.8)	131 (17.6)	23 (13.2)	
Leisure activities				.020
Low	280 (23.6)	201 (29.9)	46 (29.9)	
Moderate	566 (47.6)	306 (45.5)	73 (47.4)	
High	342 (28.8)	166 (24.7)	35 (22.7)	
Social network				.074
Poor	314 (25.2)	185 (26.2)	52 (31.3)	
Moderate	425 (34.2)	271 (38.3)	52 (31.3)	
Rich	508 (40.7)	251 (35.5)	62 (37.4)	

Notes: Data are n (%) or means ± *SD*. Missing data: 31 in body mass index, 14 in smoking status, 22 in alcohol consumption, 94 in social network, and 281 in leisure activities.

*Pairwise means comparison with Bonferroni correction: p < .05 (reference = normoglycemia).

Table 2. Incidence Rate (per 1 000 person-years), Hazards Ratios (HRs), 95% Confidence Interval (CI), and Difference in Median Age at Developing Composite Endpoint (Disability or Death), According to Glycemic Status and Modifiable Factors

		Cox Regression*			Laplace Regression*	
Factors	No. of Events	IR (95% CI)	HR (95% CI)*	HR (95% CI) †	Difference in Median Age*	Difference in Median Age†
Normoglycemia	723	56.9 (52.9, 61.2)	Reference	Reference	Reference	Reference
Prediabetes	489	74.4 (68.1, 81.3)	1.02 (0.91, 1.15)	1.00 (0.89, 1.13)	0.20 (−0.56, 0.98)	0.20 (−0.64, 1.04)
T2DM	133	89.2 (75.2, 105.6)	1.40 (1.16, 1.69)	1.29 (1.06, 1.57)	−2.51 (−3.78, −1.25)	−2.15 (−3.27, −1.02)
Controlled (<7.5%)	102	91.5 (75.4, 111.2)	1.34 (1.08, 1.66)	1.27 (1.02, 1.58)	−1.73(−3.49, 0.03)	−1.60 (−3.21, 0.00)
Uncontrolled (≥7.5%)	30	81.6 (57.1, 116.7)	1.61 (1.11, 2.32)	1.34 (0.89, 2.00)	−3.81 (−5.69, −1.92)	−2.53 (−4.82, −0.24)
Smoking						
Yes (current smoker)	197	65.7 (57.1, 75.5)	Reference	Reference	Reference	Reference
No (current smoker)	1 139	64.5 (60.9, 68.4)	0.68 (0.59, 0.79)	0.66 (0.56, 0.78)	2.60 (1.67, 3.55)	2.69 (1.71, 3.68)
Former smoker	509	59.1 (54.2, 64.5)	0.70 (0.59, 0.83)	0.68 (0.57, 0.80)	2.19 (1.14, 3.21)	2.24 (1.15, 3.33)
Never smoker	630	69.7 (64.4, 75.3)	0.66 (0.56, 0.78)	0.65 (0.55, 0.77)	2.83 (1.81, 3.85)	2.73 (1.67, 3.80)
Alcohol						
Heavy	246	64.1 (56.6, 72.6)	Reference	Reference	Reference	Reference
No heavy	1 088	64.4 (56.6, 72.7)	0.79 (0.68, 0.91)	0.77 (0.67, 0.89)	1.63 (0.59, 2.69)	1.89 (0.92, 2.86)
Light to moderate	649	54.4 (50.4, 58.8)	0.76 (0.65, 0.88)	0.76 (0.65, 0.88)	1.60 (0.46, 2.75)	1.74 (0.68, 2.79)
Occasional or no	439	88.7 (80.7, 97.3)	0.83 (0.71, 0.98)	0.79 (0.66, 0.93)	1.63 (0.43, 2.81)	1.93 (0.79, 3.07)
Behaviors‡						
Unhealthy	387	65.4 (59.2, 72.3)	Reference	Reference	Reference	Reference
Healthy	941	64.0 (60.1, 68.2)	0.71 (0.63, 0.81)	0.68 (0.61, 0.78)	2.27 (1.43, 3.11)	2.38 (1.53, 3.22)
Leisure activities						
Inactive	378	69.5 (65.2, 74.1)	Reference	Reference	Reference	Reference
Active	812	43.0 (38.0, 48.6)	0.77 (0.66, 0.89)	0.78 (0.67, 0.90)	2.12 (0.97, 3.26)	1.91 (0.85, 2.97)
Moderate	560	61.2 (56.7, 66.9)	0.87 (0.76, 1.00)§	0.87 (0.76. 1.00)ǁ	0.66 (−0.48, 1.76)	0.89 (−0.01, 1.81)
High	252	43.0 (38.0, 48.6)	0.71 (0.59, 0.83)	0.71 (0.60, 0.85)	2.58 (1.15, 4.01)	2.50 (1.32, 3.68)
Social network						
Poor	402	92.0 (83.5, 101.5)	Reference	Reference	Reference	Reference
Moderate-to-rich	877	55.9 (52.3, 59.8)	0.71 (0.63, 0.80)	0.75 (0.66, 0.86)	1.82 (0.98, 2.65)	1.36 (0.50, 2.22)
Moderate	448	62.1 (56.6, 68.1)	0.72 (0.63, 0.83)	0.76 (0.66, 0.87)	1.72 (0.76, 2.68)	1.16 (0.31, 2.02)
Rich	429	50.7 (46.1, 55.7)	0.70 (0.61, 0.81)	0.75 (0.64, 0.87)	1.79 (0.80, 2.80)	1.57 (0.45, 2.69)

Notes: *HR adjusted for baseline age, sex, and education. IR = incidence rates; T2DM = type 2 diabetes mellitus.

*The composite outcome was the first occurrence of disability or death from any cause.

†HR adjusted for baseline age, sex, education, living alone, body mass index, cardiovascular diseases, cerebrovascular diseases, depression, and hypertension.

‡Healthy behaviors: no current smoking and no heavy drinking; unhealthy behaviors: presence of current smoking or heavy drinking.

§$p = .08$.

ǁ$p = .07$.

CI 0.85–2.97) or moderate-to-rich social network (HR 0.75, 95% CI 0.66–0.86; 1.36 years, 95% CI 0.50–2.22) compared to those with low engagement in leisure activities, or a poor social network (Table 2). There was no indication of a multiplicative interaction between T2DM status and lifestyle behavior ($p = .191$), leisure activity ($p = .209$), or social network ($p = .072$).

Joint Effect of Behaviors, Leisure Activities, or Social Network With T2DM on Disability-Free Survival

In joint exposure analyses, healthy behaviors (HR 1.22, 95% CI 0.98–1.52), engagement in leisure activities (HR 1.14, 95% CI 0.72–1.82), and moderate-to-rich social network (HR 1.22, 95% CI 0.95–1.55) attenuated the risk of the outcome related to T2DM, which became no longer significant after adjustment for potential confounders (Table 3). The results were not much altered after additionally adjusting for behaviors, leisure activities, or social network in the multivariate analysis when applicable (data not shown).

The association between T2DM status and different combinations of behaviors, leisure activities, and social network on disability or death is shown in Supplementary Table 1. Compared to participants with T2DM who had no optimal factors (healthy behaviors, active engagement in leisure activities, and moderate-to-rich social network), those with the presence of at least 1 optimal factor were associated with a reduced risk of disability or death. Therefore, we used "favorable lifestyle profile," defined as the presence of at least 1 of the aforementioned factors, for the subsequent analyses.

Compared to participants with T2DM-free and a favorable profile, those with diabetes and an unfavorable profile had a more than 2-fold higher risk of disability/death (HR 2.46, 95% CI 1.15–5.26; Figure 1). However, among individuals with T2DM, the risk of the outcome was significantly diminished in those with T2DM plus a favorable profile (HR 1.19, 95% CI 0.93–1.56; p for difference in HRs = 0.037; Supplementary Table 2). Further, the median age of developing disability/death was 76.3 years (95% CI 70.4–82.2) in the unfavorable profile group, and 79.6 (95% CI 74.6–84.5) years in the favorable profile group. Thus, a favorable profile prolonged disability-free survival by 3.26 (95% CI 2.33–4.18) years among participants with T2DM (Figure 2).

Table 3. Hazards Ratios (HRs), 95% Confidence Interval (CI), and Difference in Median by Lifestyle Factors, Leisure Activities, and Social Network Plus T2DM on Incident Composite Outcome

Joint Exposure			Cox Regression	Laplace Regression
Modifiable Factors	T2DM	No. of Event/*n*	HR (95% CI)*	Difference in Median Age (95% CI)*
Behaviors				
Healthy	No	840/1 427	Reference	Reference
Unhealthy	No	358/594	1.41 (1.23, 1.61)	−2.18 (−3.13, −1.23)
Healthy	Yes	101/131	1.22 (0.98, 1.52)	−1.75 (−3.19, −0.32)
Unhealthy	Yes	29/41	1.84 (1.25, 2.69)	−3.29 (−5.36, −1.21)
Leisure activities				
Active	No	844/1 353	Reference	Reference
Inactive	No	231/508	1.29 (1.10, 1.50)	−1.70 (−2.82, −0.59)
Active	Yes	21/35	1.14 (0.72, 1.82)	−1.75 (−6.62, 0.31)
Inactive	Yes	94/119	1.64 (1.27, 1.82)	−3.92 (−5.76, −2.08)
Social network				
Moderate-to-rich	No	796/1 455	Reference	Reference
Poor	No	358/499	1.41 (1.22, 1.61)	−1.36 (−2.41, −0.30)
Moderate-to-rich	Yes	82/114	1.22 (0.95, 1.55)	−1.34 (−3.15, 0.45)
Poor	Yes	44/52	1.51 (1.08, 2.09)	−1.66 (−3.28, −0.06)

Notes: *Adjusted for baseline age groups, sex, education, living alone, body mass index, cardiovascular diseases, cerebrovascular diseases, depression, and hypertension. CI = confidence interval; HR = hazard ration; T2DM = type 2 diabetes mellitus.

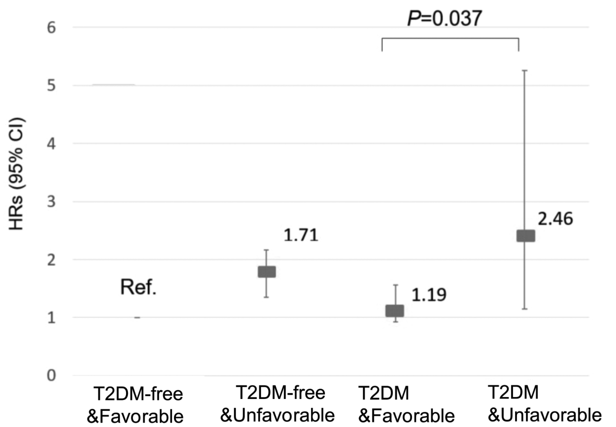

Figure 1. Joint associations between T2DM and the combination of healthy behaviors, active leisure activities, and moderate-to-rich social network on the risk of disability/death (from Cox regression models adjusted for baseline age group, sex, education, living status, body mass index, cardiovascular diseases, cerebrovascular diseases, depression, and hypertension). "Favorable profile" refers to having the presence of at least 1 of the healthy behaviors, active engagement in leisure activities, or moderate-to-rich social network. "Unfavorable profile" refers to having none of the healthy behaviors, active engagement in leisure activities, or moderate-to-rich social network. CI = confidence interval; HR = hazard ratio; T2DM = type 2 diabetes mellitus. p = .037 refers to the significance level of the risk difference for the composite endpoint between "T2DM + favorable" group and "T2DM + unfavorable" group.

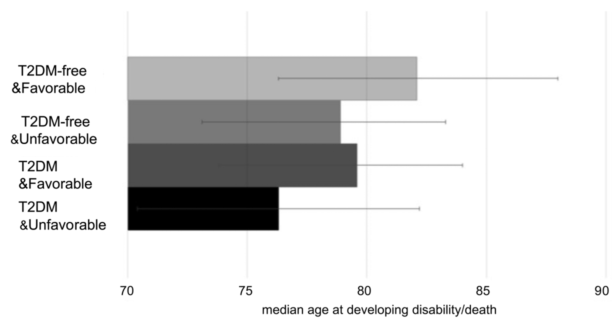

Figure 2. Median age at disability or death according to status of T2DM and favorable profile. Estimates were obtained by fitting multivariable Laplace regression models adjusted for baseline age groups, sex, education, living status, body mass index, cardiovascular diseases, cerebrovascular diseases, depression, and hypertension. "Favorable profile" refers to having the presence of at least 1 of the healthy behaviors, active engagement in leisure activities, or moderate-to-rich social network. "Unfavorable profile" refers to having none of the factors including healthy lifestyle, active leisure activities, or moderate-to-rich social network. T2DM = type 2 diabetes mellitus.

Sensitivity Analysis

Similar results to those from the initial analysis were obtained when we repeated the analyses after: (a) excluding participants with incident disability or death during the first follow-up (3-year follow-up for participants aged over 78 and 6-year follow-up for those aged under 78) to address potential reverse causality and (b) excluding participants with MMSE ≤27 at baseline to rule out potential recall bias (Supplementary Table 3). No multiplicative interactions were detected between the composite outcome and sex (female or male), cardiovascular diseases, cerebrovascular diseases, or lifestyle profile.

Discussion

In this large population-based cohort of older adults with 15 years of follow-up, we found that (a) T2DM, but not prediabetes, was significantly associated with an increased risk of disability or death and shortened disability-free survival, and (b) a favorable profile involving the presence of healthy behaviors (no smoking and no heavy alcohol drinking), participation in leisure activities, or moderate-to-rich social network attenuated the risk of T2DM on disability/death and prolonged disability-free survival by 3 years in older adults with T2DM.

Our findings are in line with previous studies showing an increased risk of disability and mortality among people with T2DM (2,3). In addition, we found that T2DM shortened disability-free survival. These results are comparable to the findings from other several studies investigating disability-free life expectancy related to T2DM using data from Australia (22), Canada (23), and the United States (24). It has been suggested that diabetes-related disability or death could start early in the prediabetic stage (2). However, a meta-analysis showed mixed associations between prediabetes and mortality (25). This discrepancy might be due to differences in study design, age of the study population, and prediabetes ascertainment. Although we recently reported that prediabetes is associated with physical function decline and disability progression (26), we did not detect a significant association between prediabetes and disability or death in this study. Furthermore research is needed to clarify the impact of prediabetes on disability and mortality.

The importance of lifestyle modification in preventing or delaying the onset of diabetic complications and long-term diabetes-related health outcomes has been emphasized by the American Diabetes Association (27). Lifestyle modification includes but is not limited to smoking cessation, leisure activities (especially engagement in physical activity), and moderate alcohol consumption. Numerous studies have shown the beneficial effect of not smoking, having only moderate alcohol consumption, and participating in leisure activities on the risk of T2DM or diabetes-related complications (4–7). In line with these studies, we also found that healthy behaviors (no smoking and no heavy drinking) and active participation in leisure activities may mitigate the risk effect of T2DM on disability and mortality.

Social network has been suggested to play a role in affecting health in people living with diabetes (28). Data from epidemiological studies appear to support the notion that a lack of social support is linked to excess mortality and diabetes-related complications (29–32). However, these results might also be affected by the chosen construct of social wellbeing, cultural differences, or the investigated outcomes. We previously reported that the combination of participation in leisure activities and having a rich social network could reduce the risk of diabetes-related dementia (4). In this study, we further found that a moderate-to-rich social network could alleviate the risk of T2DM on disability and death in addition to prolonging disability-free survival among older adults with T2DM. Given that both lifestyle and social network are modifiable and amenable to interventions, our study supports the notion that integrating not only a healthy lifestyle, but also social components to future interventions to help older adults with T2DM to prolong disability-free survival. In this regard, future trials investigating the benefits of adopting healthy lifestyle and social network in later life are needed.

The association between T2DM and disability could be due to diabetes-related complications such as cardiovascular and cerebrovascular diseases. High concentrations of glucose might lead to chronic systemic inflammation, which is part of a multifactorial process eventually resulting in disability. However, the mechanisms underlying the associations of healthy lifestyle and moderate-to-rich social network with longer disability-free survival in the context of T2DM are not well understood. Greater reductions in disability and mortality are likely to result from synergistic effects between these modifiable factors rather than from individual contributions from each factor alone, especially regarding diabetes self-management (27). Indeed, individuals who are more socially connected tend to adopt healthy behaviors including physical and mental activities, which in turn can help improve glycemic control and prevent diabetes complications (31,32). Social support from family provides practical help to people with T2DM, such as adherence to medical treatments and attending to screening for complications (33). This is also supported by social-buffering theory (34), which posits that social network and social support could modulate the association between stress and health outcomes. Indeed, having a richer social network has been linked to improvements in cardiovascular, immune, endocrine and pulmonary functions, possibly through lower inflammatory concentrations and higher serum antioxidant level (35). The benefits of healthy lifestyle factors might also lead to a reduction in cardiovascular diseases, which plays a major role in the development of disability (26).

Strengths of this study include the longitudinal design with a long follow-up, a relatively high participation rate, as well as multiple resources to identify diabetes diagnosis. In addition, the in-depth interviews between nurses and participants in SNAC-K provided a comprehensive view of participants' lifestyle, leisure activities, social network, and disability status, allowing us to capture unique information on behavioral and social aspects. Additionally, we examined the lifestyle factors in relation to disability-free survival, which is a useful measurement to quantify healthy life-span and has been widely used in risk factors and treatment prognosis research (36). However, some limitations should be pointed out. First, we relied on a single baseline assessment of the exposure and lifestyle factors, and these may have changed over follow-up. In this regard, we did not consider participants who developed incident T2DM or who used new therapeutic agents during the 15-year follow-up, because it is likely that participants would substantially change their lifestyle after diabetes diagnosis. Second, our results might be influenced by differential misclassification, as participants who were vulnerable to any of the adverse events might report inaccurate information., when we repeated all analyses after excluding participants who either developed disability or died during the first follow-up, the results were not much altered. Third, HbA1c has a relatively lower sensitivity to identify prediabetes than the oral glucose tolerance test (37), so it is possible that some prediabetes cases might have been misclassified as normoglycemia, potentially leading to an underestimation of the observed associations. Fourth, since our previous work indicates that T2DM has a different bearing on particular subtypes and severity of disability, as well as death (19,26), we investigated the affect of lifestyle profiles on the risk of a composite endpoint of disability and mortality. Fifth, the possibility of residual confounding cannot be completely ruled out in observational studies. Important confounders such as musculoskeletal diseases, cancer, or respiratory disease are likely to influence both lifestyle and disability-free years of life. Finally, our study included participants from the center of an urban area, thus caution is needed when generalizing our findings to other populations.

In summary, our study provides new evidence that a favorable lifestyle profile characterized by healthy behaviors (no smoking and no heavy alcohol drinking), active leisure activities, and/or moderate-to-rich social network can attenuate the risk of T2DM on disability or death, and prolongs disability-free survival among older adults with T2DM. Our findings highlight the importance of maintaining a healthy lifestyle (covering both behavioral and social components) for the prevention of disability and premature death among older adults with T2DM.

Supplementary Material

Supplementary data are available at *The Journals of Gerontology, Series A: Biological Sciences and Medical Sciences* online.

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Conflict of Interest

None declared.

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