12-10-2022

Socioeconomic Deprivation and Cardiometabolic Risk Factors in Individuals with Type 1 Diabetes: T1D Exchange Clinic Registry

Stephanie Griggs
Case Western Reserve University, sag153@case.edu

Sadeer Al-Kindi
Case Western Reserve University, sxa502@case.edu

Heather Hardin
Case Western Reserve University

Elliane Irani
Case Western Reserve University, exi26@case.edu

Sanjay Rajagopalan
Case Western Reserve University, sxr647@case.edu

See next page for additional authors

Recommended Citation

Griggs S, Al-Kindi S, Hardin H, Irani E, Rajagopalan S, Crawford SL, Hickman RL Jr. Socioeconomic deprivation and cardiometabolic risk factors in individuals with type 1 diabetes: T1D exchange clinic registry. Diabetes Res Clin Pract. 2023 Jan;195:110198. doi: 10.1016/j.diabres.2022.110198.

Authors
Stephanie Griggs, Sadeer Al-Kindi, Heather Hardin, Elliane Irani, Sanjay Rajagopalan, and Ronald L. Hickman Jr.

HHS Public Access
Author manuscript
Diabetes Res Clin Pract. Author manuscript; available in PMC 2024 January 01.

Published in final edited form as:
Diabetes Res Clin Pract. 2023 January ; 195: 110198. doi:10.1016/j.diabres.2022.110198.

Socioeconomic Deprivation and Cardiometabolic Risk Factors in Individuals with Type 1 Diabetes: T1D Exchange Clinic Registry

Stephanie Griggs, PhD, RN [Assistant Professor],
Case Western Reserve University, Frances Payne Bolton School of Nursing, Cleveland, OH 44106

Sadeer Al-Kindi, MD [Assistant Professor of Medicine and Radiology; Co-director],
Center for Vascular Metabolic Disease, School of Medicine

Heather Hardin, PhD, RN [Assistant Professor],
Case Western Reserve University, Frances Payne Bolton School of Nursing, Cleveland, OH 44106

Elliane Irani, PhD, RN [Assistant Professor],
Case Western Reserve University, Frances Payne Bolton School of Nursing, Cleveland, OH 44106

Sanjay Rajagopalan, MD [Professor of Medicine; Director],
Cardiovascular Research Institute, Case Western Reserve University, School of Medicine

Sybil L. Crawford, PhD [Professor of Nursing],
University of Massachusetts Chan Medical School, Graduate School of Nursing, Worcester, MA 01655

Ronald L. Hickman Jr, PhD, RN, ACNP-BC, FNAP, FAAN [Ruth M. Anderson Endowed Professor of Nursing and Associate Dean for Research]
Case Western Reserve University, Frances Payne Bolton School of Nursing, Cleveland, OH 44106

Abstract

Aims.—Social determinants of health (SDOH) influence cardiovascular health in the general population; however, the degree to which this occurs in individuals with type 1 diabetes (T1D) is not well understood. We evaluated associations among socioeconomic deprivation and

---

Stephanie.griggs@case.edu .
Declaration of author contributions:
According to the author guidelines, each of the authors named on the manuscript fit the criteria for authorship. Stephanie Griggs, PI on the grants (R00NR018886 and AASM220-BS-19), secured the funding, designed the study, acquired, analyzed, interpreted the data, and wrote the manuscript. Ronald L. Hickman, Sadeer Al-Kindi, Sanjay Rajagopalan, and Sybil Crawford contributed to the study design, analyzed, interpreted the findings, and critically revised the manuscript. Heather Hardin and Elliane Irani interpreted the findings and co-wrote the manuscript.

Conflict of interest: The authors have no conflicts of interest to disclose.

cardiometabolic risk factors (hemoglobin A_{1c}, low-density lipoprotein, blood pressure, body mass index, physical activity) in individuals with T1D from the T1D Clinic Exchange Registry.

Methods.—We evaluated the association between the social deprivation index (SDI) and cardiometabolic risk factors using multivariable and logistic regression among 18,754 participants ages 13 – 90 years (mean 29.2 ± 17) in the T1D Exchange clinic registry from 6,320 zip code tabulation areas (2007–2017).

Results.—SDI was associated with multiple cardiometabolic risk factors even after adjusting for covariates (age, biological sex, T1D duration, and race/ethnicity) in the multivariable linear regression models. Those in the highest socially deprived areas had 1.69 (unadjusted) and 1.78 (adjusted) times odds of a triple concomitant risk burden of poor glycemia, dyslipidemia, and hypertension.

Conclusions.—Persistent SDOH differences could account for a substantial degree of poor achievement of cardiometabolic targets in individuals with T1D. Our results suggest the need for a broader framework to understand the association between T1D and adverse cardiometabolic outcomes.

Keywords

cardiometabolic risk; type 1 diabetes; social determinants of health; social deprivation

1. Introduction

Social determinants of health (SDOH) are conditions in the social and built environments that affect an individual's health and well-being [1]. An area-level determinant of health, socioeconomic deprivation, is a multidimensional indicator of how neighborhood or community poverty or economic disadvantage affect social resources, including income, occupation, education, and housing, and is linked to health disparities and inequities. Across studies, socioeconomic deprivation has been operationalized as a SDOH and is associated with poor long-term physical and mental health, increased prevalence of cardiometabolic risk factors, and may be a modifiable risk factor for cardiovascular disease (CVD) [2, 3]. Indeed, adverse cardiovascular health outcomes such as myocardial infarction, stroke, and coronary death have increased with higher levels of individual and area-level socioeconomic deprivation [4–7].

Cardiometabolic risk factors (e.g., glycemia, blood pressure, cholesterol, BMI) and poor access to health care are linked to cardiovascular disease in the general population and could be additive or synergistic in individuals with type 1 diabetes (T1D) [8, 9]. Achieving glycemic, blood pressure, body mass index (BMI) and cholesterol targets through intensive treatment while minimizing acute hypoglycemia has positive effects on both microvascular (e.g., retinopathy, nephropathy, and neuropathy) and macrovascular (e.g., coronary artery disease, stroke, and peripheral artery disease) complications in individuals with T1D [10]. The relationship between healthcare need and access is complex, and an imbalance in this relationship can result in healthcare access inequity and a widening of cardiometabolic disparities among individuals living with T1D [11–13]. Socially marginalized and disadvantaged individuals are most susceptible to experiencing health inequity that in turn predisposes them to higher states of disease burden and more costly, reactive care as opposed to preventative care [14].

Adverse cardiometabolic risk factors (e.g., poor glycemia, hypertension, dyslipidemia, overweight/obesity, lack of physical activity) amplify the association between T1D and CVD [8, 9]. A better understanding of the relationship between risk factors at an area-level and their association with SDOH could improve our understanding in order to facilitate rational allocation of resources and appropriate interventions. The social deprivation index is a composite indicator of socioeconomic disadvantage in six domains outside the defined health care setting: income, education, housing, household characteristics, transportation, and employment. There is significant variation in the distribution of cardiometabolic risk factors at different geographic scales [15]. The role of socioeconomic deprivation in other populations has been considered, however, to our knowledge socioeconomic deprivation has not been considered in T1D [15, 16]. The purpose of this study was to quantify levels of socioeconomic deprivation and examine associations among socioeconomic deprivation and cardiometabolic risk factors in individuals with T1D; while adjusting for covariates (e.g., age, T1D duration, biological sex aka sex assigned at birth, and racial and ethnic identity). The hypothesis was that higher socioeconomic deprivation would be associated with higher cardiometabolic risk (defined by a higher HbA1c, low-density lipoprotein, blood pressure, body mass index, and lower physical activity) in adolescents and adults with T1D.

2. Methods

2.1. Data sources and study population

Demographic and clinical data were obtained retrospectively from the T1D Exchange Clinic Registry between the years of 2007–2017. The T1D Exchange Clinic Registry collects information from participants across 67 endocrinology centers in the United States who elected to enroll and complete demographic information and a medical history questionnaire. The T1D Clinic Exchange Registry also extracts data from medical charts. All T1D Exchange Clinic Registry study materials were reviewed and approved by Jaeb Institutional Review Board (Tampa, FL). We also received approval for this study from the Institutional Review Board of the lead author's university, Case Western Reserve University Institutional Review Board, Cleveland, OH (STUDY20211607).

2.2. Measures

The *Social Deprivation Index (SDI)* is a composite measure of area-level deprivation based on six domains collected in the American Community Survey: income (percent living in poverty), education (percent with less than 12 years of education), housing (percent living in rented housing unit and percent living in overcrowded housing unit), household characteristics (percent single-parent households with dependents <18 years), transportation (percent of households without a car), and employment (percent non-employed adults under 65 years of age) [17]. Lower area levels of socioeconomic status are associated with hypertension and obesity [18]. The SDI is an estimate of health care access and health outcomes within a rational primary care service area based on zip code tabulation (ZCTA). ZCTA's are generalized U.S. Postal Service Zip Codes.

The SDI was initially developed based on 2005–2009 American Community Survey 5-year estimates by Butler and colleagues (2012). The index and measures are updated each year and we used the updated data from 5-year estimates from 2008–2012 and 2011–2015 to align with the data collection period from the current sample [17]. The American Community Survey is a nationwide survey including social, economic, housing, and demographic characteristics. We used ZCTA's in this study based on generalized U.S. Postal Service Zip Codes [17].

Cardiometabolic risk factors were assessed using biomarkers indicating risk for cardiometabolic disease, including HbA_{1C}, low-density lipoprotein cholesterol (LDL-C), systolic and diastolic blood pressure (SBP and DBP), body mass index (BMI), and physical activity. We computed the BMI from the participant's height (cm) and weight (kg) (kg/m^2) measured at the T1 clinic visit. BP, $HbA_{1c,}$ and LDL-C data were obtained at clinic visits using standard operating procedures and collected from the chart. Fasting status is unknown for LDL-C. Physical activity was measured using self-reported total hours per week, hours per week of low, moderate, and high activity, days per week of exercise, as well as aerobic/anaerobic exercise [19]. We examined each cardiometabolic risk factor continuously and dichotomously according to national recommendations or established cut points ($HbA_{1c} \geq$ 7% (53 mmol/mol), LDL-C ≥100 mg/dL, SBP ≥130 mmHg / DBP ≥ 80 mmHg, and BMI ≥ 25.0) [10, 20]. In addition, physical activity was included as an additional independent variable for other cardiometabolic risk outcomes. Covariates were selected based on a *priori* knowledge and included age, T1D duration, biological sex (sex assigned at birth), and race/ethnicity identity. Race/ethnicity identity included 7 categories (White Non-Hispanic, Black/African American, Hispanic, Asian, More than 1 race, American Indian/Alaska Native, and Native Hawaiian/Other Pacific Islander).

2.3. Statistical analysis

A quantitative descriptive approach was used to characterize socioeconomic deprivation and cardiometabolic risk factors among the individuals in the study. Bivariate correlations, multivariable linear, and logistic regression models were used to examine the relationships among socioeconomic deprivation and cardiometabolic risk factors. To evaluate explanatory contributions of socioeconomic deprivation to cardiometabolic risk factors, we performed a series of multivariable linear regression models. We ran separate models for cardiometabolic risk factors as outcomes. Outcomes were transformed, log and square root, to satisfy model assumptions, including normally distributed residuals [21]. We included SDI and physical activity with the covariates age, T1D duration, biological sex, and race/ethnicity.

In addition to the series of linear regression models, we used logistic regression to determine the odds of hypertension (SBP >130mmHg or DBP >80 mmHg), overweight and obesity (BMI > 25.0 kg/m^2), dyslipidemia (LDL-C >100), and poor glycemia (HbA_{1c} > 7%, 53 mmol/mol) separately and as a triple concomitant risk burden of hypertension, dyslipidemia, and poor glycemia [10]. To assess exposure in the logistic regression model, overall SDI was dichotomized into two groups (10% most socially deprived and the remaining 90% as a comparator group). This approach for determining risk in those most socially deprived, highest 10% of SDI scores, has been documented in previous research [22]. Statistical significance was set at $p < .05$.

3. Results

3.1. Sample Characteristics

A population of 18,754 individuals ages 13 – 90 years (mean 29.2 ± 17 years, 51.7% female), with T1D residing across 6,320 ZCTA's were analyzed. Close to half of the participants were overweight or obese (43.3%), a majority did not meet glycemic targets (84.6% HbA_{1C} >7%), and one in five (19.7%) had hypertension. Mean BMI was 25.17 ± 5.23 kg/m^2, mean HbA_{1c} was 8.32 ± 1.45% (67 mmol/mol), mean T1D duration was 11.11 ± 11.88 years. There was substantial variation in cardiometabolic risk and socioeconomic deprivation across all ZCTA's. We present demographic and clinical characteristics for the overall sample and by SDI quartiles in Table 1. We also present the demographic and clinical characteristics by age and BMI in Supplemental Table 1.

3.2. Socioeconomic deprivation and cardiometabolic risk factors

Cardiometabolic risk factors were higher in areas with higher social deprivation indices. We examined the unadjusted association between SDI and cardiometabolic risk factors in the first set of linear regression models. The unadjusted association between SDI and all cardiometabolic risk factors (HbA_{1c}, BMI, LDL-C, and blood pressure [systolic and diastolic]) was statistically significant ($p < .001$) (Table 2). Also, the unadjusted association between SDI and physical activity was statistically significant ($p = .002$).

In the second set of models, we examined socioeconomic deprivation and cardiometabolic risk factors after adjusting for covariates (age, biological sex, T1D duration, and race/ethnicity) using multivariable linear regression. The associations between SDI and cardiometabolic risk factors (HbA_{1c} $\beta = .139$, BMI $\beta = .135$, LDL-C $\beta = .024$, SBP $\beta = .056$) remained statistically significant after controlling for age, biological sex, T1D duration, and race/ethnicity ($p < .001$). The association between SDI and physical activity also remained statistically significant after adjusting for covariates ($p = .006$).

We added physical activity as an independent variable in the third set of models using multivariable linear regression. The associations between socioeconomic deprivation and most cardiometabolic risk factors (except diastolic blood pressure) remained statistically significant after adding in physical activity and controlling for age, biological sex, T1D duration, and race/ethnicity (all $p \leq .005$). Physical activity was significantly associated with BMI and HbA_{1c}, and diastolic blood pressure ($p \leq .05$). The association between physical activity and LDL-C or systolic blood pressure was not significant.

In the unadjusted logistic regression models, individuals with T1D living in the most socially deprived areas had 1.4 times higher odds of not achieving glycemic targets (OR = 1.43, 95% confidence interval [1.23, 1.67]) and 1.2 times higher odds of dyslipidemia (OR = 1.20, 95% confidence interval [1.07, 1.34]) than those living in less socially deprived areas (Table 3). The associations in the adjusted logistic regression models for glycemia, dyslipidemia, and systolic hypertension were no longer significant ($p = .618$, p = .089, p

= .725 respectively) (covariates were age, biological sex, T1D duration, and race/ethnicity). In the adjusted and unadjusted models, individuals with T1D residing in the most socially deprived areas had odds 1.2 and 1.6 times higher for hypertension (diastolic) than those living in less socially deprived areas (*OR* = 1.20, 95% confidence interval [1.06, 1.36]; *aOR* = 1.61, 95% confidence interval [1.01, 1.33]). In the unadjusted and adjusted models, those in the highest socially deprived areas had odds 1.7 and 1.8 times higher for a triple concomitant risk burden of poor glycemia, dyslipidemia, and hypertension (*OR* = 1.69, 95% confidence interval [1.22, 2.34]; *aOR* = 1.78, 95% confidence interval [1.23, 2.58]. The adjusted or unadjusted associations were not significant with overweight/obesity as an outcome ($p > .05$). We present the single and concomitant cardiometabolic risk factor prevalence % (low-density lipoprotein, systolic blood pressure, hemoglobin A_{1c}) by social deprivation index quartiles in Figure 1. Scatter plots of SDI and cardiometabolic risk are presented in Supplemental Figure 1.

4. Discussion

We systematically investigated the association of socioeconomic deprivation with adverse cardiometabolic risk factors, finding that higher socioeconomic deprivation was associated with higher cardiometabolic risk among a large representative sample of adolescents and adults living with T1D. We found that those in more socially deprived areas had an almost 2-fold increase in the likelihood of a triple concomitant risk burden of not achieving glycemic, cholesterol, or blood pressure targets. The associations persisted even after adjusting for multiple covariates, including physical activity. We also found a significant association between physical activity and SDI. There is a paucity of literature on the underlying causes of cardiometabolic risk factors in individuals with T1D. To our knowledge, we are the first to report associations between objective measures of socioeconomic (area-level) deprivation and cardiometabolic risk among a large representative cohort of adolescents and adults living with T1D. These findings add to the disparate literature on cardiometabolic risk in individuals with T1D and the role of social determinants of health in perpetuating cardiometabolic risk in this population.

The findings from the current study build on previous studies on cardiometabolic risk in T1D and other populations. In individuals with T1D, the prevalence of overweight and obesity was lower than the general population in the 1980s and ‘90s; however, in the past two decades, it has risen by close to 50% [23, 24]. There has also been a general upward trend in the prevalence of multiple cardiometabolic risk factors in T1D (obesity, insulin resistance, hypertension, and dyslipidemia) [25]. These changes are concomitant with the obesity epidemic and intensive insulin therapy. Weight gain is a consequence of a positive energy balance over time and is partially explained by intensive insulin therapy and increased hypoglycemic episodes, which are associated with a generalized increased food craving [24]. Also, hypoglycemic episodes are barriers to physical activity and sleep. Intensive insulin therapy plays a direct role in weight gain through a reduction in glycosuria and an anabolic effect of insulin on lean and fat mass [24]. Excessive weight gain also increases insulin resistance and is associated with hypertension and dyslipidemia [24]. Modest increments in moderate to vigorous physical activity have been shown to have a clinically meaningful impact in cardiometabolic risk [26, 27]. Tailored programs are needed to account for the additional barriers in physical activity among adults with T1D. Further, socioeconomically disadvantaged neighborhoods have unsafe living conditions, including poor walkability with limited available green space to encourage physical activity [28].

Adolescent and adult overweight and obesity continue to be an intractable problem in the United States [29, 30], and nearly a quarter of the adolescents (24.8%) and half of the adults (50.8%) with T1D in this study were overweight or obese. It is necessary to consider lifestyle interventions and other treatment modalities to address weight in this demographic already at heightened risk of poor cardiovascular outcomes. Mobile clinics, telehealth services, and pharmacy deliveries may improve access to care and treatment and decrease the cardiometabolic risk burden for those residing in these highly deprived areas with limited access to health care [31].

Close to 7% of the current sample had a triple concomitant risk burden of cardiometabolic risk factors (poor glycemia, hypertension, and dyslipidemia) and those residing in more socially deprived areas had an almost two-fold risk of this triple burden compared to those residing in less socially deprived areas. Individuals living with a triple burden residing in socioeconomically deprived areas are susceptible to poor health outcomes. Thus, models of care are needed to address SDOH and overcome the adverse effects of living in a socioeconomically deprived area. Rural areas tend to have greater socioeconomic deprivation than their urban and suburban counterparts, and people living in rural areas have poorer health outcomes in T1D and cardiovascular disease [32]. Rural areas typically have greater socioeconomic deprivation due to low household income [33], lack of or limited health insurance, and lack of access to preventative health care services, resulting in poorer management of T1D [34]. T1D may be more common among youth living in rural areas —complicating an already challenging problem—and is hypothesized to be related to the underdevelopment of the immune system due to the social isolation of rural living [32, 35, 36]. The incidence of T1D is greatest in areas of low population density (rural) across the United States, with rates of 2.28 times (95% CI 2.08 – 2.50) that of individuals living in high-density areas [36].

Drug therapies may also be considered. Metformin with titrated insulin therapy is FDA approved and has been shown to reduce glucose concentrations, metabolic syndrome, and insulin dose requirement, with radiologic evidence of reduced coronary artery calcium in adults with T1D [37]. Specifically in a double blind, placebo-controlled trial of metformin in 493 adults with T1D over the age of 40 years, progression of carotid intima-media thickness was not significantly reduced, but maximal carotid intima media thickness was reduced along with HbA_{1c}, bodyweight, LDL-C supporting that metformin has a wider role in cardiovascular disease risk management [37]. Other drugs such as glucagon-like peptide-1 analogues have restored endothelial function, induced vasodilatation, and reduced plasma lipids in individuals with T2D [38]; however their safety and efficacy need to be established in T1D.

The findings should be interpreted within the context of the strengths and limitations of the current study. All participants in the T1D clinic registry are treated at T1D focused specialty care centers thus, those uninsured are likely underrepresented in this cohort. Higher HbA_{1c}

values may be expected in a national, population-based sample or among adolescents and adults treated in primary care instead of diabetes specialty clinics, thereby underestimating the associations observed here. Based on a population-based US study, it is estimated that 14% of individuals with T1D receive treatment in primary care only [39]. Although BMI is a commonly used generic obesity indicator, it does not distinguish between central and peripheral obesity [40]. It is primarily central obesity (mainly visceral obesity) that increases blood glucose levels and the risk of micro-and macrovascular complications [4, 41, 42]. Not all aspects of social capital, which links closely with SDI, are related to health care services [43]. There is potential for wide variations of SDOH, heterogenous populations, and health outcomes within one zip code. Elucidating the associations using smaller geographic levels (e.g., census tracts or blocks) or at the individual level with long-term cardiovascular outcomes would add further insight into the findings in the present study. It is unknown how long participants lived at the reported zip-code at the time of examination. Also, measuring physical activity by self-report is subject to self-report bias and the way physical activity was measured in the current study is subject to recall bias (total hours per week, hours per week of low, moderate, and high activity, days per week of exercise, as well as aerobic/anaerobic exercise). Further study is needed to unravel the relationship between socioeconomic deprivation and cardiometabolic risk in individuals with T1D.

5. Conclusion

Socioeconomic deprivation characteristics may serve as novel targets to improve premature micro- and macrovascular complications in individuals with T1D. The high proportion of individuals not achieving glycemia-related and other cardiometabolic risk factor targets make advanced technology development and dissemination imperative. For instance, HbA_{1c} is lower in individuals using continuous glucose monitors across the lifespan [44]. In order to reduce these socioeconomic differences upstream, key stakeholders and policymakers should consider the characteristics of the areas in which people live as well as the characteristics of the people who live in those areas. Clinicians should incorporate screening and support of area-level factors (e.g., SDOH) to connect individuals with appropriate services to address downstream determinants. For example, health care systems are adopting and deploying community health workers. These frontline public health workers have a closer understanding of the community served and can act as a liaison between health services and the community to facilitate access and improve quality. The emerging problem of an increasing number of cardiometabolic risk factors, particularly overweight and obesity in a population where this was not once a burden requires special attention in clinical practice and research to establish evidence informed interventions to prevent a significant burden from worsening.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgments:

The authors are grateful to the T1D Exchange Clinic Registry and the patients who provide their time and effort in contributing critical information. Without their assistance, this research would not have been possible. SG acquired, analyzed, interpreted the data, and wrote the manuscript.

Funding:

The first author SG is funded by the National Institute of Nursing Research (NINR) R00NR018886 and the American Academy of Sleep Medicine (AASM), 220-BS-19. Its contents are solely the responsibility of the authors and do not necessarily represent the official view of NIH or AASM.

References

1. Hill-Briggs F, Adler NE, Berkowitz SA, Chin MH, Gary-Webb TL, Navas-Acien A, Thornton PL, Haire-Joshu D (2021): Social determinants of health and diabetes: a scientific review. Diabetes Care 44, 258–279
2. Ludwig J, Sanbonmatsu L, Gennetian L, Adam E, Duncan GJ, Katz LF, Kessler RC, Kling JR, Lindau ST, Whitaker RC, McDade TW (2011): Neighborhoods, obesity, and diabetes--a randomized social experiment. N Engl J Med 365, 1509–19 [PubMed: 22010917]
3. Ludwig J, Duncan GJ, Gennetian LA, Katz LF, Kessler RC, Kling JR, Sanbonmatsu L (2012): Neighborhood effects on the long-term well-being of low-income adults. Science 337, 1505–10 [PubMed: 22997331]
4. Anonymous (1994): Effect of intensive diabetes treatment on the development and progression of long-term complications in adolescents with insulin-dependent diabetes mellitus: Diabetes Control and Complications Trial. Diabetes Control and Complications Trial Research Group. Journal of Pediatrics 125, 177–88 [PubMed: 8040759]
5. Avendano M, Kunst AE, Huisman M, Lenthe FV, Bopp M, Regidor E, Glickman M, Costa G, Spadea T, Deboosere P, Borrell C, Valkonen T, Gisser R, Borgan JK, Gadeyne S, Mackenbach JP (2006): Socioeconomic status and ischaemic heart disease mortality in 10 western European populations during the 1990s. Heart 92, 461–7 [PubMed: 16216862]
6. Clark AM, DesMeules M, Luo W, Duncan AS, Wielgosz A (2009): Socioeconomic status and cardiovascular disease: risks and implications for care. Nat Rev Cardiol 6, 712–22 [PubMed: 19770848]
7. Dupre ME, George LK, Liu G, Peterson ED (2012): The cumulative effect of unemployment on risks for acute myocardial infarction. Arch Intern Med 172, 1731–7 [PubMed: 23401888]
8. Jones CA, Perera A, Chow M, Ho I, Nguyen J, Davachi S (2009): Cardiovascular disease risk among the poor and homeless-what we know so far. Current Cardiology Reviews 5, 69–77 [PubMed: 20066152]
9. Cleland SJ (2012): Cardiovascular risk in double diabetes mellitus--when two worlds collide. Nat Rev Endocrinol 8, 476–85 [PubMed: 22488644]
10. American Diabetes Association (2021): 10. Cardiovascular disease and risk management: Standards of medical care in diabetes—2021. Diabetes Care 44, S125 [PubMed: 33298421]
11. Hendryx MS, Ahern MM, Lovrich NP, McCurdy AH (2002): Access to health care and community social capital. Health services research 37, 85
12. Wang F, Luo W (2005): Assessing spatial and nonspatial factors for healthcare access: towards an integrated approach to defining health professional shortage areas. Health Place 11, 131–46 [PubMed: 15629681]
13. McGrail MR, Humphreys JS (2009): The index of rural access: an innovative integrated approach for measuring primary care access. BMC Health Serv Res 9, 124 [PubMed: 19624859]
14. Dixon-Woods M, Cavers D, Agarwal S, Annandale E, Arthur A, Harvey J, Hsu R, Katbamna S, Olsen R, Smith L, Riley R, Sutton AJ (2006): Conducting a critical interpretive synthesis of the literature on access to healthcare by vulnerable groups. BMC Med Res Methodol 6, 35 [PubMed: 16872487]

15. Toms R, Bonney A, Mayne DJ, Feng X, Walsan R (2019): Geographic and area-level socioeconomic variation in cardiometabolic risk factor distribution: a systematic review of the literature. Int J Health Geogr 18, 1 [PubMed: 30621786]
16. Schofield J, Ho J, Soran H (2019): Cardiovascular Risk in Type 1 Diabetes Mellitus. Diabetes Ther 10, 773–789 [PubMed: 31004282]
17. Butler DC, Petterson S, Phillips RL, Bazemore AW (2013): Measures of social deprivation that predict health care access and need within a rational area of primary care service delivery. Health Serv Res 48, 539–59 [PubMed: 22816561]
18. Leal C, Chaix B (2011): The influence of geographic life environments on cardiometabolic risk factors: a systematic review, a methodological assessment and a research agenda. Obes Rev 12, 217–30 [PubMed: 20202135]
19. Craig CL, Marshall AL, Sjöström M, Bauman AE, Booth ML, Ainsworth BE, Pratt M, Ekelund U, Yngve A, Sallis JF, Oja P (2003): International physical activity questionnaire: 12-country reliability and validity. Med Sci Sports Exerc 35, 1381–95 [PubMed: 12900694]
20. Whelton PK et al. (2018): 2017 ACC/AHA/AAPA/ABC/ACPM/AGS/APhA/ASH/ASPC/NMA/PCNA guideline for the prevention, detection, evaluation, and management of high blood pressure in adults: Executive summary: A report of the American College of Cardiology/American Heart Association Task Force on clinical practice guidelines. Circulation 138, e426–e483 [PubMed: 30354655]
21. Berk KN (2002): Repeated measures with zeros. Statistical Methods in Medical Research 11, 303–316 [PubMed: 12197298]
22. Basile Ibrahim B, Barcelona V, Condon EM, Crusto CA, Taylor JY (2021): The Association Between Neighborhood Social Vulnerability and Cardiovascular Health Risk Among Black/African American Women in the InterGEN Study. Nurs Res 70, S3–S12 [PubMed: 34074961]
23. Nathan DM, Group DER (2014): The diabetes control and complications trial/epidemiology of diabetes interventions and complications study at 30 years: overview. Diabetes Care 37, 9–16 [PubMed: 24356592]
24. Purnell JQ, Hokanson JE, Marcovina SM, Steffes MW, Cleary PA, Brunzell JD (1998): Effect of excessive weight gain with intensive therapy of type 1 diabetes on lipid levels and blood pressure: results from the DCCT. Diabetes Control and Complications Trial. JAMA 280, 140–6 [PubMed: 9669786]
25. Leroux C, Brazeau AS, Gingras V, Desjardins K, Strychar I, Rabasa-Lhoret R (2014): Lifestyle and cardiometabolic risk in adults with type 1 diabetes: a review. Can J Diabetes 38, 62–9 [PubMed: 24485215]
26. Balducci S et al. (2022): Relationships of Changes in Physical Activity and Sedentary Behavior With Changes in Physical Fitness and Cardiometabolic Risk Profile in Individuals With Type 2 Diabetes: The Italian Diabetes and Exercise Study 2 (IDES_2). Diabetes Care 45, 213–221 [PubMed: 34728529]
27. Ash GI, Griggs S, Nally LM, Stults-Kolehmainen M, Jeon S, Brandt C, Gulanski BI, Spanakis EK, Baker JS, Whittemore R, Weinzimer SA, Fucito LM (2021): Evaluation of Web-Based and In-Person Methods to Recruit Adults With Type 1 Diabetes for a Mobile Exercise Intervention: Prospective Observational Study. JMIR Diabetes 6, e28309 [PubMed: 34047700]
28. Javed Z, Haisum Maqsood M, Yahya T, Amin Z, Acquah I, Valero-Elizondo J, Andrieni J, Dubey P, Jackson RK, Daffin MA, Cainzos-Achirica M, Hyder AA, Nasir K (2022): Race, Racism, and Cardiovascular Health: Applying a Social Determinants of Health Framework to Racial/Ethnic Disparities in Cardiovascular Disease. Circ Cardiovasc Qual Outcomes 15, e007917 [PubMed: 35041484]
29. Moore SM, Borawski EA, Love TE, Jones S, Casey T, McAleer S, Thomas C, Adegbite-Adeniyi C, Uli NK, Hardin HK, Trapl ES, Plow M, Stevens J, Truesdale KP, Pratt CA, Long M, Nevar A (2019): Two Family Interventions to Reduce BMI in Low-Income Urban Youth: A Randomized Trial. Pediatrics 143
30. Hales CM, Carroll MD, Fryar CD, Ogden CL (2017): Prevalence of Obesity Among Adults and Youth: United States, 2015–2016. NCHS Data Brief, 1–8

31. Schwamm LH, Chumbler N, Brown E, Fonarow GC, Berube D, Nystrom K, Suter R, Zavala M, Polsky D, Radhakrishnan K, Lacktman N, Horton K, Malcarney MB, Halamka J, Tiner AC, Committee AHAAC (2017): Recommendations for the Implementation of Telehealth in Cardiovascular and Stroke Care: A Policy Statement From the American Heart Association. Circulation 135, e24–e44 [PubMed: 27998940]
32. Borchers AT, Uibo R, Gershwin ME (2010): The geoepidemiology of type 1 diabetes. Autoimmun Rev 9, A355–65 [PubMed: 19969107]
33. Kassam S, Serrano-Lomelin J, Hicks A, Crawford S, Bakal JA, Ospina MB (2021): Geography as a Determinant of Health: Health Services Utilization of Pediatric Respiratory Illness in a Canadian Province. Int J Environ Res Public Health 18
34. Chepulis L, Tamatea JAU, Wang C, Goldsmith J, Mayo CTH, Paul RG (2021): Glycaemic control across the lifespan in a cohort of New Zealand patients with type 1 diabetes mellitus. Intern Med J 51, 725–731 [PubMed: 32175657]
35. Castillo-Reinado K, Maier W, Holle R, Stahl-Pehe A, Baechle C, Kuss O, Hermann J, Holl RW, Rosenbauer J (2020): Associations of area deprivation and urban/rural traits with the incidence of type 1 diabetes: analysis at the municipality level in North Rhine-Westphalia, Germany. Diabet Med 37, 2089–2097 [PubMed: 31999840]
36. Rogers MAM (2019): Onset of type 1 diabetes mellitus in rural areas of the USA. J Epidemiol Community Health 73, 1136–1138 [PubMed: 31563896]
37. Petrie JR, Chaturvedi N, Ford I, Brouwers MCGJ, Greenlaw N, Tillin T, Hramiak I, Hughes AD, Jenkins AJ, Klein BEK, Klein R, Ooi TC, Rossing P, Stehouwer CDA, Sattar N, Colhoun HM, Group RS (2017): Cardiovascular and metabolic effects of metformin in patients with type 1 diabetes (REMOVAL): a double-blind, randomised, placebo-controlled trial. Lancet Diabetes Endocrinol 5, 597–609 [PubMed: 28615149]
38. Saraiva JFK, Franco D (2021): Oral GLP-1 analogue: perspectives and impact on atherosclerosis in type 2 diabetic patients. Cardiovasc Diabetol 20, 235 [PubMed: 34911560]
39. Slåtsve KB, Claudi T, Lappegård KT, Jenum AK, Larsen M, Nøkleby K, Cooper JG, Sandberg S, Berg TJ (2021): Factors associated with treatment in primary versus specialist care: A population-based study of people with type 2 and type 1 diabetes. Diabet Med 38, e14580 [PubMed: 33834523]
40. Nakanishi S, Matsuura B, Hirooka M, Ueda T, Niiya T, Furukawa S, Abe M, Hiasa Y, Kubo Y, Onji M (2007): Clinical usefulness of quantitative evaluation of visceral fat by ultrasonography. J Med Ultrason (2001) 34, 151–7 [PubMed: 27278400]
41. Hanai K, Babazono T, Nyumura I, Toya K, Ohta M, Bouchi R, Suzuki K, Inoue A, Iwamoto Y (2010): Involvement of visceral fat in the pathogenesis of albuminuria in patients with type 2 diabetes with early stage of nephropathy. Clin Exp Nephrol 14, 132–6 [PubMed: 20091203]
42. Kurozumi A, Okada Y, Arao T, Tanaka Y (2016): Excess Visceral Adipose Tissue Worsens the Vascular Endothelial Function in Patients with Type 2 Diabetes Mellitus. Intern Med 55, 3091–3095 [PubMed: 27803400]
43. Hwang J, Rudnisky C, Bowen S, Johnson JA (2017): Measuring socioeconomic inequalities in eye care services among patients with diabetes in Alberta, Canada, 1995–2009. Diabetes Res Clin Pract 127, 205–211 [PubMed: 28391137]
44. Foster NC, Beck RW, Miller KM, Clements MA, Rickels MR, DiMeglio LA, Maahs DM, Tamborlane WV, Bergenstal R, Smith E (2019): State of type 1 diabetes management and outcomes from the T1D Exchange in 2016–2018. Diabetes Technology & Therapeutics 21, 66–72 [PubMed: 30657336]

Highlights

- Adolescents and adults with type 1 diabetes living in more socially deprived areas have an almost 2-fold increase in the odds of a triple concomitant risk burden (poor glycemia, dyslipidemia, and hypertension)
- Close to 7% of adolescents and adults with type 1 diabetes have a triple concomitant risk burden of hypertension, dyslipidemia, and poor glycemia.
- Socioeconomic deprivation and physical activity characteristics are novel targets to prevent premature micro- and macrovascular complications in individuals with type 1 diabetes
- Special attention in clinical practice and research is needed to address the increasing number of cardiometabolic risk factors in type 1 diabetes

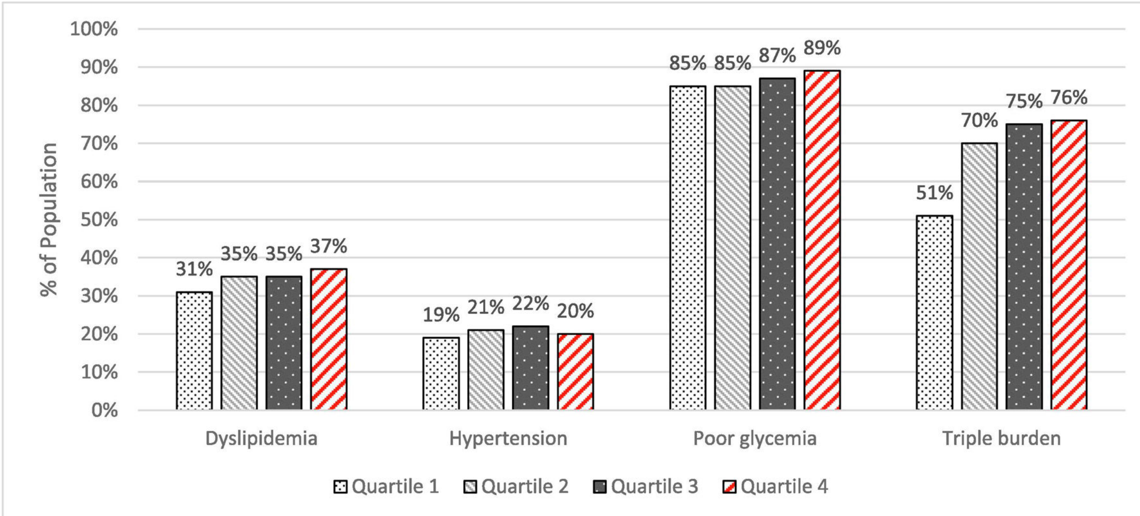

Fig. 1.

Single and concomitant cardiometabolic risk factor (low-density lipoprotein, systolic blood pressure, hemoglobin A_{1c}) prevalence % by social deprivation index quartiles.

Table 1

Sample characteristics by social deprivation index quartiles (N = 18,754).

	Overall	SDI Quartile 1	SDI Quartile 2	SDI Quartile 3	SDI Quartile 4
	Mean (SD)	**Mean (SD)**	**Mean (SD)**	**Mean (SD)**	**Mean (SD)**
n	18,754	4,710	4,679	4,752	4,613
Age, mean	29.24 (17.1)	29.54 (17.49)	30.70 (17.81)	29.23 (17.02)	27.48 (15.64)
T1D Duration, mean	11.11 (11.88)	14.71 (12.98)	15.16 (13.19)	14.67 (12.98)	13.25 (11.56)
HbA1c, mean	8.32 (1.45)	8.11 (1.27)	8.21 (1.38)	8.32 (1.42)	8.65 (1.65)
BMI, mean	25.17 (5.25)	24.81 (5.06)	25.16 (5.30)	25.32 (5.24)	25.38 (5.33)
Systolic blood pressure, mean	119.58 (13.44)	118.37 (13.32)	119.65 (13.41)	120.40 (13.73)	119.85 (13.55)
Diastolic blood pressure, mean	70.57 (8.98)	69.85 (9.08)	70.50 (8.81)	70.89 (8.86)	71.02 (9.15)
Low density lipoprotein, mean	92.03 (29.11)	90.02 (26.82)	92.31 (28.89)	92.34 (29.53)	93.37 (30.81)
Physical activity (hours per week)	6.75 (7.43)	7.14 (7.37)	6.89 (7.21)	6.88 (8.27)	6.02 (6.72)
	N (%)	**n (%)**	**n (%)**	**n (%)**	**n (%)**
BMI categories					
<18.5 %	1,013 (6.3)	261 (6.5)	261 (6.7)	237 (5.8)	244 (6.0)
18.5–24.9 %	7,897 (48.9)	2,057 (51.2)	1,916 (49.0)	1,935 (47.7)	1,938 (47.9)
25.0–29.9 %	4,668 (28.9)	1,132 (28.2)	1,099 (28.1)	1,205 (29.7)	1,198 (29.6)
30–34.9 %	1,749 (10.8)	394 (9.8)	441 (11.3)	458 (11.3)	443 (10.9)
35.0–39.9 %	590 (3.7)	125 (2.7)	138 (3.5)	172 (4.2)	151 (3.7)
>40 %	231 (1.4)	45 (1.0)	58 (1.5)	52 (1.3)	73 (1.8)

Table 2

Socioeconomic deprivation, physical activity, and covariates to cardiometabolic outcomes (Linear Regression Models).

Model	Independent Variable/s	Dependent Variable/s	B	SE	β	R^2	P value
Model 1 (unadjusted)	Social deprivation index	HbA_{1c}	**0.001**	**0.000**	**0.145**	**0.021**	**<0.001**
		Body mass index	**0.000**	**0.000**	**0.043**	**0.002**	**<0.001**
		Low density lipoprotein	**0.002**	**0.000**	**0.040**	**0.002**	**<0.001**
		Systolic blood pressure	**0.019**	**0.004**	**0.039**	**0.002**	**<0.001**
		Diastolic blood pressure	**0.017**	**0.002**	**0.053**	**0.003**	**<0.001**
Model 2 (adjusted for covariates)	Social deprivation index	HbA_{1c}	**0.001**	**0.000**	**0.107**	**0.139**	**<0.001**
		Body mass index	**0.000**	**0.000**	**0.055**	**0.135**	**<0.001**
		Low density lipoprotein	**0.001**	**0.000**	**0.024**	**0.024**	**0.004**
		Systolic blood pressure	**0.027**	**0.004**	**0.056**	**0.091**	**<0.001**
		Diastolic blood pressure	**0.019**	**0.002**	**0.060**	**0.012**	**<0.001**
Model 3 (adjusted for covariates and physical activity)	Social deprivation index	HbA_{1c}	**0.001**	**0.000**	**0.098**	**0.140**	**<0.001**
		Body mass index	**0.000**	**0.000**	**0.037**	**0.124**	**0.036**
		Low density lipoprotein	**0.003**	**0.001**	**0.054**	**0.012**	**0.005**
		Systolic blood pressure	**0.017**	**0.009**	**0.034**	**0.077**	**0.049**
		Diastolic blood pressure	0.004	0.006	0.013	0.012	0.465
	Physical Activity	HbA_{1c}	**0.001**	**0.000**	**0.034**	**0.149**	**0.037**
		Body mass index	**−0.001**	**0.000**	**−0.044**	**0.124**	**0.012**
		Low density lipoprotein	−0.005	0.004	−0.028	0.012	0.142
		Systolic blood pressure	0.056	0.031	0.031	0.077	0.066
		Diastolic blood pressure	**−0.059**	**0.021**	**−0.050**	**0.012**	**0.005**

Note. BMI and HbA_{1c} were log transformed and LDL was square root transformed. **Bolded values are significant.**

Table 3

Socioeconomic deprivation, poor glycemia, overweight/obesity, dyslipidemia, and hypertension (Logistic Regression Models). Residence in 10% most deprived areas.

Social deprivation index						
	OR	**95 % CI**	**p value**	**aOR**	**95 % CI**	**p value**
Poor glycemia	**1.43**	**[1.23, 1.67]**	**<0.001**	1.04	[0.882, 1.24]	0.618
Overweight/obesity	1.05	[0.959, 1.17]	0.253	1.04	[0.929, 1.17]	0.490
Dyslipidemia	**1.20**	**1.07, 1.34]**	**0.001**	1.11	[0.984, 1.25]	0.089
Hypertension (systolic)	0.979	[0.868, 1.10]	0.723	0.979	[0.855, 1.12]	0.752
Hypertension (diastolic)	**1.20**	**[1.06, 1.36]**	**0.003**	**1.61**	**[1.01, 1.33]**	**0.030**
Triple burden (poor glycemia/dyslipidemia/hypertension)	**1.69**	**[1.22, 2.34]**	**0.002**	**1.78**	**[1.23, 2.58]**	**0.002**

Note: CI = confidence interval; OR = odds ratio; aOR = adjusted odds ratio; HbA_{1c}; hypertension categories (systolic blood pressure > 130 or diastolic blood pressure > 80 mmHg).