Designing a Co-created Intervention to Promote Motivation and Maintenance of Time-Restricted Eating in Individuals With Overweight and Type 2 Diabetes

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ABSTRACT
Objective: To design an appealing time-restricted eating (TRE) intervention by exploring behavioral and social mechanisms to improve TRE adoption and maintenance among people with type 2 diabetes (T2D) and overweight. Time-restricted eating is an intermittent fasting regimen suggested to improve glycemic control and body weight.

Methods: Intervention development combined coherence theory and empirical data (workshops and semistructured interviews with the target group, their relatives, and health care professionals [HCPs]). Abductive analysis was applied.

Results: The analysis suggested designing the TRE intervention in 2 phases: a short period with strict TRE, followed by a longer period focusing on adapting TRE to individual needs with support from HCPs, relatives, and peers. To reinforce TRE motivation and maintenance, HCPs should adopt a whole-person approach that focuses on participants’ previous experiences.

Conclusions and Implications: Important intervention elements to promote TRE adoption and maintenance are suggested to include a 2-phase design and support from professionals, family, and peers.

Key Words: time-restricted eating, type 2 diabetes, behavioral mechanisms, intervention, overweight

INTRODUCTION
A guiding principle in treating individuals with type 2 diabetes (T2D) and overweight is the recommendation to lose weight. Among people with T2D, weight loss, achieved through physical activity and dietary changes, is associated with improved glycemic control and improved markers of cardiovascular health. Dietary recommendations to prevent and treat overweight and T2D are primarily based on restricting energy intake and improving diet quality, both of which require skills and knowledge. Moreover, new dietary habits can be challenging to maintain, particularly in the long run. This calls for rethinking interventions to include more appropriate and appealing aspects to individuals with T2D and overweight.

Time-restricted eating (TRE) is a strategy for restricting energy intake that limits the consumption of food and beverages to the same daily time window, typically 4–10 hours. TRE allows ad libitum intake within the window without quality or quantity restrictions on foods or beverages. Time-restricted eating has been highlighted as a tangible and simple strategy requiring less nutritional knowledge than other dietary interventions. Among people at high risk of T2D, TRE has positive effects on body weight, glucose metabolism, and cardiometabolic health, and it has been shown that TRE can improve glycemic control and reduce body weight and also
Little is known about how TRE adoption and maintenance in treating T2D among adults. In a small pilot study, 2 weeks of TRE in a 4–6 hour daily window was perceived as manageable by 7 out of 10 participants with T2D, and 6 participants wanted to continue it after the intervention ended in a modified form.14,15 In addition, a recent feasibility study including 24 participants with T2D showed that 4 weeks of 9-hour TRE was achievable among the 19 participants completing the study.16 However, the findings highlighted a need for more support to overcome potential barriers to adherence and implement and maintain TRE daily.

Little is known about how TRE interventions targeting people with T2D and overweight should be designed to promote motivation, engagement, and maintenance. Existing evidence focuses primarily on biomedical mechanisms and effects. However, health behavior is complex, and understanding mechanisms triggering health-promoting behaviors often draws on disciplines other than biomedicine. Therefore, evidence, principles, and methods from the behavioral and social sciences can contribute to understanding health behaviors and increase the effectiveness of lifestyle interventions.18 We aimed to design an intervention targeting adults with T2D and overweight by examining behavioral and social mechanisms necessary to improve TRE adoption and maintenance in daily life.

**METHODS**

This study is part of a larger investigation that includes intervention development, a pilot study, and a 1-year randomized controlled trial of TRE with a 10-hour daily eating window to promote weight loss, improve glycemic control, and enhance the quality of life (eg, well-being and sleep). The developed intervention design is structured in a logic model.19 The model structures our theoretical and empirical assumptions about how the intervention will work, for whom, and under what conditions. The model describes the design of the intervention in relation to format and content.

This study involved human participants and was conducted in accordance with the Declaration of Helsinki. The study and the protocol were approved by the Institutional Review Committee at Steno Diabetes Center Copenhagen, consisting of clinicians and research leaders and the Danish Data Protection Agency (P-2020-658). Qualitative research is not subject to research ethics committee approval in Denmark.

**Data Collection and Study Participants**

Empirical data sources include data from 7 workshops and 8 individual semistructured interviews with 32 participating individuals (Table 3). In practice, a workshop guide was followed in terms of activities and topics to address. It was developed by research team members and reviewed and revised after each workshop. Each workshop lasted about 2 hours. The relatively large number of informants, the applied workshop format and the iterative process of data collection and analysis improved

| Table 1. Characteristics of Persons With Type 2 Diabetes and Relatives Participating in Workshops/Interviews (n = 20) |
| --- | --- | --- |
| Characteristics | Person With T2D and Overweight (n = 15) | Relatives/Next-of-kin (n = 5) |
| Participated in workshops (n) | 7 | 5 |
| Participated in an individual interview (n) | 8 | 0 |
| Female/male (n) | 4/11 | 5/0 |
| Age, mean (range), y | 65 (45−75) | 64 (39−77) |
| Employed (n) | 5 | 3 |
| Pensioner/flex job (n) | 10 | 2 |
| Married/living with a partner (n) | 11 | 4 |
| Years since T2D was diagnosed, mean, (range), y | 15 (1−26) | 0 |
| Would most likely participate in TRE to support the user in the TRE study (n) | — | 4 |

T2D indicates type 2 diabetes; TRE, time-restricted eating.
The workshop approach differs from other research methods in creating peer-to-peer reflection and learning among participants. To encourage people with T2D and overweight and their relatives to openly share their perceptions and views, workshops were semistructured, focusing on topics related to eating and daily life, previous experiences with weight loss or diet change, and thoughts and perceptions about the TRE concept. Workshops with HCPs focused on similar topics, their experiences with the target group, and their perceptions of the TRE concept. Probes such as dialogue tools were used to promote reflection, engagement, and participant interaction about subjects such as TRE and weight loss. This is valuable for both participants and researchers, for whom it can lead to more dynamic and in-depth knowledge. The My Day visual tool guided the food intake and daily activities discussion. Two other tools made for the purpose were used to stimulate reflections about preferred outcomes in relation to dietary behavior changes. The coronavirus disease 2019 pandemic precluded conducting workshops with the last 9 participants, who were interviewed individually via web conferencing or phone using the same semistructured interview guide. All workshops and individual interviews were audio recorded and transcribed verbatim.

**Theoretical Underpinning**

The study draws on Antonovsky’s sense of coherence (SOC) theory, inspired by the salutogenic orientation, as the foundation for intervention development. The salutogenic orientation offers a crucial lens for understanding the importance of supporting people in identifying and using different resources for health promotion. By experiencing coherence in life, people perceive the world as more or less comprehensible, manageable, and meaningful—the 3 central concepts in SOC theory. Comprehensibility refers to the degree to which an individual feels that inner and outer stimuli are cognitively understandable and provide coherent information. Manageability refers to how an individual perceives available resources sufficient to deal with specific situations. Meaningfulness, a motivational aspect, refers to the degree to which an individual experiences that life makes sense, and challenges are worthy of commitment. This implies that life stressors (eg, emotional problems or relocating) are a natural part of life that must be handled and that an individual actively interacts with both inner and outer environments. Antonovsky emphasized that a strong experience of manageability depends on a strong experience of comprehensibility. Furthermore, without motivation, an individual stops reacting to stimuli; confusion results in a lack of willingness to search for resources. A strong SOC helps identify and use resources needed to solve emerging problems, such as health behavior change. This framework stresses the vital need for a TRE intervention to be designed in a motivational and meaningful way, perceived by participants as a concept worth their commitment.

**The Logic Model for the Intervention Design**

A logic model is a simplified representation of a hypothesis about how an intervention will work. In this study, the TRE adoption and maintenance logic model draws on empirical data and the SOC theory. The shaping of the logic model is inspired by the realist approach. The main principle of the realistic approach is that all complex interventions have underlying theories, referred to as program theories, describing the relationships between intervention context, mechanisms, and outcomes. These can be formulated before testing the intervention and refined during implementation. Context includes time and layers such as individuals, interpersonal relations, institutional settings, and infrastructure. Our study addresses individual and interpersonal needs, and preferences for design features prompting TRE adoption and maintenance, not the intervention’s wider social and economic setting. A mechanism is an element of reasoning or reaction because of the implementation of an intervention, causing a change in outcome. This study captures behavioral and social mechanisms contributing to TRE adoption and maintenance outcomes, not biological mechanisms contributing to weight loss and glycemic control.

**Data Analysis**

Overall, qualitative descriptive methodology, typically directed toward discovering the who, what, and where of events or experiences, was applied to shed light on the target groups’ views of, motivation for, and experiences related to TRE. In staying close to data and to the surface of words and events, qualitative description is particularly appropriate when addressing questions relevant to policy and practice. An abductive analysis process was conducted, and coding was performed in 2 steps. The first step was inductive, in which codes were derived from data, whereas the second included deductive, theoretical coding. To strengthen the validity of the study findings, 2 qualitative researchers independently coded data. They first read all workshop and interview transcripts to become familiar with the
Table 3. Description of Workshops, Interviews, and Dialogue Tool Use (n = 31)

<table>
<thead>
<tr>
<th>Method</th>
<th>Year</th>
<th>Aim</th>
<th>Participants (n)</th>
<th>Background of Participants</th>
<th>Dialogue Tool</th>
</tr>
</thead>
<tbody>
<tr>
<td>Workshop</td>
<td>2020</td>
<td>To gain insight into the thought about weight loss, lifestyle changes and the intervention of persons with T2D</td>
<td>7</td>
<td>Persons with T2D</td>
<td>My Day, weight loss, regulation of blood glucose</td>
</tr>
<tr>
<td>Workshop</td>
<td>2020</td>
<td>To gain insight into how the relatives have supported lifestyle changes regarding diabetes in the past, how they can support during the intervention, and the challenges in supporting</td>
<td>3</td>
<td>Relatives</td>
<td>My Day, weight loss, regulation of blood glucose</td>
</tr>
<tr>
<td>Workshop</td>
<td>2020</td>
<td>To gain insight into how the relatives have supported lifestyle changes regarding diabetes in the past, how they can support them during the intervention, and the challenges in supporting them. Discussion of dividing the intervention into 2 phases</td>
<td>2</td>
<td>Relatives</td>
<td>My Day, weight loss, regulation of blood glucose</td>
</tr>
<tr>
<td>Workshop</td>
<td>2020</td>
<td>To gain insight into the MDs experiences with lifestyle changes among persons with T2D and obtain input to the intervention regarding the treatment of T2D</td>
<td>3</td>
<td>MDs</td>
<td>Weight loss, regulation of blood glucose</td>
</tr>
<tr>
<td>Workshop</td>
<td>2020</td>
<td>To gain insight into how the HCPs experiences lifestyle changes among persons with T2D and obtain input to the intervention in the context of treating T2D</td>
<td>4</td>
<td>3 nurses, 1 MD</td>
<td>Weight loss, regulation of blood glucose</td>
</tr>
<tr>
<td>Workshop</td>
<td>2020</td>
<td>To gain insight into how the HCPs experiences lifestyle changes among persons with T2D and obtain input to the intervention in the context of treating T2D</td>
<td>3</td>
<td>2 dietitians, 1 nurse</td>
<td></td>
</tr>
<tr>
<td>Workshop</td>
<td>2020</td>
<td>To gain insight into how the HCPs experiences lifestyle changes among persons with T2D and obtain input to the intervention in the context of treating T2D</td>
<td>2</td>
<td>Nurses</td>
<td></td>
</tr>
<tr>
<td>Interview (phone)</td>
<td>2020</td>
<td>To gain insight into the thought of persons with T2D concerning weight loss, lifestyle changes and the intervention</td>
<td>1</td>
<td>Person with T2D</td>
<td>My Day</td>
</tr>
<tr>
<td>Interview (phone)</td>
<td>2020</td>
<td>To gain insight into the thought of persons with T2D concerning weight loss, lifestyle changes and the intervention</td>
<td>1</td>
<td>Person with T2D</td>
<td>My Day</td>
</tr>
<tr>
<td>Interview (in-person)</td>
<td>2020</td>
<td>To gain insight into the thought of persons with T2D concerning weight loss, lifestyle changes and the intervention</td>
<td>1</td>
<td>Person with T2D</td>
<td>My Day, weight loss, regulation of blood glucose</td>
</tr>
</tbody>
</table>
data and develop an understanding of the whole. Second, they sorted data into descriptive codes. Data were then revisited to identify relevant excerpts within each code, adding subcodes as appropriate. Finally, in the second step, descriptive codes were organized into themes guided by comprehensibility, manageability, and meaningfulness (Supplementary Table). All authors discussed and agreed on the content of the codes and the findings.

RESULTS

All 32 participants were ethnic Danes and spoke fluent Danish. The 15 participants with T2D and overweight were aged 45–74 years (mean age, 64 years). Five were relatives, all women. The remaining participants were HCPs (see complete participant characteristics in Tables 1–3).

Three key themes were generated from the analysis of TRE as a feasible concept, HCP approach and support activities, and experiences among people with T2D (Supplementary Table). Themes, codes, and their combination with SOC concepts informed the design of the intervention, which is depicted in the logic model (Figure). The model addresses the intervention context and social and behavioral mechanisms expected to drive outcomes changes. It also focuses on intermediate outcomes of expected behavior changes that are necessary milestones for achieving clinical and psychosocial outcomes.

Context

Interviewees were generally positive about the TRE concept. Health care professionals and people with T2D found the TRE concept manageable and appealing because of its simplicity. People with T2D noted that it would be easier to focus on when they ate than what they ate. As a participant in the 70s with T2D said:

I am thinking that it sounds like there is a lot of freedom embedded into it. And that combined with less specific thinking (about food) and strict sheets on what and how to act.
However, some participants preferred to receive dietary education during TRE, whereas others favored the exclusive focus on timing. Only a few participants remarked that they had no interest in the TRE concept. Most interviewees expressed a sense of meaningfulness related to its appropriateness for weight loss and improved glycemic control.

Several people with T2D and their relatives expressed concerns about sticking to a 10-hour daily eating window. This was particularly true for social events, as a relative in the 70s described:

"I think if it's just my husband and I, then we would be able to eat like that. But I think it would be uphill concerning grandchildren and our leisure activities and friends. So, I can't really wrap my head around it."

Participants with T2D were also worried about late-night evening snacking or coffee. A dietitian also mentioned that people might feel excluded from social arrangements if they followed TRE strictly. Workshop participants emphasized the crucial importance of the motivation of individualization by, for instance, a day off every week or month, evening coffee now and then, or a longer window of 1 or 2 days each week to accommodate individual needs. However, some interviewees worried that making too many adjustments at the outset could provide a limited experience of TRE, curtailing insight into individual adjustments needed for long-term maintenance.

Based on their previous experiences with weight loss and health behavior change among people with T2D, interviewees stressed the importance of supporting individuals in TRE maintenance. People with T2D, their relatives, and HCPs highlighted the essential nature of continuous support and contact with HCPs while maintaining daily TRE. This was particularly important in the long run. One participant in the 60s with T2D said:

"I also think it is important that there is something. There must be some kind of contact, supervision maybe. Because if you stand alone, then (for someone), managing diabetes will be neglected."

However, HCPs also noted that the needed intensity and frequency of their support would likely vary substantially among people with T2D.

Participants emphasized that written materials describing the intervention were important; relatives and participants with T2D described needing something to rely on to understand how TRE worked in practice and how to perform it daily. From a relative in the 70s:

"So something written is always good. I think sometimes you experience that when you are in the middle of something (during a conversation), then you are caught up by it, and when you get home, you can't always remember it all."

This perspective emphasizes explaining and clarifying TRE goals and procedures to promote engagement. It also addresses that people feel safe to engage in TRE and rely on the support provided. For example, workshop participants discussed the risk of hypoglycemia. Generally, HCPs and people with T2D expressed little concern; even so, most people with T2D preferred contacting a nurse if they became worried about potential medication adjustments and hypoglycemia.

Some workshop and interview participants described peer support as an important part of a TRE intervention; it was less important to...
others. One participant in the 50s with T2D said:

*Until you have made your body accustomed to only taking in food within this time period. Then it might be a very good idea to have someone to lean on — besides my friend.*

Interviewees stressed their preference for HCP-facilitated peer support and described varying preferences for peer support intensity and format (ie, virtual vs in-person).

People with T2D preferred to have family members involved, but some mentioned that they lacked close relatives. Family members described the importance of their active involvement so they understood TRE and felt equipped to support their relative with T2D. One relative in the 60s put it this way:

*Then I think you would have to do it the good old-fashioned way of saying “we’ll inform you both at once.” So, like, we have the same information and knowledge about why this a good idea and so on.*

Relatives also stressed the importance of involving those in the households of participants with T2D because meals were often structured around household needs.

**Mechanisms**

Mechanisms are formulated as necessary conditions and prerequisites for people to adopt and maintain TRE (Figure). They represent the perspectives, reflections, and thoughts of people with T2D and HCPs. In general, interviewees were preoccupied with health care delivery. Good communication skills of HCPs delivering the intervention were mentioned as essential for gaining knowledge and skills related to adopting TRE. In the words of a participant in the 50s with T2D:

*The best path, in my opinion, is to try and find someone who is good at motivating and withholding your attention (towards TRE). . . . it needs to be someone who can “sell” the concept.*

Participants with T2D preferred TRE to be delivered in a whole-person approach, articulating it as focused on their needs, life conditions, and previous experiences with weight loss or health behavior change.

Participants with T2D described the educational background of the HCP delivering the intervention as less important. In contrast, they emphasized the HCP’s approach and attitude, stressing the importance of being a good listener, inclusive, empathetic, and nonjudgmental. Dietitians described some people as not wanting to consult them to avoid being told what to eat. Endocrinologists primarily focused on timeliness in terms of reaching people when they were motivated, which they generally found difficult. Moreover, they worried that the intervention would be too hard to implement for patients with difficulty managing their T2D and limited social support. Dietitians and nurses did not share this concern and focused instead on factors that could ease TRE adoption and maintenance, such as supporting and involving relatives.

People with T2D described TRE as a way to structure daily life beyond food intake, meals, and snacking. Interviewees discussed how a perspective on daily life could be integrated into TRE delivery, informed by the My Day tool used in workshops and individual interviews. In addition, interviewees described their motivation to perform TRE as closely related to the degree to which the intervention centered around their daily life structure, including their leisure time, work life, social life, and so on. In this way, focusing on everyday life could facilitate a sense of meaningfulness for engaging in TRE and promote motivation for maintaining it.

**Intervention Elements to Drive Behavior Change**

The findings suggested designing the TRE intervention in 2 phases: a short period with strict TRE, followed by a long period focusing on tailoring TRE to individual needs to improve long-term maintenance. The short period would allow participants to have experienced and identified challenges with TRE, they could discuss with an HCP before integrating individual adjustments. In addition, the findings suggested that supporting activities (eg, phone calls from HCPs and written materials providing an overview of the process and how TRE works in practice) should be mandatory in the intervention design. The approach of HCPs was also considered vital to motivation, engagement, and TRE maintenance. The analysis suggested focusing on previous experiences and emphasizing a whole-person approach that included all parts of daily life, which using a My Day tool during conversations could facilitate. Furthermore, peer support and involving relatives were identified as important elements to promote maintenance, but they should remain optional because of varying interviewee preferences.

**DISCUSSION**

Drawing on the theory of SOC by Antonovsky and empirical data, our analysis showed that the manageability of TRE is likely to be promoted with a 2-phase design allowing for a short period of lived experiences with strict TRE, followed by a longer phase with necessary individual adjustments to maintain it. Support from HCPs, family, and peers, as desired by participants, is likely to reinforce motivation.

To the best of our knowledge, ours is the first study to examine context and mechanisms for a manageable TRE intervention by eliciting the needs, perspectives, and experiences of a wide range of stakeholders, including people with T2D, their relatives, and dietitians, nurses, and endocrinologists. Findings of other studies examining TRE adoption and related challenges are consistent with ours. However, existing knowledge primarily sheds light on the challenges among people at risk for T2D. We previously found general satisfaction with and high appeal of the simplicity of performing TRE during a 12-week intervention among people with overweight and at high risk of T2D. However, TRE often required more than simply changing the time window for consuming food.
and beverages. Daily life structures and eating out during evening social events posed some of the largest barriers to TRE engagement and maintenance and a lack of support from families and friends. Other studies also emphasize that low levels of social support and eating out in the evening with family or friends are barriers to successfully integrating TRE into daily life.

According to Antonovsky, people with previous success at changing health behaviors would be at an advantage in performing TRE compared with those without such experiences. Indeed, life experiences leading to a strong SOC allow individuals to seek help and apply resources appropriate to a specific stressor, such as behavior change. Previous experiences will likely shape the course of TRE and provide insight into the support and guidance needed to implement and maintain it in daily life for people with T2D. The applicability of SOC theory to a TRE intervention builds on the premise that SOC is changeable from a life-course perspective. Antonovsky described SOC as experienced and molded by one’s culture and position in the social structure. It has been debated whether SOC, as defined by Antonovsky, can be perceived as fixed for individuals. Later in his career, Antonovsky was less settled on the conclusion that SOC could only be shaped and manipulated in childhood. Super et al points to the behavioral mechanism of SOC as a promising theoretical underpinning for health promotion interventions and highlight the possibility of empowering people to use their resources in stressful situations. Consistent with our findings, the perceptual mechanism suggested by Super et al enhances the ability of people to deal with life stressors. It is essential for people to reflect on their understanding of the stressful situation and available resources. The intervention could focus on enhancing collective SOC, as described by Antonovsky. The concept of collective SOC is based on the understanding that an individual is part of larger institutions that can contribute to it. In this study, collective SOC was reflected in the attitude, communication style, and behaviors of the HCP delivering the TRE intervention in keeping with the paradigm of patient empowerment. The interviewees’ endorsement also reflected on the whole-person approach focusing on resources and the ability to live according to one’s values and wishes rather than on an approach only treating specific symptoms.

The study has strengths and limitations. Workshops and individual interviews contributed to in-depth data, which informed the logic model of the intervention in combination with SOC theory. Other social and behavioral theories may have shed light on other perspectives of importance to the intervention. We included the perspectives and experiences of different stakeholders to examine motivation, engagement, and maintenance related to TRE. However, some potentially relevant perspectives may have been omitted. One could argue that we could recruit people with T2D who were more motivated and resourceful, and the transferability of our findings to the larger population with T2D may not be complete. However, the online and phone interviews necessitated by the coronavirus disease 2019 pandemic may have allowed a more diverse group of participants regarding geography and social background. In addition, by obtaining in-depth insights from people with T2D, their relatives, and HCPs with diverse professional backgrounds, we obtained rich empirical data supporting the validity of the findings.

**IMPLICATIONS FOR RESEARCH AND PRACTICE**

In conclusion, the approach and findings in this study served as a basis for formulating design features and content of TRE interventions. Applying the knowledge outlined in this article, future TRE interventions targeting people with T2D and overweight are likely to be improved and will be applied in a pilot study to test the feasibility of a TRE intervention focusing on the daily life of people with T2D and overweight. Important intervention elements to promote TRE adoption and maintenance are suggested to include a 2-phase design and support from professionals, family, and peers.

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**SUPPLEMENTARY DATA**

Supplementary data related to this article can be found at [https://doi.org/10.1016/j.jneb.2023.03.001](https://doi.org/10.1016/j.jneb.2023.03.001).

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