Complex Network Analysis of Psychological Resilience in Adolescents with Type 1 Diabetes Based on Multi-Source Illness Stigma: Postprint

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Abstract

Background Psychological resilience can effectively improve health outcomes and quality of life in adolescents with type 1 diabetes (T1D). However, this population is profoundly affected by multi-source stigma, which severely undermines their psychological resilience. Currently, the mechanisms through which stigma from different sources influences psychological resilience remain unclear.

Objective To explore the pathways through which multi-source stigma influences psychological resilience in adolescent patients with T1D, identify core sources of stigma, and provide evidence for stigma reduction and resilience enhancement.

Methods From July 2022 to July 2024, 364 adolescent T1D patients were conveniently selected from two tertiary grade A hospitals in Nanjing. The investigation was conducted using the Adolescent Type 1 Diabetes Stigma Assessment Scale, the Adolescent Diabetes Quality of Life Scale, and the Adolescent Diabetes Strengths and Resilience Scale. Complex network analysis was performed using R software, with subgroup analysis conducted by age.

Results Among multi-source stigma, "being perceived as defective" (1.248), "worrying about negative reactions from others" (1.132), and "being excluded by others" (1.125) exhibited the greatest expected influence in the network. Between multi-source stigma variables, "worrying about negative reactions from others" and "concealing diabetes" showed the strongest positive correlation in the network (r=0.562). Disease concealment behavior was negatively correlated with the "seeking help" dimension of psychological resilience (r=-0.098), whereas parental overprotection was positively correlated with the "family resources" dimension of psychological resilience (r=0.007). The pre-adolescence group demonstrated denser network connectivity than the late adolescence group (S=0.10, GS_{pre}=10.47, GS_{late}=10.36, P=0.789).

Conclusion Public misunderstanding, social exclusion, and individual anticipated discrimination are key stigma sources that constrain the development of psychological resilience in adolescent T1D patients, with pre-adolescent patients being more vulnerable to stigma-related distress. Healthcare professionals should identify and eliminate these key sources of stigma.

Full Text

Complex Network Analysis of Resilience in Adolescents with Type 1 Diabetes Based on Multi-Sourced Stigma

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Abstract

Background Resilience can effectively improve health outcomes and enhance quality of life for adolescents with Type 1 Diabetes (T1D). However, this population is plagued by multi-sourced stigma, which severely undermines their resilience. Currently, the mechanism of how stigma from different sources affects resilience remains unclear.

Objective To explore the pathways of multi-sourced stigma on the resilience of adolescents with T1D, and identify the core sources of stigma to provide evidence for eliminating stigma and improving resilience.

Methods From July 2022 to July 2024, a total of 364 adolescents with T1D were conveniently selected from two tertiary hospitals in Nanjing. Data were collected using the Type 1 Diabetes Stigma Assessment Scale, the Short Form of the Chinese version Diabetes Quality of Life for Youth Scale, and the Diabetes Strengths and Resilience Measure for Adolescents With Type 1 Diabetes. Complex network analysis was performed using R software, and subgroup analysis was conducted based on age.

Results Within multi-sourced stigma, "being perceived as defective" (1.248), "worrying about negative reactions from others" (1.132), and "being excluded

by others" (1.125) had the greatest expected influence in the network. "Worrying about negative reactions from others" and "concealing diabetes" showed the strongest positive correlation (r=0.562). Concealment of the disease was negatively related to the resilience dimension "help-seeking" (r=-0.098), while parental overprotection was positively related to the resilience dimension "family resources" (r=0.007). The network connections were tighter in the early adolescent group compared to the late adolescent group (S=0.10, GS_{early}=10.47, GS_{late}=10.36, P=0.789).

Conclusion Public misunderstanding, social exclusion, and individual anticipated discrimination are core sources of stigma that hinder the development of resilience in adolescents with T1D. Moreover, early adolescents are more susceptible to stigma. Healthcare professionals should identify and address these core sources of stigma.

Key words Diabetes mellitus, type 1; Adolescents; Stigma; Resilience; Complex network analysis

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Introduction

Type 1 diabetes (T1D) is a common chronic disease among adolescents, requiring lifelong management to prevent complications [**?**]. The prevalence of adolescent T1D in China ranks highest in Asia, with approximately 56,000 new cases annually, yet disease control rates remain at only 15.5%, imposing a heavy burden on patients' learning and daily life [**?**]. Research demonstrates that resilience can effectively improve self-management behaviors, reduce negative emotions, and maintain stable blood glucose levels in adolescents with T1D [**?**]. Resilience refers to an individual' s capacity to maintain a positive attitude and achieve favorable health outcomes when facing significant challenges or setbacks [**?**].

Due to its incurable nature, complex management requirements, and the visibility of treatment devices and symptoms, adolescents with T1D frequently experience profound stigma [**?**]. Stigma encompasses the negative emotional experiences—including fear, shame, and self-deprecation—that patients develop when they perceive unjust treatment, rejection, discrimination, and blame from others due to their disease and its management [**?**]. A cross-sectional survey revealed that up to 63.4% of adolescents with T1D have experienced discrimination [**?**]. Studies confirm that stigma severely damages psychological resilience

in this population [?]. Therefore, reducing stigma and enhancing resilience are crucial for improving health outcomes and quality of life.

Adolescents with T1D face multiple sources of stigma, including internal stigma (such as fear of discrimination and embarrassment) [?] and external stigma (such as peer discrimination, public misunderstanding, and parental over-concern) [?]. LI et al. [?] found that stigma from different sources can interact and reinforce one another. However, no studies have examined the relationships among different stigma sources in adolescents with T1D or the mechanisms linking multi-sourced stigma to resilience. Complex network analysis is a data analysis method that can quantify associations between symptoms and construct visual networks reflecting their interaction mechanisms [?]. In such networks, centrality indices reflect the importance of specific symptoms, helping identify core symptoms and intervention targets [?]. This study aims to construct a complex network of resilience in adolescents with T1D, identify key stigma sources, and provide evidence for eliminating stigma and improving resilience.

1.1 Study Participants

Adolescents with T1D attending regular follow-up appointments at two tertiary hospitals in Nanjing were selected as study participants. Inclusion criteria were: (1) diagnosed with T1D [?]; (2) aged 10-19 years (according to WHO standards) [?]; (3) disease duration $ $6 months; (4) ability to read Chinese and communicate fluently in Mandarin; and (5) informed consent from both participants and parents. Exclusion criteria were: (1) presence of other severe functional or organic diseases such as thyroid disease, asthma, or hypertension; (2) complications including diabetic ketoacidosis, severe hypoglycemia, insulinoma, or Cushing' s syndrome that could affect glycemic monitoring and disease assessment; and (3) history of mental illness such as psychiatric disorders or cognitive impairment. This study was approved by the Ethics Committee of Children' s Hospital of Nanjing Medical University (Approval No.: 202309003-1).

1.2 Measures

1.2.1 Basic Information A self-designed general information questionnaire was used to collect participants' demographic characteristics (e.g., gender, age, residence, medical payment method) and clinical features (e.g., disease duration, insulin treatment regimen). Participants' glycosylated hemoglobin (HbA1c) values from the past three months were extracted from hospital electronic medical records. If HbA1c had not been tested within three months, venous blood samples were collected on-site and measured using a Siemens DCA analyzer via high-performance liquid chromatography. HbA1c <7.5% indicated good glycemic control [?].

1.2.2 Multi-Sourced Stigma Internal stigma sources were measured using 5 items from the "Identity Issues" dimension of the Type 1 Diabetes Stigma Assessment Scale (DSAS-1), which primarily reflect patients' distress regarding

discrimination and embarrassment related to identity [**?**]. External stigma was measured using 12 items from the "Differential Treatment" and "Complaints and Comments" dimensions of DSAS-1, plus 3 items from the "Parental Over-concern" dimension of the Short Form of the Chinese version Diabetes Quality of Life for Youth Scale (C-DQOLY-SF), covering peer discrimination, public misunderstanding, and parental over-concern [**?**]. Since DSAS-1 does not include parental over-concern, C-DQOLY-SF was incorporated to comprehensively assess external stigma sources.

The DSAS-1 comprises 17 items across three dimensions: "Identity Issues," "Differential Treatment," and "Complaints and Comments." Items are rated on a 5-point Likert scale from 1 (strongly disagree) to 5 (strongly agree), with higher scores indicating greater stigma [**?**]. The scale demonstrated good reliability and validity, with a Cronbach' s α coefficient of 0.92 in this study. The parental over-concern dimension of C-DQOLY-SF includes three items: "parents are overprotective," "parents worry excessively about diabetes," and "parents act as if diabetes is their disease." Items are rated on a 5-point Likert scale from 1 (never) to 5 (always), with higher scores indicating greater perceived parental over-concern and lower quality of life [**?**]. This scale also showed good reliability and validity, with a Cronbach' s α coefficient of 0.89 in this study.

1.2.3 Resilience The Diabetes Strengths and Resilience Measure for Adolescents With Type 1 Diabetes (DSTAR-Teen) was used to assess resilience [**?**]. The scale includes three dimensions: "self-care confidence," "family resources," and "help-seeking," evaluating resilience at individual, family, and social levels. It contains 12 items rated on a 5-point Likert scale from 1 (never) to 5 (always), with higher scores indicating greater diabetes-related resilience. The scale demonstrated good reliability and validity, with a Cronbach' s α coefficient of 0.90 in this study.

1.3 Survey and Quality Control

Questionnaire administrators received unified formal training before data collection. After obtaining informed consent, they explained the survey' s purpose, content, and significance before distributing paper questionnaires. Administrators provided immediate clarification for any questions or confusion during completion. Completed questionnaires were collected on-site and reviewed, with any missing or unclear answers verified promptly with participants. All data were double-entered and verified by a third person to ensure accuracy.

1.4 Statistical Analysis

SPSS 26.0 was used for descriptive analysis of participant characteristics. Normally distributed continuous variables were expressed as (x-±s), and categorical variables as frequencies and percentages. R 4.3.2 with the qgraph package was used to generate complex networks, with relationships between nodes estimated via Pearson correlation analysis using the EBICglasso function [**?**]. Each

item from the multi-sourced stigma measures served as a node representing different stigma sources, while dimensions from the resilience measure served as nodes representing individual, family, and social-level resilience. Edge weights between nodes represented partial correlations, with larger values indicating stronger relationships. The mgm function estimated node predictability—highly predictable nodes are more susceptible to neighboring nodes and can be controlled through them [**?**]. The centralityPlot function calculated expected influence (EI) to measure node centrality and importance; intervening on high-EI nodes can effectively interrupt their influence on neighboring nodes [**?**]. The NetworkComparisonTest package compared network connectivity between early (10-14 years) and late (15-19 years) adolescent groups (per WHO standards) [**?**] to explore differential intervention difficulty. Network connectivity was assessed via global strength (GS), the sum of absolute edge weights across the network —tighter connections indicate greater node vulnerability [**?**]. The bootnet package performed bootstrap tests to evaluate network accuracy and stability. Accuracy was estimated via 95% confidence intervals for edge weights (narrower intervals indicate higher accuracy) [**?**]. Stability was assessed via correlation stability coefficient (CS) using case-dropping bootstrap, which sequentially removed individual cases and recalculated CS to assess fluctuation across different sample combinations. CS minimum (caseMin) and maximum (caseMax) values reflect lower and upper bounds of stability impact from individual samples [**?**]. CS>0.25 indicates acceptable stability, and >0.50 good stability [**?**]. P<0.05 was considered statistically significant.

Results

2.1 Participant Characteristics

The 364 recruited adolescents with T1D came from 9 provinces and 36 cities nationwide. The sample included 162 males (44.5%) and 202 females (55.5%), with a mean age of $(13.8\$\pm2.8) years, mean disease duration of (8.9\pm3.5) years, and mean HbA1c of (8.7\pm\$2.6)\%$. A total of 216 patients (59.3%) had suboptimal glycemic control. Detailed characteristics are shown in Table 1 .

2.2 Scores on Multi-Sourced Stigma and Resilience Scales

The mean DSAS-1 score was $(36.22\$\pm13.44), representing a moderate - to - low level relative to the total possible score of 85. The top three scoring stigma items were "parents worry excessively related blame" [(2.65\pm1.40)]. The mean DSTAR-Teen score was (38.25\pm9.70), representing a moderate-to-high level relative to the total possible score of 60. Among the three dimensions, "family resources" had the highe$
Detailed item scores are shown in Table 2 .

2.3 Complex Network Analysis

2.3.1 Complex Network Relationships The complex network of resilience based on multi-sourced stigma is shown in Figure 1

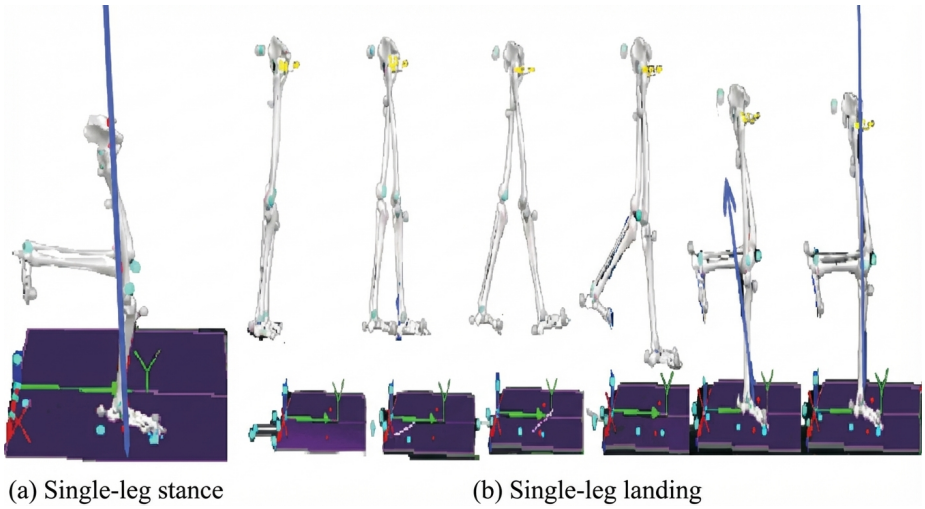

Figure 1: Figure 1

. The strongest partial correlation occurred within multi-sourced stigma, between "worrying about negative reactions from others" (a2) and "concealing diabetes"(a4) (r=0.562). Between multi-sourced stigma and resilience, "concealing diabetes" (a4) was negatively correlated with the "help-seeking" dimension (Y3) (r=-0.098), suggesting disease concealment hinders help-seeking behavior. However, certain stigma sources positively influenced resilience: "being perceived as defective" (b6) was positively correlated with "help-seeking" (Y3) (r=0.026), and "parents act as if diabetes is their disease" (d3) was positively correlated with "family resources" (Y2) (r=0.007), indicating that perceived misunderstanding can promote active help-seeking, while family overprotection can enrich family resources and strengthen resilience. Additionally, "being perceived as defective" (b6) showed the strongest predictability in the entire network, with 73.1% of its variance explainable by adjacent nodes, suggesting intervention on this node could effectively mitigate the impact of neighboring stigma sources.

2.3.2 Centrality Indices Expected influence results for each node are shown in Figure 2 [FIGURE:2]. "Being perceived as defective" (b6), "worrying about negative reactions from others"(a2), and "being excluded by others"(b5) had the highest EI values (1.248, 1.132, and 1.125, respectively), indicating that adolescents with T1D primarily experience interpersonal-level misunderstanding and rejection, coupled with internalized stigma and concerns about discriminatory behavior from others.

2.3.3 Network Comparison Analysis Network structure did not differ significantly between early and late adolescent groups (M=0.25, P>0.05). While network connectivity showed no statistically significant difference

between groups, the early adolescent group demonstrated tighter network connections than the late adolescent group (S=0.10, GS_{early}=10.47, GS_{late}=10.36, P=0.789), suggesting greater intervention difficulty for early adolescents. Although node EI did not differ significantly between groups (P>0.05), substantial differences emerged for specific nodes. The node showing the greatest EI change was "misunderstanding the need for insulin" (c1), while the most stable node was "low expectations from others" (b2). Further EI analysis of the two networks (Figure 3

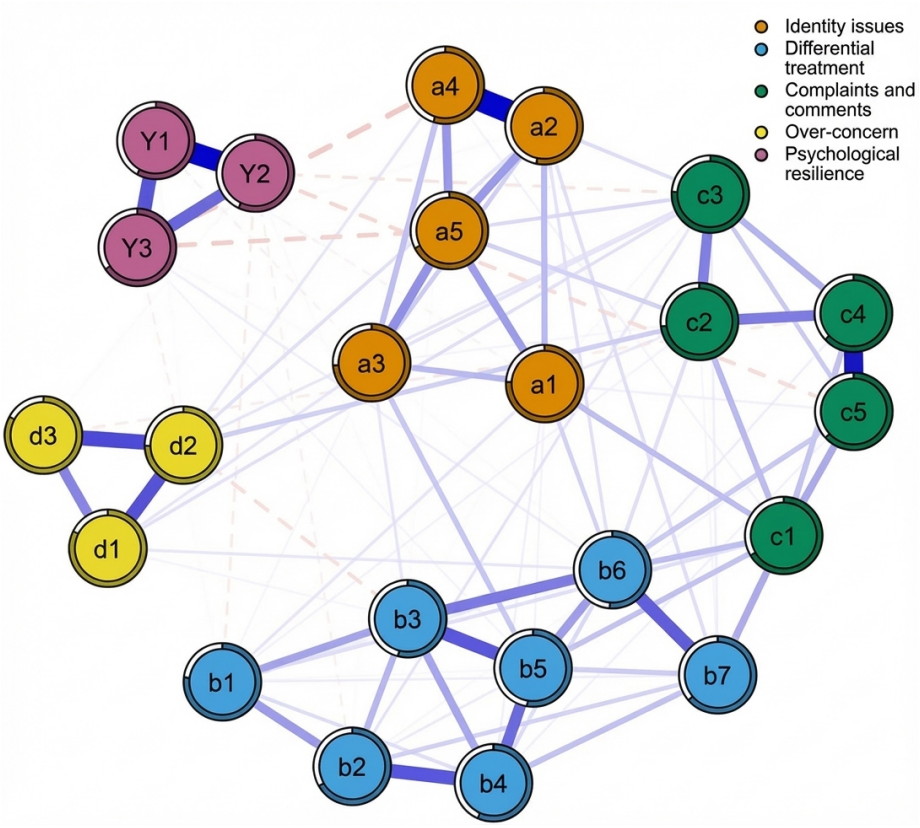

Figure 2: Figure 3

) revealed that "misunderstanding the need for insulin"(c1) had an EI of 1.036 in the early adolescent group versus 0.795 in the late adolescent group, indicating that younger adolescents experience more misunderstanding.

The 95% confidence intervals were narrow: -0.156~1.387 for the total sample, -0.158~1.363 for the early adolescent group, and -0.229~1.458 for the late adolescent group, suggesting relatively accurate edge weight estimation and good network accuracy. Using case-dropping bootstrap, CS values for EI were 0.750 (caseMin=0.673, caseMax=1) for the total sample, 0.593 (caseMin=0.517, case-

Max=0.674) for the early adolescent group, and 0.438 (caseMin=0.359, caseMax=0.516) for the late adolescent group—all exceeding 0.25, indicating good stability of centrality indices (Figure 4 [FIGURE:4]).

Discussion

3.1 Primary Stigma Sources in Adolescents with T1D

Our complex network analysis revealed that "being perceived as defective," "worrying about negative reactions from others," and "being excluded by others" had the greatest expected influence, indicating that adolescents with T1D suffer not only from individual identity concerns but also from interpersonal misunderstanding and rejection. Similar findings from stigma network analysis in breast cancer patients support intervening at individual and interpersonal levels [**?**]. At the individual level, the strongest correlation between "worrying about negative reactions from others" and "concealing diabetes" corroborates MOMANI et al.' s [**?**] finding that anticipated discrimination leads adolescents with T1D to conceal their condition. However, CHALMERS et al. [**?**] found that some adolescents with high self-awareness and stigma resistance could counter external discrimination through self-advocacy and humor. Future interventions using cognitive-behavioral therapy could enhance stigma resistance and reduce anticipated discrimination [**?**].

At the interpersonal level, adolescents with T1D frequently face misunderstanding, specifically "being perceived as defective." A systematic review noted that teachers' and parents' misunderstandings of children with chronic illnesses may differ from public misconceptions [**?**]. WANG et al. [**?**] reported that some teachers believe adolescents with T1D cannot handle class responsibilities, while STEVEN [**?**] noted that teachers and parents may have lower academic expectations for children with chronic conditions. HOLMSTRÖM et al. [**?**] found that teachers' differential treatment stems not only from knowledge deficits but also from lack of confidence in diabetes management. Nurses can provide diabetes education and parenting guidance for teachers and parents, while schools should improve management policies to ensure equal rights for all students. Public misunderstanding—including the perception that people with diabetes have reproductive defects, leading to lower status in romantic relationships [**?**]—can be addressed through video-based and contact interventions [**?**]. SEKAR et al. [**?**] demonstrated that community-based participatory theater enables the public to experience life with diabetes firsthand, effectively reducing misunderstanding and rejection.

3.2 Dual Role of Multi-Sourced Stigma in the Resilience Network

Our findings indicate that multi-sourced stigma plays a dual role in the resilience network. The negative correlation between "concealing diabetes" and the "help-seeking" dimension confirms that disease concealment obstructs help-seeking behavior, consistent with KIM et al.' s [**?**] finding that concealment reduces

social support and leads to poorer clinical outcomes. However, PACHANKIS et al. [?] found that in highly stigmatizing contexts, concealment may increase life satisfaction by protecting patients from discrimination, suggesting that selective disclosure should be tailored to environmental contexts. Anonymous social media platforms can provide safe social opportunities for patients with varying needs [?], while internet-based T1D peer communities facilitate disease information exchange and mutual support [?].

Interestingly, "parents act as if diabetes is their disease" was positively correlated with the "family resources" dimension, suggesting parental over-concern can enrich family resources and strengthen resilience. However, HAPUNDA et al. [?] found that adolescents with T1D perceive excessive parental involvement as autonomy-infringing and conflict-generating. A review noted that while parental involvement generally improves glycemic control and reduces family conflict, the degree and manner of involvement are critical [?]. LIN et al. [?] emphasized that parents should adjust communication styles and gradually transfer diabetes management responsibilities as children age. Healthcare professionals should advise families based on their interaction patterns and help allocate management tasks appropriately according to patient age, fostering self-management skills and promoting healthy family partnerships.

Furthermore, "being perceived as defective" was positively correlated with the "help-seeking" dimension, indicating that adolescents maintain help-seeking intentions despite experiencing prejudice. A qualitative study showed that adolescents with T1D seek support from friends or family after perceiving stigma [?]. However, KARMAKAR et al. [?] found that some adolescents withdraw socially after internalizing external misunderstandings. Attribution theory suggests that individuals' illness attributions affect psychological adaptation and coping strategies [?]. JIANG et al. [?] noted that individuals with higher mindfulness are more likely to attribute stigma to external bias rather than personal defects, making them more likely to seek help. Healthcare providers can use positive cognitive restructuring and acceptance-commitment therapy to reduce over-identification with internal attributions [?], and employ virtual reality technology for coping skills training [?].

3.3 Age-Related Changes in the Relationship Between Multi-Sourced Stigma and Resilience

Our study revealed that the resilience network based on multi-sourced stigma changes with age. Network comparison showed tighter connections in early versus late adolescents, suggesting that stigma in younger patients is more resistant to intervention due to network hysteresis—a phenomenon where continuous mutual activation between nodes creates strong connections that persist even after causal factors are removed, making psychological disorders more entrenched [?]. The lower expected influence of "misunderstanding the need for insulin" in the late adolescent network indicates that older adolescents experience less misunderstanding. KHALAFALLA et al. [?] reported similar findings, noting that as

students age and acquire more disease knowledge, misunderstandings decrease. In China, high school biology curricula cover diabetes-related knowledge, promoting understanding and acceptance [**?**]. Nurses could conduct regular school education sessions, collaborating with teachers to help younger students understand diabetes through comics, videos, and games.

Limitations

This study employed a cross-sectional design, precluding identification of causal relationships and temporal changes between multi-sourced stigma and resilience. Future longitudinal studies are needed to validate our findings. Given the relatively small sample size and large number of nodes, which may affect network stability, we analyzed only resilience dimensions as nodes. Future research with larger samples could examine individual items from both stigma and resilience scales as nodes. Although our sample was drawn from only two Nanjing tertiary hospitals, their broad service radius covering multiple regions provides some representativeness.

Conclusion

This study used complex network analysis to explore relationships between multi-sourced stigma and resilience in adolescents with T1D, revealing that stigma exerts dual effects on resilience. Public misunderstanding, social exclusion, and individual anticipated discrimination are key modifiable stigma sources whose targeted elimination could enhance resilience. Healthcare professionals should also recognize specific stigma sources that may protect resilience. Furthermore, the network relationship between multi-sourced stigma and resilience changes with age, suggesting that future interventions should be tailored to different developmental stages.

Author Contributions: WANG Rui was responsible for study implementation, data collection, statistical analysis, drafting the manuscript, and final revisions, with overall responsibility for the article. YANG Cuicui and WENG Xinyi participated in data collection and organization. WANG Yubing and XU Jingjing participated in data collection and quality control. LUO Dan conceptualized the study, designed the research protocol, oversaw quality control and review, had overall responsibility for the article, and provided funding support.

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