Review

Aligning Behaviour with Physiology: The Potential of Time-Restricted Eating for Rural Obesity Control

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Posted Date: 27 February 2024

doi: 10.20944/preprints202402.1492.v1

Keywords: circadian rhythm; obesity; rural; time-restricted eating

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Aligning Behaviour with Physiology: The Potential of Time-Restricted Eating for Rural Obesity Control

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Abstract: Obesity presents significant challenges in rural communities worldwide, often exacerbated by limited resources and access to healthcare. In addressing this issue, practical, scalable, and culturally sensitive approaches are imperative. Time-Restricted Eating (TRE), which involves aligning food intake with circadian rhythms, emerges as a promising strategy. By confining eating to specific time windows, TRE synchronizes with the body's internal clock, potentially offering metabolic health benefits. This review explores the potential of TRE in managing obesity in rural areas, emphasizing its simplicity, scalability, and alignment with certain rural characteristics. While TRE holds promise in addressing rural health disparities, it is essential to recognize cultural considerations and challenges such as undernutrition for effective implementation. In summary, TRE shows potential in enhancing metabolic health and overall well-being among rural populations.

Keywords: circadian rhythm; obesity; rural; time-restricted eating

1. Introduction

The global prevalence of obesity has surged dramatically over the past few decades, more than tripling since 1975 [1]. Currently, obesity affects around 13% of adults worldwide, or over 650 million people, along with millions of children. [1–5]. Although initially perceived as an issue predominantly in industrialized nations, obesity has extended its reach to low- and middle-income countries, particularly those undergoing rural-urban transition.[3–6]. The escalating rates of obesity in developing countries, especially among children, are particularly concerning, with some low-income nations experiencing a prevalence increase of tens of times [5,7]. Moreover, obesity is not merely a singular problem; it serves as the root cause of major noncommunicable diseases, including cardiovascular diseases, stroke, cancer, and diabetes. It is also contributing to approximately 4 million deaths annually and placing a significant burden on healthcare systems while reducing both the quality and length of life [5,8].

In rural areas, high obesity rates and its chronic impacts exacerbate existing burdens, compounded by scarcities of resources such as facilities, medication, and healthcare practitioners [6]. While obesity develops from a complex interplay of genetic, environmental, and lifestyle factors, diet emerges as one of the most significant contributors [9–11]. Traditional dietary interventions like calorie restriction, together with another lifestyle modification, often yield only a short-term results, with weight regain being common [12,13]. The challenges of achieving long-term weight maintenance after initial weight loss are well-documented in many studies due to multiple and complex reasons, spanning behavioral aspects to physiological factors [13,14]. Advance interventions such as medications, like the recently approved glucagon-like-peptide 1 (GLP-1), and surgical procedures like bariatric surgery offer alternatives, but they frequently produce similar short-term results and are not universally available or suitable for everyone due to several reasons [15,16]. In addition to its availability and affordability favoring higher socioeconomic levels and areas with advanced healthcare, the risks and costs of those interventions make them feasible only for specific groups [16]. Meanwhile, the rise of average body-mass index and obesity rates is higher among rural

 doi:10.20944/preprints202402.1492.v1

areas and lower socioeconomic groups, exacerbating health disparities [4,17]. Therefore, additional strategies are needed to effectively manage obesity, especially in disadvantaged communities. Given that rural obesity is the main driver of the global obesity epidemic among adults, exploring innovative and integrated approaches to rural nutrition problems is urgent.

The growing evidence regarding the influence of meal timing on metabolism and weight control represents one promising novel area for innovative approaches to obesity control [18]. In this context, emerging evidence and popularity around approaches based on timing of food intake, such as intermittent fasting, have garnered attentions in both public and academic spheres [19]. Additionally, the daily type of intermittent fasting known as time-restricted eating (TRE) is gaining traction, relying on the body's circadian rhythm. This approach has become the most popular type of intermittent fasting among the public, including in the US.[19] Numerous animal studies have demonstrated its efficacy in weight loss and improving metabolic health, and several human trials have confirmed these findings, although more studies with higher power and longer duration are warranted [20,21]. Additionally, the simplicity offered by TRE has been confirmed by research, with high adherence observed among participants in both trial settings and community dwellings [22,23]. Altogether, the potential efficacy and ease of implementation of TRE present a potential solution to help control obesity in rural areas, where other approaches may be challenging due to multiple conditions, including lack of access to affordable healthy food, transportation barriers, financial insufficiency, lower education, barriers to physical activity, and limited healthcare infrastructure. This review explores the potential of embracing TRE to mitigate the burden of obesity in rural areas, including its opportunities and challenges to improve rural health.

2. Obesity Burden in Rural Setting

Obesity has reached alarming levels globally, with the rising body mass index (BMI) in rural areas being a primary driver of this epidemic in adults [8]. While some studies suggest that the trajectory in many developed countries is starting to flatten, its rise in low-income countries and underprivileged areas is increasing exponentially [5,6,8,24]. One possible cause of this discrepancy is the practice of healthy eating, which depends on various factors including environment and food accessibility [24–26].

In many countries, particularly developed ones like the UK and Australia, rural populations exhibit higher rates of obesity [9,27]. However, the patterns differ in low- and middle-income nations, where urban populations still have a higher proportion of obesity. Nevertheless, the gap between urban and rural areas has narrowed in many countries [28], as evidenced by numerous studies worldwide. This transition of the obesity epidemic to rural areas is likely driven by complex socioeconomic, cultural, and environmental factors.[6]

The surge of obesity, particularly in low- and middle-income countries (LMIC), poses a significant concern. In LMICs, this trend is emerging as a formidable threat to global health, surpassing undernutrition and infectious diseases [1]. Moreover, obesity serves as a modifiable risk factor for various cancers and cardiovascular conditions [29], which are the primary causes of mortality worldwide [30]. It is linked to the development of cardiovascular diseases, diabetes, kidney disease, and neoplasms [30]. Moreover, the COVID-19 pandemic has shown that obesity is linked to various infectious diseases, making patients more vulnerable and eventually associated with increased severity, higher hospitalization, and even mortality rates [6,31]. It is becoming increasingly clear and important to control obesity before it develops and becomes part of the management of these diseases, as handling them within rural settings is very challenging.

It is well-documented that rural communities face multiple challenges in terms of accessing healthcare as well as implementing a healthy lifestyle. Rural residents, who are already more likely to have low-income, substandard housing, or low educational attainment compared to their urban counterparts, face bigger barriers from their environment, such as limited healthcare infrastructure, lack of access to affordable healthy food options, transportation problems, and barriers to physical activity facilities.[24,25] All of these are linked to high obesity prevalence among children and adults

 doi:10.20944/preprints202402.1492.v1

[6,24,25]. Although not all rural areas are the same and varied, this situation is common in many countries leading to unfavorable health outcomes among rural residents [24].

In addition to these existing challenges, urbanization and lifestyle also exacerbate the higher risk of developing obesity. Urbanization and the advent of electricity have significantly impacted human lifestyles, allowing for prolonged wakefulness and activity after sunset [32]. Research indicates that exposure to electric light delays sleep onset and reduces sleep duration, potentially leading to disruptions in circadian rhythms [32,33]. Moreover, urbanization and access to electricity are linked to increased body weight and related health issues due to inadequate sleep and mistimed feeding patterns [33].

Many interventions and policies have been carried out to address the obesity problem globally and also in rural settings. Until now, almost no program and no countries have adequately addressed this problem, mainly as the proposed solutions are slow in adoption, only continued to support and outdated approaches that have been shown ineffective, and lead to inadequacies relative to the scale of the epidemic In rural areas, one recent review also identified several programs that have been carried out and documented in the last 5 years [6]. It encompasses approaches such as school-based interventions, clinical trials, cluster-controlled trials in addition to general public health policy. But all of them are only producing small-scale positive impacts as it found that the scalability of solutions matters most [6].

As diet has been identified as the major contributor not only for weight control but also various morbidity and mortality, public health interventions that aim to reduce the prevalence of unhealthy dietary behaviors must serve as the priority [11]. Particularly, addressing this aspect in lower socioeconomic groups may be an effective strategy to improve overall population health. Promoting a better food environment is believed to be a good avenue for this purpose, but it is not easy to implement [24,25]. Providing financial incentives to reduce the price of fruit, vegetables, and water was successful in the rural low-income population, but it may not be sustainable due to limited funding sources [10]. There are plenty of barriers to preferring healthier food choices, including a lack of time and competing priorities, the cost of healthy food, adjusting habits to favor a healthier diet, geographic isolation, and difficulty avoiding unhealthy food at community venues or gatherings [25]. As a result, high consumption of highly processed, cheaper food and the adoption of sedentary lifestyles are common among rural populations [25]. Additionally, cultural attitudes towards obesity in rural areas also contribute, with overweight and obesity often associated with prestige and beauty. Studies also found that rural populations have suboptimal dietary intake in terms of quality [24,25,34].

Implementing a calorie restriction diet, which remains the basis of many weight control approaches, often yields only short-term positive results. While this concept sounds simple, such interventions are notoriously difficult to sustain for most patients, as they involve complex behavior changes and require support from healthcare practitioners, along with multiple visits to intensive programs[35]. These requirements pose a significant challenge in rural settings where resources are more limited. Furthermore, increased hunger, lower eating satisfaction, and the perceived difficulty of compliance lead to poor adherence to this approach in the long term [35]. These difficulties are not adequately addressed in current recommendations, resulting in unsatisfactory outcomes.

For more complex treatments like medication and surgery, more barriers exist and are even bigger. In addition to limited access to services, healthcare professionals themselves are unclear and hesitant about when to treat obesity [36,37]. Many practitioners are unsure about when to refer a patient for surgery, as it requires a long process from initiation of discussion to referral, to post-operative management, so extensive training is needed [37]. It is clear that rural communities have unfavorable determinants of a healthy lifestyle to manage obesity [38]. Within such a situation, cost-effective efforts that focus on lifestyle modification and have a better scalability potential need to be prioritized in rural areas [6,16,39].

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3. Circadian Rhythm and Time-Restricted Eating to Improve Metabolic Health

Most organisms, including humans, have evolved intrinsic circadian rhythms to prepare metabolic functions for anticipated changes in light, temperature, and nutrient availability. These rhythms regulate cell processes and hormone secretion, optimizing times for sleep, activity, and nutrient intake within the 24-hour day. Aligning these activities with circadian biological rhythms enhances organ functions and overall health. Conversely, activities occurring outside these optimal windows can disrupt rhythms, compromising organ functions and increasing the risk of diseases, both infectious and noninfectious [18,21,40].

In the modern postindustrial era, humans frequently encounter disruptions to their circadian rhythms, often stemming from inadequate exposure to light, irregular sleep patterns, and haphazard eating habits [21]. These disruptions, prevalent among shift workers, contribute to the development of chronic diseases, including obesity. Light and food intake act as cues for circadian rhythm, and the use of artificial lighting and erratic eating patterns have been linked to various health issues [41]. Circadian misalignment is increasingly recognized as a risk factor for obesity and cardiometabolic disease.[18] Notably, particular groups like shift workers face an elevated risk of chronic conditions due to circadian disruption, underscoring the importance of maintaining a balanced circadian rhythm [21,42]. While shift workers are most affected, there is a growing understanding that milder shifts in eating and sleeping patterns, such as social jetlag and eating jetlag, can also have adverse health consequences.[18]

Eating during the biological night, characterized by melatonin synthesis, may pose risks for cardiovascular problems, overweight, and other health concerns. Studies suggest that feeding patterns, including consuming meals later in the day, are associated with higher body fat and adverse metabolic outcomes [43,44]. Additionally, prolonged wakefulness contributes to longer food intake durations, increasing energy consumption and correlating with negative health outcomes [42,43,45,46].

Aligning food intake with the optimal circadian eating window has been demonstrated to benefit various health conditions in both animal studies and some human research [21,47]. Time-restricted eating (TRE), a dietary strategy that limits food intake to a 4 to 10-hour window each day, is one approach that aligns with the circadian lifestyle [19–21,47]. The benefits of TRE stem from several mechanisms. It promotes optimal metabolic function by allowing the body to enter prolonged fasting periods, which facilitates processes such as autophagy, cellular repair, and metabolic switching [20,47,48]. Additionally, TRE promotes synchronization between feeding and activity patterns, enhancing metabolic efficiency and energy utilization [21,47].

Numerous animal studies and several small-scale human studies have suggested that TRE may significantly reduce body weight and improve metabolic health [20,21,49]. One study published in the New England Journal of Medicine (NEJM) has demonstrated that Time-Restricted Eating (TRE) was equally effective as calorie restriction in promoting weight loss over at least one year of follow-up. The study also suggested that TRE is a viable and safe long-term approach for managing obesity.[19,50]. Another study also reported that applying behaviors that align with circadian physiology of metabolism, called chrononutrition, has been shown to be beneficial and associated with higher odds of weight loss. In a study involving 91 overweight/obese non-shift workers, it was demonstrated that compared to the group with unsatisfactory weight loss outcomes, the satisfactory group was associated with a greater proportion of energy intake in the morning (Mean difference (MD): +3.2%, 95% CI: 1.6, 4.9, $p < .001$), smaller intake during later in the day (MD: −2.6%, 95% CI: −5.1, −0.1, $p = .045$), earlier last mealtime (MD: −49.5 min, 95% CI: −86.5, −12.6, $p = .009$), shorter eating window (−0.8 h, 95% CI: −1.4, −0.1, $p = .031$), and greater reduction in night eating syndrome score (MD: −2.4, 95% CI: −4.3, −0.5, $p = .015$) [51].

Several clinical trials have also shown that TRE may not only help lose weight but also improve metabolic and cardiovascular function, reduce oxidative stress, improve sleep, and ameliorate glycemic control [19,20]. In contrast to calorie restriction, TRE has been associated with higher patient adherence, greater dietary satisfaction, less need for specialized knowledge, and reduced perceived difficulty [22,23,35,52]. This simplicity is an essential feature of TRE compared to other dietary

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measures, allowing it to be practiced more easily in disadvantaged groups such as people living in remote and socially disadvantaged areas.

TRE's simple instruction, which involves limiting food intake to less than 10-12 hours a day and consuming only non-calorie beverages for the rest of the day, is a powerful and easily understandable approach for patients and relatively easy to follow [21,53]. Without necessarily needing to modify the amount or type of food consumed, TRE offers a promising approach to promoting weight loss, reducing waist circumference, improving glucose control, and modulating lipid profiles. This makes it particularly relevant for addressing obesity in rural communities where fewer resources are available.

4. Potential of TRE in Rural Obesity Control

The potential of TRE in rural obesity control lies in its simplicity and flexibility, making it accessible to individuals with limited resources and healthcare infrastructure, which aligns with the needs and conditions of rural populations. According to the Behavior Change Wheel (BCW) Framework, modifying behavior involves addressing three components: capability, opportunity, and motivation [54]. TRE effectively addresses these components: it enhances capability by providing a straightforward approach to weight management, utilizes existing opportunities within rural communities such as natural meal timing rhythms, and motivates individuals through its ease of adoption and potential health benefits.

While capability and motivation can be addressed through education, training, and capacity building, opportunity is often closely tied to resource availability. In this regard, TRE has a clear advantage over other methods as it aligns with rural conditions, providing an opportunity for its implementation. Many rural settings exhibit characteristics conducive to practicing TRE, such as less reliance on artificial lighting, fewer late-night eating habits, and earlier meal timing,[34] which can facilitate its adoption within these communities and integrate it into their existing habits and culture..

The rise in popularity of TRE is mostly likely due to its simplicity and the fact that it does not require individuals to count calories to lose weight.[19] Unlike complex interventions, practicing TRE requires no specialized knowledge, is perceived as less difficult, and does not necessitate specialized equipment or additional health personnel [35,52]. Limited access to health services, scarce availability of healthy food options, and cultural preferences for earlier meal timing advocate for tailored interventions promoting TRE implementation in rural communities. The simplicity and practicality of TRE make it a feasible and scalable solution for controlling chronic diseases in these areas.[53]

Moreover, previous studies have shown that telehealth can help retain rural adults to practice lifestyle changes leading to improvements greater or equal to in-person interventions and has been recommended and shown to be beneficial [6]. By harnessing the potential of telehealth to deliver messages from practitioners, simple dietary advice like TRE can be promoted to patients and rural community, aligning with this approach to reach adequate scale and producing meaningful impact.

While TRE holds promise as a public health intervention in rural settings, several challenges must be addressed for successful implementation. Cultural considerations, including dietary habits and meal timing preferences, require careful attention to ensure the acceptability and adherence of TRE interventions. Potential barriers to TRE mainly relate to social events and eating occasions, as eating is not only physical and biological but also social [22]. Acknowledging cultural differences is crucial when communicating the message about TRE. Additionally, addressing potential challenges related to undernutrition is paramount for successful implementation in diverse cultural contexts, especially in areas with a higher proportion of indigenous peoples who may have unique cultural values and perspectives [55].

Another aspect that warrants consideration and necessitates further research is the potential risk of TRE to individuals and communities. The simplistic messaging of TRE, which solely focuses on meal timing without adequately addressing the importance of modifying food composition, could yield negative consequences, particularly in rural communities. Misinterpretations of TRE may exacerbate the dietary habits of communities already facing challenges due to poor food environments [24] and a predisposition towards consuming unhealthy foods [24,25]. TRE could

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inadvertently encourage detrimental practices that diminish the significance of food quality and variety. Although some studies have indicated that TRE typically does not alter the pattern and proportion of food consumption [56], this risk still requires mitigation and merits additional research,[19] particularly given that certain studies have already highlighted this concern,[57] especially in instances where no adequate explanation is provided.

Although implementing TRE may seem straightforward, sustainable efforts require a more complex approach addressing multiple social determinants of health. According to the BCW Model, behavior adoption involves changing capability, opportunity, and motivation factors, necessitating different approaches. Education can improve psychological capability and motivation, while training can enhance physical capability, and environmental restructuring can increase physical and social opportunities [54]. The combination of various approaches must be tailored to address obstacles to behavior adoption effectively.

Conflicting cultural norms and perceptions of food as a luxury may pose challenges [58,59], particularly considering that some individuals, including children, may experience undernutrition. However, despite these challenges, studies like the one conducted by Driscoll et al. in rural primary care in Canada have demonstrated the feasibility and effectiveness of TRE [60]. Driscoll et al.'s intervention resulted in significant reductions in body weight and waist circumference (9% and 8.6% respectively) over 12 months, with high compliance among participants where average overnight fasting duration among participants was 15 hours/day and they practiced this approach for 6.2 days/week, as well as experiencing only few side effects [60]. This study highlights the potential of TRE in low-resource settings and underscores its simplicity and ease of adoption, paving the way for further exploration and implementation in rural communities.

Considering the potential and challenges of obesity control in rural communities, TRE appears as a promising avenue that potentially aligns with rural conditions. It conforms with some rural characteristics that are still evident in many rural areas such as shorter eating duration, less use of electricity, and earlier eating time, and also does not bother with limited resources that rural residents often face as the biggest challenges. **(See Figure 1)** While many other interventions need more resources, TRE appears as effective and potentially acceptable among rural communities, although more research is warranted around this area.

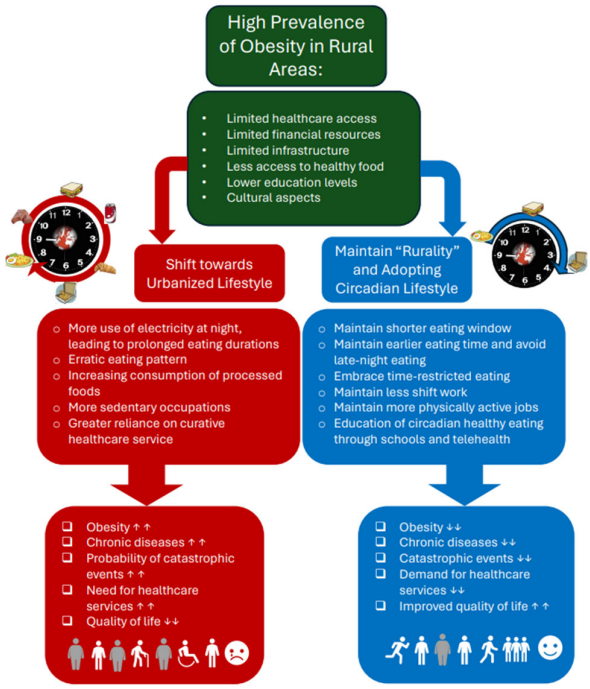

Figure 1. Illustration of the potential impact of implementing Time-Restricted Eating (TRE) and lifestyle practices aligned with circadian physiology and rural culture in controlling obesity. Rural

 doi:10.20944/preprints202402.1492.v1

communities face a decision at the crossroads of the obesity and chronic condition pathway, determining which lifestyle practices are best suited for their overall well-being.

5. Future Directions and Implications

Addressing the challenges associated with implementing TRE in rural settings is critical for its successful adoption. Cultural factors, such as dietary habits and meal timing preferences, require careful consideration to ensure that TRE interventions are not only effective but also acceptable within these communities.

To facilitate the integration of TRE into rural lifestyles, collaboration among multiple stakeholders is essential. General practitioners and primary care providers in rural areas can play a pivotal role in promoting TRE as a viable option for residents to manage weight and associated diseases. However, for this to become a reality, it is imperative that dietary and obesity guidelines remain responsive to emerging evidence [61], and include TRE as a recognized intervention for meal timing modification.

Introducing education about food timing into school curriculums could serve as a promising starting point. Previous review has highlighted that school-based interventions have been widely adopted and demonstrated feasibility and acceptability among rural communities.[6] Within this approach, teachers may not require extensive training to educate about the principles of TRE or healthy eating behavior that align with circadian physiology. Given the rising rates of obesity in children, promoting healthy eating patterns characterized by consistent meal times and adherence to a non-urban lifestyle, which is often associated with shorter eating windows and non-random eating patterns, should be encouraged.

Moreover, considering the challenges of recruiting and retaining healthcare professionals in rural areas, disseminating simple messages such as TRE could offer a promising avenue for improving health outcomes [53]. Along with the potential use of telehealth in rural settings [6], TRE advice and counseling can be delivered to as many rural and remote communities as possible. This two-way communication facilitated by telehealth in the situation of scarcity of residing healthcare practitioners can assist a personalized approach to adopting different variations of TRE that consider motivation, opportunity, lifestyle, and capability, while remaining culturally sensitive.

Further research on the implementation of TRE in rural settings is necessary. Clinical trials of TRE on specific population, including rural populations, are still very rare.[19] Additionally, there are no studies examining the acceptability of this approach among rural populations. With stronger and better evidence available in the near future, we will be more confident in recommending TRE as an option for obesity control interventions in rural areas. Community-driven interventions, supported by evidence-based guidelines and tailored to local contexts, have the potential to empower individuals and communities to adopt healthier lifestyles. Integrating a simple yet effective message like TRE into public health initiatives can potentially address scalability issues that existed in previous approaches due to limited resources. Providing an approach that promotes a holistic lifestyle aligned with circadian physiology, with TRE as part of the broader strategy, can potentially improve rural health and well-being, going beyond just reducing the burden of obesity.

6. Conclusions

Time-Restricted Eating emerges as a practical solution for addressing rural obesity by harmonizing behavior with physiology. Integrating TRE into public health initiatives holds significant promise for enhancing metabolic health in underserved rural populations. By incorporating TRE into dietary guidelines and advocating for meal timing-based approaches, practitioners can effectively mitigate the impact of obesity, particularly in marginalized communities. Continued exploration of TRE's implementation in rural settings is essential for innovating obesity interventions and tailoring them to the unique needs of rural populations. Community-driven interventions, grounded in evidence-based practices, have the potential to empower individuals to embrace healthier lifestyles. TRE's simplicity and accessibility make it a promising tool for improving rural health outcomes. Moving forward, sustained commitment to research and implementation

 doi:10.20944/preprints202402.1492.v1

efforts will ensure the seamless integration of TRE into rural health initiatives, thereby fostering improved well-being and health equity.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Not applicable.

Conflicts of Interest: The authors declare no conflict of interest.

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