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ORIGINAL ARTICLE

Vulnerability or Resiliency? A Two-Wave Panel Analysis of Social Network Factors Associated with Glycemic Levels among Mexican Immigrants in the Bronx, NYC, Before and During COVID-19

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Abstract Latinos have high rates of type 2 diabetes mellitus (T2DM) yet are characterized as having health-promoting social networks. The impacts of COVID-19 on personal networks were complex, especially in urban areas with high proportion of immigrants such as the Bronx in NYC. Our objective was to test the extent to which network characteristics increase vulnerability or resiliency for glycemic control based on data gathered from Mexican-origin Bronx dwellers. We used two-wave panel study analyzing self-reported personal social networks (n=30$_{\text{participants}}$; 600$_{\text{network members}}$) and HbA1c levels via dried blood spots in 2019, before the COVID-19 pandemic, and in 2021, a time after initial lockdowns and when the pandemic was still ravaging the community of study. Regression models adjusted for individual-level variables including sociodemographic and health indicators (i.e., physical health including COVID-19 and mental health). We found that an increase in the proportion of network members with diabetes predicted an increase in participant's HbA1c levels from 2019 to 2021 (β=0.044, $p < 0.05$). Also, a greater proportion of network members consuming

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"an American diet" in 2019 predicted a decrease in participant's HbA1c levels (β=−0.028, $p < 0.01$), while a greater proportion of network members that encouraged participants' health in 2019 predicted an increase in participant's HbA1c levels (β=0.033, $p < 0.05$). Our study sheds light on specific social network characteristics relevant to individual diabetes outcomes, including potential longitudinal mechanistic effects that played out at the peak of the COVID-19 crisis.

Keywords Glycated hemoglobin (HbA1c) · COVID-19 · Immigrants · Panel study · Bronx, New York

Background

The age-adjusted percentage of Mexican Americans ages 18 and over with diagnosed type 2 diabetes mellitus (T2DM) is 14.4%, almost twice that of non-Latino whites [1]. As the largest subgroup of Latinos in the USA, they also face elevated risk from complications related to T2DM [2]. These risks are driven in part, by a high proportion of undiagnosed disease, especially among the immigrants [3]. But even diagnosed Mexican Americans are less likely than non-Latino white diabetics to receive glucose-lowering medication at hemoglobin A1c values of 7.0% or higher [4] and to receive at least two A1c measurements per calendar year (66.7% vs. 78.1%) [1].

Such vulnerabilities are in stark opposition to a key source of health resilience for Mexican Americans: their social networks. Researchers have highlighted health-promoting social networks among Latinos as a major reason for their lower-than-expected all-cause mortality relative to non-Latino whites based on socioeconomic status [5]. Associations have been found with various positive health outcomes (e.g., obesity, diet, physical activity) and social network density [6], size [7, 8], immigrant composition [9], and social influence [10].

Extensive research examining the links between social networks and health has documented that social network functions, including social support and social influence, as well as the structure of social networks (e.g., density, change in social contacts) can improve (or hinder) a range of health outcomes [11]. Research among non-Latinos that focused specifically on the links between social networks and diabetes suggests some social ties (e.g., spouses, siblings) are more important than others [12]. This work also indicates that structural network features, such as smaller network size, and compositional features, such as having a higher proportion of network members who are family, are associated with more T2DM-related complications [13].

The COVID-19 pandemic likely complicated the link between the protective health effects of US Latinos' social networks. The group experienced high COVID-19 mortality [14], and the pandemic severely blunted a trend in which the Bronx was experiencing the fastest growth of any NYC borough due solely to increasing numbers of immigrants, many of them Latinos of Mexican origin [15]. In addition to a disproportionate representation in essential and face-to-face industries, difficulties in accessing health care, and high rates of crowding in their homes [8], Latinos in the Bronx largely live in neighborhoods with high burden of COVID-19, with infection and mortality rates exacerbated by greater structural barriers to health and higher rates of pre-existing conditions such as diabetes [15]. Diabetes was the most common morbidity with people infected with COVID-19 in the USA [16]. One of the highest rates reported in the scientific literature was among those admitted to hospitals in NYC, at 33.8% [17]. About 35% of hospitalized patients who died due to COVID-19 in a public hospital system in NYC had diabetes [18]. There is also evidence suggesting COVID-19 has a bidirectional relationship with diabetes, in that COVID patients with and without T2DM had a high likelihood of new onset of hyperglycemia [16]. Though the pathogenic mechanism is still unclear, sociodemographic risk factors may play a role. For example, poverty and high food insecurity are two key risk factors for T2DM, and both factors increased more among Latinos than non-Latino white residents in NYC during the height of the pandemic [19]. Taken together, it is also likely that the relationships between social networks and diabetes-related health outcomes were disrupted and further complicated during the pandemic, due to social distancing and the financial and health crises disproportionally experienced by Latino immigrants. An important but unanswered question is: what is the extent to which social networks were a source of vulnerability and resiliency for glycemic control among Mexican immigrants in NYC.

The Current Study

It is within this social, geographic, and temporal context that this study situates our research of social networks among Mexican immigrants, and their role in shaping diabetes-related outcomes. Our study leverages unique longitudinal personal social network data gathered from participating Mexican immigrants who live in the Bronx, which captured the social connections that surround each focal individual, from their own perspective. The first wave of data was collected in winter/summer 2019, prior to the pandemic, and the second was gathered in spring/fall 2021 between the Delta and Omicron COVID waves. Our conceptual framework, drawn from a parent project, seeks to understand the synergistic role of social networks in relation to T2DM and related health behaviors (see Fig. 1). Specifically, it investigates the personal social networks of Mexican immigrants within their sociodemographic realities (e.g., socioeconomic status, acculturation) as well as their current physical and mental health using a convergent mixed-method design [20]. The current study built upon this parent study by collecting additional COVID-19 correlates to further understand sources of resiliency and vulnerability in this community during the pandemic. The main research question was: what features of Mexican immigrant's personal social networks, including access to social support, diabetes-relevant social influences, and change in their network composition, are related to positive or negative changes in participants' blood glucose from pre- to mid-pandemic?

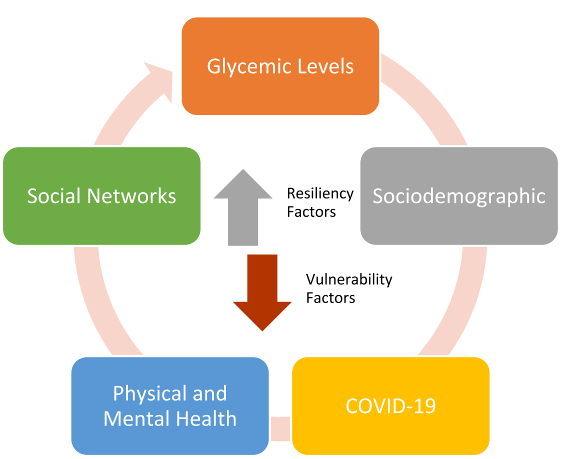

Fig. 1 Conceptual framework

As such, the goal was to identify social network predictors of blood glucose changes between 2019 and 2021, controlling for known individual predictors (see Fig. 1).

Methods

Study Sample

Participants were immigrant adults who self-identified as Mexican, living in the Bronx, who were recruited through a Catholic church. Eligibility criteria did not include T2DM or any risk factors. Sampling and recruitment details have been described elsewhere [20]. Collection for the first wave of data occurred in person in January–June 2019, and the second wave of data collection occurred virtually in May–November 2021. All data was collected in English or Spanish depending on the participants' preferences, largely by the same trained bilingual research assistants. The City University of New York's internal review board approved the study (IRB# #2018-1081).

Measures

At both waves, participants completed surveys and anthropometric measures. Standard methods were used to measure their personal social networks [20, 21]. First, participants were asked to enumerate the 20 adults they know and who also know them, whom they'd been in contact with (either face-to-face, by phone call, text/phone app message, email, or social media), and whom they considered to be the most important people in their lives in recent months. The 20 individuals they named are called "alters." During wave 1, they were asked to name people who met this criteria over the past 6 months, while for wave 2 the timeframe was 12 months. Participants were then asked about each alters' demographics, frequency of contact, and relevant health characteristics. Finally, participants indicated if each pair of alters knew each other, which provides information on the structure of their personal network (e.g., if it is densely or sparsely connected).

To measure their blood glucose, trained research assistants (wave 1; n=81) and participants themselves (wave 2; n=57) collected dried blood spots from a finger prick. All the samples were collected using the same 6-step protocol and analyzed by the same lab. Other data used in this study were collected by validated survey measures, administered in person in 2019 and via Zoom/phone in 2021.

Dependent Variable

Change in HbA1c HbA1c indicates the participant's average blood glucose levels for the last 2–3 months. Change in the raw HbA1c scores between wave 1 and wave 2 calculated for each participant with valid data at both waves [22]. Descriptive statistics for participant HbA1c are also reported based on ranges from the American Diabetes Association, which defines normal as HbA1c < 5.7, prediabetes as 5.7≤HbA1c ≤6.4, and diabetes as Hba1c >6.4.

Social Network Variables

Percentage of alters with diabetes; change in the percentage of alters with diabetes across waves Participants were asked "of all the people on your list, who do you know that has been diagnosed with diabetes?" The number of alters with diabetes was divided by the number of alters in the network (n=20) to compute the percentage of their alters with diabetes at each wave. The change in this percentage between waves was computed for each participant.

Percentage of alters who are health supporters; change in the percentages of alters who are health supporters across waves Health support was assessed via the question "Who helped you or encouraged you to have a healthy lifestyle, to eat healthy foods or be active?" as well as "Who did you go for information, advice, or suggestions about your health, your family's health, or other health concerns?" Alters who provided either type of health-related support were coded as "health supporters," and the number of health supporters was divided by n=20 alters to compute the percentage. The change in this percentage between waves was computed for each participant.

Percentage of alters eating an "American" diet; change in the percentage of alters eating an "American" diet across waves Participants were asked to indicate for each alter "How much do you agree or disagree that this person eats American food most of the time?" (1= Strongly Agree, 2 = Agree, 3 = Disagree, 4 = Strongly Disagree). Alters rated as "strongly agree" or "agree" were coded as "eating an American diet," and this number was divided by n=20 alters to compute the percentage at each wave. The change in this percentage between waves was computed for each participant.

Percentage of alters living outside the US; changes in percentage of alters living outside the USA across waves Participants were asked to indicate for each alter whether they lived in the 1=same household, 2=same neighborhood, 3=same state, 4=another state, or 5=another country. Alters were coded as alters living outside the USA and this number was divided by n=20 to compute percentage at each wave. The change in this percentage between waves was computed for each participant.

Network density; change in network density Personal network density represents whether the social connections among the participants' alters are densely interconnected or sparse, with more dense networks being indicative of greater social cohesion. Density at each wave was calculated by dividing the number of reported connections among all pairs of alters (who knows who) by the total possible number of possible connections (i.e., if all alter pairs know each other). For this study with n=20 alters, this was calculated as 19*(19−1))/2 (19 because alters do not have a social tie to themselves). The calculation yields a value between 0 and 1, with 0 representing a network that is absent of any social ties, and 1 representing a completely connected network. The change in this network statistic between the two waves was computed for each participant. A positive change statistic indicates that their network became more dense over time, while a negative value indicates that their network became less dense over time.

Number of dropped alters due to death between waves Given that we had detailed data on the previous list of alters the ego enumerated (e.g., age, gender, relationship type), we asked the participants follow-up questions about those individuals who were on their wave 1 lists but not their wave 2 lists.

Specifically, we asked, "Could you tell me why this person did not make your list as an important person in your life?" and noted their open-ended response. If the participant indicated that this social contact had died, this was noted. This allowed us to quantify the total number alters that dropped from their social network between 2019 and 2021 due to death, which was included as a predictor in our study. Other common reasons included that they had lost touch due to no longer working together or the person moved away, as well as less contact because of the pandemic. Some had used different nicknames for the same person across waves, or simply forgotten to name a particular person who remained important to them.

Individual Covariates

We identified socioeconomic as well as physical and mental health indicators that the literature indicates are associated with T2DM and are listed in Fig. 1 [23].

Sociodemographic Sex (female vs. male), age (0–30, 31–40, 41–50, 51–60, 61–100), food security (very low and low food security, marginal food security, high food security, measured using a 6-item validated module from the US Department of Agriculture), health insurance (yes vs. no), and years of residency in the USA (continuous).

Physical and mental health indicators These included general physical health (excellent, very good, good vs. fair, poor), any physical activity measured with the International Physical Activity Questionnaire (none vs. moderate/vigorous), any psychological distress in the past 30 days measured with Kessler Psychological Distress Scale (K6+) (all of the time, most of the time, some of the time vs. a little of the time and none of the time).

COVID-19 outcomes At wave 2, we asked participants a series of COVID-19 questions from PhenX Toolkit [24]. This included a measure of COVID-19 infection, with response options: (1) Yes, diagnosed with test and recovered, (2) Yes, diagnosed with a test and still sick, (3) Not diagnosed or tested but have had a cough, fever, or other flu-like symptoms, and (4) No COVID.

Analytic Methods

Analytic Sample One participant from wave 1 was dropped due to being US-born, one participant was dropped in wave 2 due to missing social network data, and 27 were dropped across waves due to missing HbA1c data at wave 2. As such, the current analyses are restricted to 30 participants who answered the social network and health survey and had valid HbA1c (n=$30_{\text{participants}}$; 600_{alters}).

Statistical Analysis Descriptive statistics for both waves as well as changes between waves were computed. Then, we fit two linear regression models to test the effects of personal network characteristics on blood glucose. The network predictors included the percentage of alters, and change in the percentage, who (i) had diabetes, (ii) were health supporters, and (iii) who ate an American diet; (iv) wave 1 network density, and change in network density; and (v) the number of dropped alters due to death. Alters living outside the USA were excluded from models due to the small sample size of this exploratory study. A crude model examined the significance of diabetes-relevant social network variables (all but "number of dropped alters due to death") while controlling for the participant sex, age, and COVID-19 status. An adjusted model incorporated additional control variables, including the participant's general health, food security, health insurance, years of residency in the USA, mental health, physical activity, and the number of dropped alters due to death. Statistical significance was set at $p < 0.05$, and p-values up to 0.1 are also reported given the exploratory nature of the study. All analyses were conducted using R version 4.2.2. [25].

Results

Figure 2 shows the distribution of HbA1c across waves, which indicates that most participants at wave 1 had HbA1c levels that were equal to or less than 6%. According to the ADA [22], A1c levels between 5.7 and less than 6.5% indicate prediabetes. At wave 2, HbA1c levels shifted to 6.5% or higher, which are levels that are in the diabetes range.

Table 1 shows summary statistics for individual and social network variables. At wave 1, most of the sample was female, between the ages of 31 and 50,

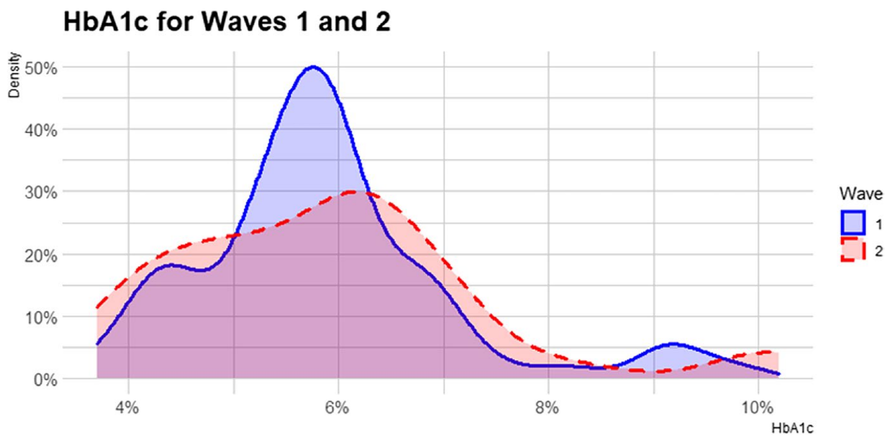

Fig. 2 Distribution of HbA1c scores at wave 1 and wave 2, n=30$_{\text{participants}}$; 600$_{\text{network members}}$

reported having health insurance, being in poor or fair health, and had a mean of almost 20 years living in the USA. At wave 2, the majority reported no COVID-19 infection. Changes in individual variables included increases in HbA1c levels and psychological distress, but most did not change their physical activity levels.

In this sample, the average percentage of alters with diabetes was 8.2% at wave 1 and 11.5% at wave 2, an increase of 3.3%, on average. The average percentage of alters who were health supporters was 19.5% at wave 1, and 19.7% at wave 2, essentially no change. The average percentage of alters who ate an American diet was 49.2% at wave 1, and 46.2% at wave 2, a decrease of 3.0%, on average. The average percentage of alters who lived outside the USA was 17.5% at wave 1, and 20.1% at wave 2, a modest increase, on average. Finally, the average network density was 0.55 at wave 1 and 0.57 at wave 2, indicating a small average increase. The 4 out of 30 participants who lost network members to death lost 1–4 people.

Table 2 first shows the crude model that controls for COVID-19 as well as sex and age. This table also shows the adjusted model, which includes additional sociodemographic variables as well as physical and mental health indicators. Both models show that change in the percentage of alters with diabetes across waves, but not the wave 1 variable, was positively and significantly associated with individual HbA1c levels. Thus, an increase in the percentage of alter diabetes predicted an increase in participant HbA1c.

The percentage of alters that were health supporters at wave 1 was positively and marginally associated with HbA1c levels in the crude model, and positively and significantly with HbA1c levels in the adjusted models. Thus, having more health supporters at wave 1 predicted an increase in participant HbA1c levels from 2019 to 2021. Change in the percentage of health supporters was not associated with HbA1c. Additionally, as Supplement Figure 1 shows, participants with a higher percentage of alters who were health supporters at wave 1, compared to those with a lower percentage of health supporters, also had lower HbA1c levels at wave 1. Thus, it may be more likely to observe increases in HbA1c levels across the waves.

A higher percentage of alters who ate an American diet at wave 1 was significantly and negatively associated with change in HbA1c levels, while change in this variable did not predict HbA1c. Thus, having more social contacts who ate an American diet in 2019 predicted a decrease in participant HbA1c between waves. Personal network density, change in network density, and having dropped alters due to death were not significantly associated with a change in participant HbA1c levels.

Discussion

There is vast evidence documenting the immense toll of the COVID-19 pandemic on vulnerable populations like Mexican immigrants living in areas like the Bronx, but less work has focused on the actual changes in personal social networks or the extent to which these are associated with specific non-COVID health outcomes like glycemic control. This study provides evidence

Table 1 Summary statistics for individual and network variables (n=30$_{participants}$; 600$_{network\ members}$)

Individual variables	Wave 1	Wave 2	Change
HbA1c			
Median (IQR[1])	5.85 (1.50)	6.15 (1.65)	0.10 (1.25)
Mean (SD[2])	5.93 (1.34)	6.12 (1.52)	0.19 (1.08)
Psychological distress			
Median (IQR[1])	4.00 (3.00)	3.50 (3.00)	0.50 (3.00)
Mean (SD[2])	4.23 (3.20)	4.46 (3.61)	0.23 (3.93)
Physical activity			
1=low	13	10	
2=medium	10	18	
3=high	7	2	
Change in physical activity[3]			
−2			2
−1			6
0			14
1			8
Sex			
Male	8		
Female	22		
Age in years			
18–30	2		
31–40	11		
41–50	12		
51–60	4		
61–100	1		
Household food security			
High security	17		
Low security	13		
Health insurance coverage			
No	10		
Yes	20		
General health			
Poor or fair	18		
Good, very good, excellent	12		
Years of residency in the USA			
Median (IQR[1])	18.5 (15.0)		
Mean (SD[2])	19.7 (9.9)		
COVID			
COVID-19 infection[4]		12	
No COVID-19		18	
Network variables	Wave 1	Wave 2	Change
% of alters with diabetes			
Median (IQR[1])	5.0 (13.8)	10.0 (10.0)	0.0 (5.0)
Mean (SD[2])	8.2 (7.8)	11.5 (11.6)	3.3 (11.0)
% of alters who encourage the ego's health			
Median (IQR[1])	10.0 (18.8)	15.0 (25.0)	−2.5 (15.0)
Mean (SD[2])	19.5 (21.9)	19.7 (18.3)	0.2 (12.6)
% of alters eating American food			

Table 1 (continued)

Individual variables	Wave 1	Wave 2	Change
Median (IQR[1])	50.0 (46.3)	50.0 (53.8)	0.0 (40.0)
Mean (SD[2])	49.2 (28.2)	46.2 (30.7)	−3.0 (32.3)
% of alters living outside the USA			
Median (IQR[1])	15 (25)	12.5 (21.7)	0.0 (18.8)
Mean (SD[2])	17.5 (18.6)	20.1 (30)	0.9 (20.6)
Network Density			
Median (IQR[1])	0.56 (0.34)	0.58 (0.32)	0.02 (0.28)
Mean (SD[2])	0.55 (0.22)	0.57 (0.21)	0.02 (0.22)
Number of dropped alters due to death			
0		26	
1		2	
2		1	
4		1	

[1]Inter-quartile range

[2]Standard deviation

[3]This represents the count of participants whose physical activity as measured by the IPAQ changed between the waves by the amount indicated. For example, IPAQ scores for 2 participants decreased by 2 from waves 1 to 2

[4]Includes "diagnosed and recovered," "diagnosed and still sick," and "not diagnosed but have symptoms"

that personal networks in this community-based sample were associated with changes in individual glycemic control. Notably, individuals who had an increase in social contacts with diabetes between 2019 and 2021 were significantly more likely to have an increase in their HbA1c in this same timeframe. Though our analysis could not account for whether the social network members were successfully managing their diabetes, data prior to the pandemic document deep inequities in T2DM outcomes among Latino immigrants in the USA, suggesting issues with management that may indicate that many alters have such issues [26]. Lack of access to healthcare and health insurance and limitations in financial resources for T2DM drugs and testing equipment are some of the structural reasons why T2DM is remarkably high among Mexican immigrants, and these factors are also likely driving their higher rate of poor glycemic control [27]. The nexus between these factors and the COVID-19 pandemic may have increased the incidence of T2DM among social network members, especially considering the relationship between COVID-19 infection and T2DM prevalence [28] though the potential metabolic and inflammatory pathways are still not entirely clear [28, 29].

This study also highlights the need to understand T2DM norms in the personal network of immigrant Mexicans for the success of any intervention or prevention strategy. Previous mixed methods work in this community highlighted that participants framed their glycemic control based on whether they were in an acute state of "sufrimiento" or pain [30]. Those who experienced physical discomfort but, due to not being in such an acute state, could still fulfill their work or caretaking duties in their everyday lives felt that glycemic control did not warrant further attention, including seeking medical care. To the extent that these values are also widely held by the personal network that people are embedded in, the impact of personal network warrants further investigation if personal networks are to be harnessed as part of the intervention strategy. Indeed, evidence suggests that Latinos tend to have largely negative perceptions of T2DM as a disease and there is high T2DM-related stigma that is particularly directed toward family members. Qualitative inquiries have elucidated intergenerational trauma bonds related to diabetes, which were fraught with narratives around the pain of structural violence experienced by Latinos in the USA [27].

Another social network characteristic that predicted changes in individual blood glucose was the percentage of their network members who were health supporters. However, having more health

Table 2 Crude and adjusted models of changes in HbA1c by individual and network variables (n=30$_{participants}$; 600$_{network\ members}$)

	Crude		Adjusted	
	Coef[1]	(SE[2])	Coef[1]	(SE[2])
Sociodemographic				
Sex: female (vs. male)	−0.54	(0.41)	−0.08-	(0.32)
Age	−0.21	(0.19)	−0.005--	(0.16)
Food security: low (vs. very low)			1.25†-	(0.59)
high (vs. very low)			1.51*	(0.53)
Health insurance			0.25	(0.32)
Years of residency in the USA			−0.025	(0.017)
Physical and mental health indicators				
General physical health			−0.009	(0.34)
Physical activity (change)			−0.22--	(0.18)
Psychological distress (K6) (change)			−0.098*	(0.04)
No COVID-19	−0.91*	(0.35)	−1.27**	(0.31)
Network changes between waves±				
Density	−1.08	(0.85)	−1.22	(0.75)
% alters with diabetes: (wave 1)	−0.0031	(0.026)	−0.012 --	(0.032)
(change)	0.039* -	(0.016)	0.047*	(0.015)
% alters encouraging ego's health (wave 1)	0.017†	(0.010)	0.027*	(0.011)
(change)	0.0031--	(0.017)	−0.002	(0.017)
% alters eating American food: (wave 1)	−0.020**	(0.0068)	−0.024***	(0.0053)
(change)	−0.0045 -	(0.0062)	−0.0035	(0.0051)
Number of dropped alters due to death			−0.14	(0.25)
R^2	0.6163		0.8889	
Adjusted R^2	0.4143		0.7072	

**$p < 0.01$; *$p < 0.05$; †$p<0.1$

[1]Coefficient. [2]Standard error

± % of alters living outside the USA and changes in alters across waves dropped due to small sample size

supporters in 2019 was associated with an *increase* in individual HbA1c between 2019 and 2021. This finding stands in contrast to past social network studies with Latino populations that suggested participants lacked a network member who encouraged healthy eating and physical activity [31]. It may also appear counterintuitive to how researchers typically situate social support and diabetes risk [32]; however, our study focuses on changes in HbA1c levels as the dependent variable, while previous literature has primarily examined cross-sectional levels of HbA1c. Additionally, health support may be provided in response to difficulties adopting a healthy lifestyle or recommended diabetes management practices. Therefore, individuals with more difficulty managing blood glucose, who have a greater risk over time, may have more people in their personal networks providing them with health support. These network changes and attributes are important factors to consider if we are to create effective interventions among Mexican Americans and diminish their burden of T2DM.

Finally, our findings identified another social network characteristic that predicted changes in individual blood glucose: the extent to which social network members ate an American diet. In this case, having a higher proportion of network members who ate an American diet in 2019 was a protective factor, and associated with decline in individual Hba1c levels between 2019 and 2021. While the Standard American Diet includes high consumption of processed foods, including sugar-sweetened beverages [33] and nutritional epidemiological research finds healthful diet-related behaviors decrease among Latinos with greater acculturation in the USA [34], this may suggest, in line with previous qualitative work among Mexican Americans [35], that participants consider the term as relating to healthier (e.g., smaller portions, fewer fatty foods) relative to traditional Mexican patterns [20].

Limitations and Strengths

The study had several limitations. Our small sample size limited our ability to incorporate a larger set of variables in our analysis, such as those that capture a richer set of characteristics of social network members including geographic location of the alters as well as structural network characteristics. In addition, the convenience sampling used in our study limits the generalizability of our results. However, we believe that our findings are valuable as a pilot study to better understand individual and network-level predictors for glucose regulation for this sub-population that has traditionally been difficult to study due to their mobility and social vulnerability. Despite this limitation, it is very rare to have personal network data among immigrant populations at two time points before and during a global pandemic. Moreover, our panel results corroborate previous cross-sectional findings regarding the role of diabetic alters [30] and heed the call for research that seeks to understand diabetes risk and potential prevention factors among immigrant populations through a transnational lens and macro-level social determinants of health framework [32].

Conclusion

Personal social networks may serve as powerful conduits for the formulation and maintenance of norms around T2DM and related self-care health behaviors (e.g., diet, physical activity). Latinos, especially Mexican immigrants, are characterized as potentially having strong health-promoting networks. Yet rarely are these network structures deeply investigated. Our exploratory study found several social network characteristics that predicted change in a crucial indicator of diabetes—HbA1c levels—among Mexican immigrants in the early stages of the COVID-19 pandemic in NYC. Future research, including those with promising new sampling techniques among immigrant populations with transnational ties, is warranted and might reshape our current approaches in T2DM interventions among Mexican American adults in the USA and beyond.

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References

1. Office of Minority Health. Diabetes and Hispanic Americans. In: *Secondary Diabetes and Hispanic Americans*; 2021. https://minorityhealth.hhs.gov/diabetes-and-hispanic-americans. Accessed 23 Jan 2024
2. Fang M, Selvin E. Thirty-year trends in complications in U.S. adults with newly Diagnosed type 2 diabetes. *Diabetes Care.* 2021;44(3):699–706. https://doi.org/10.2337/dc20-2304.
3. Hsueh L, Wu W, Hirsh AT, de Groot M, Mather KJ, Stewart JC. Undiagnosed diabetes among immigrant and racial/ethnic minority adults in the United States: National Health and Nutrition Examination Survey 2011-2018. *Ann Epidemiol.* 2020;51:14–9. https://doi.org/10.1016/j.annepidem.2020.07.009.
4. Fang M, Wang D, Coresh J, Selvin E. Trends in diabetes treatment and control in U.S. adults, 1999-2018. *N Engl J Med.* 2021;384(23):2219–28. https://doi.org/10.1056/NEJMsa2032271.
5. Ruiz JM, Steffen P, Smith TB. Hispanic mortality paradox: a systematic review and meta-analysis of the longitudinal literature. *Am J Public Health.* 2013;103(3):e52–60. https://doi.org/10.2105/AJPH.2012.301103.
6. Flores M, O'Neill RM, Boyd SM, Uchino BN, Ruiz JM. Examining between-group differences in social network density and high-sensitivity C-reactive protein in older adults: implications for the Hispanic mortality paradox. *Psychosom Med.* 2023;85(2):165–74. https://doi.org/10.1097/PSY.0000000000001157.
7. Marquez B, Elder JP, Arredondo EM, Madanat H, Ji M, Ayala GX. Social network characteristics associated with health promoting behaviors among Latinos. *Health Psychol.* 2014;33(6):544–53. https://doi.org/10.1037/hea0000092.
8. Shelton RC, McNeill LH, Puleo E, Wolin KY, Emmons KM, Bennett GG. The association between social factors and physical activity among low-income adults living in public housing. *Am J Public Health.* 2011;101(11):2102–10. https://doi.org/10.2105/AJPH.2010.196030.
9. Creighton MJ, Goldman N, Teruel G, Rubalcava L. Migrant networks and pathways to child obesity in Mexico. *Soc Sci Med.* 2011;72(5):685–93. https://doi.org/10.1016/j.socscimed.2010.12.006.
10. Ashida S, Wilkinson AV, Koehly LM. Social influence and motivation to change health behaviors among Mexican-origin adults: implications for diet and physical activity. *Am J Health Promot.* 2012;26(3):176–9. https://doi.org/10.4278/ajhp.100107-QUAN-2.

11. Valente TW. Social networks and health: models, methods, and applications. New York, New York: Oxford University Press; 2010.
12. Raghavan S, Pachucki MC, Chang Y, et al. Incident type 2 diabetes risk is influenced by obesity and diabetes in social contacts: a social network analysis. *J Gen Intern Med.* 2016;31(10):1127–33. https://doi.org/10.1007/s11606-016-3723-1.
13. Brinkhues S, Dukers-Muijrers N, Hoebe C, et al. Social network characteristics are associated with type 2 diabetes complications: the Maastricht study. *Diabetes Care.* 2018;41(8):1654–62. https://doi.org/10.2337/dc17-2144.
14. Arias E, Xu J. United States Life Tables, 2020. *Natl Vital Stat Rep.* 2022;71(1):1–64.
15. DiNapoli TP, Jain R. Recent trends and impact of COVID-19 in the Bronx: Office fo the New York State Comptroller, 2021.
16. Singh AK, Khunti K. COVID-19 and diabetes. *Annu Rev Med.* 2022;73:129–47. https://doi.org/10.1146/annurev-med-042220-011857.
17. Richardson S, Hirsch JS, Narasimhan M, et al. Presenting characteristics, comorbidities, and outcomes among 5700 patients hospitalized with COVID-19 in the New York City area. *JAMA.* 2020;323(20):2052–9. https://doi.org/10.1001/jama.2020.6775.
18. Kalyanaraman Marcello R, Dolle J, Grami S, et al. Characteristics and outcomes of COVID-19 patients in New York City's public hospital system. *PLoS One.* 2020;15(12):e0243027. https://doi.org/10.1371/journal.pone.0243027.
19. Arasteh K. Prevalence of comorbidities and risks associated with COVID-19 among Black and Hispanic populations in New York City: an examination of the 2018 New York City Community Health Survey. *J Racial Ethn Health Disparities.* 2021;8(4):863–9. https://doi.org/10.1007/s40615-020-00844-1.
20. Florez KR, Bell BM, Galvez A, Hernandez M, Verdaguer S, de la Haye K. Nosotros mismos nos estamos matando/We are the ones killing ourselves: unraveling individual and network characteristics associated with negative dietary acculturation among Mexican Americans in New York City. *Appetite.* 2023;184:106488. https://doi.org/10.1016/j.appet.2023.106488.
21. Crossley N, Bellotti E, Edwards G, Everett MG, Koskinen J, Tranmer M. *Social network analysis for ego-nets: social network analysis for actor-centred networks*: Sage; 2015.
22. Marathe PH, Gao HX, Close KL. American Diabetes Association standards of medical care in diabetes 2017. *J Diabetes.* 2017;9(4):320–4. https://doi.org/10.1111/1753-0407.12524.
23. Aviles-Santa ML, Colon-Ramos U, Lindberg NM, Mattei J, Pasquel FJ, Perez CM. From sea to shining sea and the great plains to Patagonia: a review on current knowledge of diabetes mellitus in Hispanics/Latinos in the US and Latin America. *Front Endocrinol (Lausanne).* 2017;8:298. https://doi.org/10.3389/fendo.2017.00298.
24. Hamilton CM, Strader LC, Pratt JG, et al. The PhenX Toolkit: get the most from your measures. *Am J Epidemiol.* 2011;174(3):253–60. https://doi.org/10.1093/aje/kwr193.
25. R Foundation for Statistical Computing. *R: a language and enviroment for statistical computing [program].* Vienna, Austria: R Foundation for Statistical Computing; 2021.
26. Barcellos SH, Goldman DP, Smith JP. Undiagnosed disease, especially diabetes, casts doubt on some of reported health 'advantage' of recent Mexican immigrants. *Health Aff (Millwood).* 2012;31(12):2727–37. https://doi.org/10.1377/hlthaff.2011.0973.
27. Page-Reeves J, Regino L, Schleder T. Policy implications of structural violence and syndemic dynamics: a lens for addressing Latinx immigrant diabetes health disparities. *Curr Diab Rep.* 2022;22(3):137–45. https://doi.org/10.1007/s11892-022-01450-7.
28. Rubino F, Amiel SA, Zimmet P, et al. New-onset diabetes in Covid-19. *N Engl J Med.* 2020;383(8):789–90. https://doi.org/10.1056/NEJMc2018688.
29. Sathish T, Tapp RJ, Cooper ME, Zimmet P. Potential metabolic and inflammatory pathways between COVID-19 and new-onset diabetes. *Diabetes Metab.* 2021;47(2):101204. https://doi.org/10.1016/j.diabet.2020.10.002.
30. Flórez KR, Hwang NS, Hernandez M, Verdaguer-Johe S, Rahnama Rad K. No sufro, estoy bien/I am not suffering, so I am doing OK: A mixed method exploration of individual and network-level factors and Type 2 Diabetes Mellitus (T2DM) among Mexican American adults in New York City. *PLoS One.* 2024;19(1):e0295499. https://doi.org/10.1371/journal.pone.0295499.
31. Aisha AF, Abu-Salah KM, Ismail Z, Majid AM. In vitro and in vivo anti-colon cancer effects of Garcinia mangostana xanthones extract. *BMC Complement Altern Med.* 2012;12:104. https://doi.org/10.1186/1472-6882-12-104.
32. Dias J, Echeverria S, Mayer V, Janevic T. Diabetes risk and control in multi-ethnic US immigrant populations. *Curr Diab Rep.* 2020;20(12):73. https://doi.org/10.1007/s11892-020-01358-0.
33. Grotto D, Zied E. The Standard American Diet and its relationship to the health status of Americans. *Nutr Clin Pract.* 2010;25(6):603–12. https://doi.org/10.1177/0884533610386234.
34. Perez-Escamilla R, Putnik P. The role of acculturation in nutrition, lifestyle, and incidence of type 2 diabetes among Latinos. *J Nutr.* 2007;137(4):860–70.
35. Ramirez AS, Golash-Boza T, Unger JB, Baezconde-Garbanati L. Questioning the dietary acculturation paradox: a mixed-methods study of the relationship between food and ethnic identity in a group of Mexican-American women. *J Acad Nutr Diet.* 2018;118(3):431–9. https://doi.org/10.1016/j.jand.2017.10.008.

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