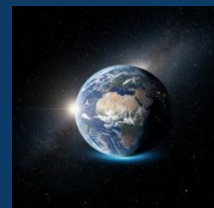




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The Impact of Regular Physical Activity on the Prevention of Type 2 Diabetes in Rural Populations - A Narrative Review

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ABSTRACT

Background.

Type 2 diabetes mellitus (T2DM) is one of the fastest-growing chronic diseases worldwide, with rural populations experiencing disproportionately higher incidence, prevalence, and mortality compared to urban areas. Despite engaging in heavy physical labor, rural residents often exhibit low levels of recreational physical activity - a phenomenon known as the “rural paradox.” While numerous reviews have confirmed the protective role of physical activity in T2DM prevention, most focus on general or urban populations, leaving a significant gap in evidence specifically addressing rural communities.

Aim.

The aim of this narrative literature review was to evaluate the impact of regular physical activity on the prevention of type 2 diabetes mellitus in rural populations, identify key barriers and facilitators, and assess the effectiveness of community-based interventions.

Results.

Rural residents have significantly higher T2DM prevalence (9-17% higher than urban areas) and mortality, coupled with lower recreational physical activity despite high occupational demands (H1). Regular physical activity, particularly the combination of aerobic and resistance training, reduces T2DM risk by up to 47% through improvements in insulin sensitivity, β -cell function, and inflammation (H2). Community-based interventions tailored to rural barriers (infrastructure, transport, digital divide, cultural norms) and actively involving local leaders were markedly more effective than standard urban-designed programs (H3). Successful models included the low-tech GODART telehealth intervention in rural USA, the mosque-based faith-integrated program in rural Bangladesh (42.5% relative risk reduction), and the Co-LID community-led intervention in rural Nepal.

Keywords: physical activity; type 2 diabetes; rural populations; prevention; barriers

1. Introduction

The epidemic of type 2 diabetes in rural areas

Type 2 diabetes (T2DM) is currently among the fastest-growing chronic diseases worldwide. According to the latest report by the International Diabetes Federation, in 2024, 589 million adults aged 20-79 years suffered from diabetes, representing 11.1% of the global adult population [1]. This number is expected to rise to 853 million by 2050. Diabetes was the direct cause of 3.4 million deaths in 2024 (equivalent to one death every 9 seconds), with the fastest increase in incidence observed in low- and middle-income countries (LMICs) [1].

This problem takes on a particularly dramatic dimension in rural areas. In the United States, the prevalence of diabetes in rural areas is, on average, 9-17% higher than in urban areas [2]. In 2021, it was 14.3% in rural areas compared to 11.2% in cities [2]. Similar disparities are observed across many regions of the world, including South Asian countries. In rural Bangladesh, studies showed a high incidence of T2DM among individuals with prediabetes, underlining the global nature of the problem [3].

Higher incidence in rural areas is accompanied by significantly higher mortality and poorer treatment outcomes. In rural counties of the U.S., diabetes mortality rates are substantially higher than in urban counties, and this gap persists or widens over time [4]. Rural residents with T2DM also face increased risks of cardiovascular and renal complications, lower limb amputations, and poorer glycemic control compared to urban populations [5,6].

The main causes of these adverse disparities include limited access to specialized healthcare (including endocrinology and diabetology), greater distances to medical facilities, lack or severe limitation of public transport, lower education and health awareness, poorer infrastructure (lack of safe walking routes, sidewalks, or sports facilities), and lower socioeconomic status [2,7]. These factors result not only in a higher incidence of T2DM among rural residents but also reduced chances for effective prevention, early detection, and optimal treatment.

The role of physical activity in the prevention of type 2 diabetes

Physical activity is recognized as one of the most important modifiable risk factors for type 2 diabetes (T2DM) [1]. Numerous prospective studies and meta-analyses have shown that regular physical activity significantly reduces the risk of developing T2DM, independently of other risk factors such as obesity or genetic predisposition [8]. A meta-analysis by Uusitupa et

al. demonstrated that physical activity interventions alone reduce the risk of developing T2DM by 47% compared to controls in people with impaired glucose tolerance [8]. A key long-term study confirmed that intensive lifestyle interventions (diet and physical activity) reduce T2DM incidence by more than 50% over 15 years of follow-up [9].

The mechanisms by which physical activity beneficially affects glucose metabolism are multiple and well-documented. Regular exercise improves peripheral tissue insulin sensitivity (mainly in skeletal muscles), increases glucose transport via GLUT4, reduces visceral fat mass, and has anti-inflammatory effects by lowering pro-inflammatory cytokines (e.g., TNF- α , IL-6) [8]. These mechanisms are supported by studies demonstrating physical activity's influence on gene expression related to glucose metabolism and inflammation [10-12]. Additionally, physical activity positively affects pancreatic β -cell function, improving both early and late phases of insulin secretion and enhancing cell survival [13,14]. Zhang et al. (2023) showed that moderate-intensity endurance training increased late-phase β -cell function by 38% in people with T2DM [15].

International health organizations have issued clear recommendations regarding physical activity for T2DM prevention [16]. The World Health Organization (WHO) and the American Diabetes Association (ADA) recommend that adults with prediabetes or high risk for T2DM engage in at least 150-300 minutes per week of moderate-intensity or 75-150 minutes of vigorous aerobic activity, complemented by resistance training at least twice a week [16]. A systematic review of guidelines by Tonga et al. (2025) confirmed that most national and international recommendations include a combination of aerobic and resistance exercise as the most effective preventive strategy [17].

Despite the proven effectiveness, the level of physical activity in the general population remains alarmingly low. In many countries, including Poland and other European nations, less than half of adults meet the recommended weekly physical activity levels [18]. Particularly concerning is the situation among people with prediabetes or diagnosed T2DM, where psychological, social, and environmental barriers further restrict regular exercise [19,20]. This gap between demonstrated benefits and actual physical activity underscores the need to develop effective, tailored interventions promoting physical activity, especially among high-risk groups such as rural residents.

Specificity of rural populations - why standard recommendations may not be enough

Rural residents constitute a special group for whom classic physical activity recommendations (mostly developed with urban populations in mind) often prove insufficient

or ineffective. There is a characteristic rural paradox: people living in villages, especially farmers, perform physically demanding occupational work with high energy expenditure daily, yet their levels of recreational and sports activity remain low. Consequently, they do not achieve the recommended health-related physical activity doses, contributing to a higher risk of T2DM [2,4,5].

The main differences between rural and urban populations in the ability to undertake regular physical activity include:

- Limited access to sports facilities and gyms - rural areas lack dedicated recreational facilities, swimming pools, or fitness clubs that in cities form the basic infrastructure for promoting physical activity [21-23],
- Poorer infrastructure - absence of sidewalks, street lighting, safe cycling and walking routes, and managed green spaces limits safe and comfortable outdoor physical activity [21-23],
- Transportation problems - long distances to activity venues, lack or irregular public transport, and high fuel costs are significant barriers, especially for the elderly and low-income individuals [10,21-23],
- Lower socioeconomic status - lower income, higher poverty rates, and limited health insurance access translate into fewer financial resources for sports equipment, classes, or travel [2,4,6,10],
- Different cultural norms and lifestyle - rural communities are dominated by a traditional lifestyle model where physical activity is viewed mainly as occupational work rather than recreation. Additionally, lower health awareness and limited trust in “urban” health programs reduce the willingness to participate in standard interventions [17,19,21,22,24].

Classic physical activity promotion programs, designed primarily for urban dwellers (mobile apps, gyms, group classes in fitness centers, online campaigns), often fail in rural contexts. For example, the GODART pilot study emphasized that digital technology-based interventions face a “digital divide” barrier - low adoption of smartphones and the internet, especially among older rural residents with low socioeconomic status [10,24]. Researchers responded with low-tech solutions based on automated phone conversations (IVR) and simple pedometers, which substantially improved intervention feasibility [24].

Similar conclusions come from studies in LMICs. In rural Bangladesh, prevention programs succeed only when deeply embedded within local social and cultural structures (e.g., mosque meetings led by imams) [3]. The Co-LID study protocol in Nepal confirmed that group

interventions led by trained community health workers and peer leaders, considering real access and cost barriers, are much more acceptable and feasible in rural settings than standard urban programs [21,23].

These differences and limitations make it clear that without proper cultural, technological, and organizational adaptation, even well-evidenced WHO and ADA physical activity recommendations do not translate into increased activity levels in rural populations. This constitutes a key argument for developing interventions specifically tailored to rural contexts [17,19,21,22].

Knowledge gap and justification for the proposal

In recent years, several reviews and narratives have been published regarding the role of risk in the prevention and management of type 2 diabetes (T2DM). These studies address the risk of T2DM and the management of glycemic control [8, 13, 14, 17]. However, the data from these studies refer to general applications, which include connections in urban indoor spaces, where access to sports facilities, electrical technology, and specialized authorities is better [2, 6, 7]. Nevertheless, a comprehensive, up-to-date literature review focusing solely on rural populations is lacking. The preceding studies either marginally address rural coverage (as a subgroup in the national analysis) or are limited to a selected area (e.g., coverage barriers in the overall T2DM context) [19, 21, 22]. There is no synthesis that systematically examines the various action options and activity levels, as well as the associated barriers and comorbidities in rural settings worldwide.

Such a review is urgently needed for several reasons. First, rural populations are aging faster than urban populations, increasing the access to T2DM resources [1, 2]. Second, rural-urban disparities are not only related but are exacerbated in many countries. The prevalence of T2DM in rural areas is 9-17% higher than in urban areas, and mortality is associated with it [2, 4, 7]. Third, in the lowest-income care systems, they are particularly useful, cost-effective, and scalable. Studies from rural Bangladesh and Nepal indicate that programs deeply embedded in community structures (e.g., meetings within organizations led by imams or groups led by community workers) can be equally effective and culturally acceptable [3, 21, 23]. Similar conclusions emerge from the GODART pilot study in rural USA, which confirmed that low-tech approaches, combined with alternative transportation barriers, are implemented and effective [10, 24]. The lack of comprehensive knowledge about which forms of physical activity, doses, and patterns are most prevalent in rural populations complicates policy planning and the implementation of preventive programs [25, 26]. A narrative literature review aims to

address this gap by collecting and critically monitoring usage from various regions of the world, with specific details relevant to rural areas.

Research Objective, Problems, and Hypotheses

Research Objective:

The aim of this literature review was to assess the impact of regular physical activity on the prevention of type 2 diabetes in rural populations, identify key barriers and facilitators, and evaluate the effectiveness of social interventions.

Research Question:

What are the differences in the coverage and incidence of type 2 diabetes between rural and urban areas?

Although rural residents frequently expend energy, their level of recreational activity is low, and the incidence and mortality of T2DM are significantly higher than those associated with urban populations. However, equivalent data regarding both objective incidence and prevalence rates of T2DM in different regions of the world are lacking [2, 4-7]. What forms of activity and interventions are most effective in the treatment of type 2 diabetes in rural populations?

This includes the prevalence of T2DM in the prevention of generalized T2DM. Data on specific forms (aerobic, resistance, HIIT, walking, team sports) and doses (minutes per week, MET-min) are lacking for rural settings, taking into account differences in age, race, and specific occupation (farmers vs. other rural residents) [8, 13-15, 17, 21].

What are the main barriers and facilitators associated with activity among rural residents?

Rural populations are characterized by a range of barriers (limited access to sports infrastructure, transportation problems, socioeconomic status, digital divide, cultural norms) that differ from those found in cities. Published in the justification (community support, local leaders, natural environment) can be used in calculations [10, 19, 20, 22, 24, 27].

What physical activity promotion interventions have proven effective in rural settings?

Classic physical activity promotion programs designed for urban populations often fail in rural areas. However, there is a lack of comprehensive knowledge regarding which intervention models (community-based, faith-based, low-tech telehealth, group-based

interventions with local leaders) are most effective, acceptable, and implementable in various rural contexts worldwide [3, 21, 23, 24].

Research hypotheses:

H1: Residents of rural areas have significantly lower levels of recreational physical activity and a higher risk of developing type 2 diabetes compared to the urban population.

H2: Regular physical activity, particularly a combination of aerobic and resistance training, significantly reduces the risk of developing type 2 diabetes in rural populations.

H3: Physical activity promotion interventions tailored to rural settings (taking into account local infrastructure, transportation, digital and cultural barriers, and with the active participation of communities and local leaders) are significantly more effective than standard programs designed for urban populations.

2. Research materials and methods

2.1. Search strategy

Public searches were conducted in the following databases: PubMed/MEDLINE, Scopus, Web of Science, Cochrane Library, and Google Scholar. The search strategy was based on a combination of keywords and MeSH/Emtree terms with Boolean operators: (“physical activity” OR “exercise” OR “aerobic training” OR “resistance training” OR “physical inactivity”) AND (“type 2 diabetes” OR “T2DM” OR “prediabetes” OR “diabetes prevention”) AND (“rural” OR “rural population” OR “rural communities” OR “village” OR “countryside” OR “non-urban”). The search was limited to publications in English published from January 2021 to May 2026 (with the possibility of including key older, high-impact papers).

2.2. Inclusion and exclusion criteria (participants/population)

Publications meeting the following criteria were included in the review:

Inclusion criteria:

Studies focusing on the adult population (≥ 18 years) living in rural areas (defined according to national or international criteria, e.g., RUCA codes ≥ 4 in the US, or equivalent definitions in other countries); studies assessing the impact of regular physical activity (any type: aerobic, resistance, HIIT, walking, group interventions) on preventing or delaying the development of T2DM or improving glycemic control in people with prediabetes; primary studies (RCTs, cohort studies, cross-sectional studies, qualitative studies) and systematic and narrative reviews; publications reporting data on barriers, facilitators, or the effectiveness of

physical activity interventions in rural settings; studies conducted in any country (with a focus on the US, Europe, Asia, Latin America, and Africa).

Exclusion criteria:

Studies exclusively on urban or mixed populations without a distinct rural subgroup; studies exclusively on children, adolescents, or pregnant women; publications in the form of conference abstracts, letters to the editor, or commentaries without empirical data; studies focusing solely on pharmacotherapy or diet without a physical activity component.

2.3. Data collection and analysis/statistical analysis

The publication selection process was conducted in two stages. In the first stage, the authors screened titles and abstracts for compliance with the inclusion criteria. In the second stage, the full text of the selected publications was analyzed. Discrepancies were resolved through team discussion. Data extraction was performed using a standardized form that included: authors and year of publication, country and definition of rural area, sample size and characteristics, type of intervention or exposure (physical activity), outcomes measured (T2DM incidence, HbA1c, insulin sensitivity, physical activity level, barriers), key findings, and study limitations. For systematic reviews, the methodology and main findings were also extracted.

2.4. Data analysis and synthesis (statistical analysis)

A narrative thematic synthesis was used, and data were grouped into four main thematic categories corresponding to the review objectives:

1. Epidemiological disparities in activity and the burden of T2DM between rural and urban areas,
2. Effectiveness of various forms and doses of activity in rural populations,
3. Barriers that facilitate and enable action in rural areas,
4. Theoretical testing.

As part of the synthesis, patterns, differences, and distinctions between studies were identified, with particular attention given to the rural context (e.g., rural paradox, cultural adaptations, and the role of local leaders). The results were presented in a descriptive format, with references to the studies.

2.5. AI

AI was utilized for two specific purposes in this research. Text analysis of clinical reasoning narratives to identify linguistic patterns associated with specific logical fallacies. Assistance in refining the academic English language of the manuscript, ensuring clarity, consistency, and

adherence to scientific writing standards. **AI** were used for additional linguistic refinement of the research manuscript, ensuring proper English grammar, style, and clarity in the presentation of results. It is important to emphasize that all AI tools were used strictly as assistive instruments under human supervision. The final interpretation of results, classification of errors, and conclusions were determined by human experts in clinical medicine and formal logic. The AI tools served primarily to enhance efficiency in data processing, pattern recognition, and linguistic refinement, rather than replacing human judgment in the analytical process.

3. Testing of research hypotheses.

The synthesis identified patterns, similarities, and differences between studies, paying particular attention to the rural context (e.g., rural paradox, cultural adaptations, the role of local leaders). The results were presented in a descriptive format with references to specific studies.

3.1 Epidemiological Disparities in Physical Activity and the Burden of Type 2 Diabetes in Rural Areas

Disparities in the burden of type 2 diabetes (T2DM) between rural and urban areas constitute one of the most consistent and universal epidemiological patterns observed worldwide. This problem affects both highly developed countries (USA, Europe) and low- and middle-income countries (LMICs), indicating its global and systemic nature [1, 2, 4].

3.1.1 Differences in the level of physical activity recommendations between rural and urban residents

Rural residents are significantly less likely to achieve recommended levels of physical activity compared to the urban population. Although many rural people perform heavy physical labor (especially farmers), their recreational and sporting activities remain low - a phenomenon known as the rural paradox. Vilafranca Cartagena et al. (2021), in a comprehensive scoping review of barriers to physical activity in people with T2DM, found that rural residents were significantly more likely to report a lack of access to sports facilities, gyms, and safe walking and cycling routes [19]. Thielen et al. (2023) confirmed that people with prediabetes or diagnosed T2DM living in rural areas had significantly lower levels of weekly physical activity than their urban counterparts, which resulted from both infrastructure barriers and lower motivation, alongside a lack of social support for recreational activity [20].

Additionally, studies by Pelletier et al. (2025) and Brown et al. (2024) conducted among adult rural residents with obesity and T2DM revealed that the main barriers included not only a lack of infrastructure, but also transportation problems, lack of time resulting from seasonal

agricultural work, and cultural norms in which physical activity outside of work is not perceived as a priority [22, 27].

3.1.2 Differences in T2DM Incidence and Burden Between Rural and Urban Areas

In the United States, the prevalence of diabetes in rural areas is, on average, 9-17% higher than in urban areas [2]. According to the latest data from 2021, the prevalence was 14.3% (95% CI: 13.5-15.0%) in rural areas compared to 11.2% (95% CI: 10.9-11.4%) in urban areas [2]. These differences persisted even after adjusting for age, gender, race, and ethnicity, and were particularly pronounced in some states (e.g., North Carolina, Oregon) [2]. The mortality data are even more alarming. Dugani et al. (2022), in an analysis covering the years 1999-2018, demonstrated that rural counties in the US have significantly higher diabetes mortality rates than urban counties, with this gap not narrowing and even widening in some groups (men, Black people) [4].

The problem is equally serious in low- and middle-income countries. Bhowmik et al. (2025), in a study conducted in rural Bangladesh, noted a high incidence of T2DM among people with prediabetes, emphasizing that rural communities with low socioeconomic status are particularly vulnerable [3]. Similar patterns have been observed in Nepal and other Asian and Latin American countries, where rapid urbanization and lifestyle changes combine with a lack of access to healthcare in rural areas [21].

3.1.3 Are disparities greater among people already living with diabetes or in the general population?

Data indicate that urban-rural disparities are already evident in the general population but become much more pronounced among those already diagnosed with type 2 diabetes. Foss et al. (2023) demonstrated that rural patients with T2DM have significantly worse treatment outcomes (higher HbA1c values, more frequent hospitalizations due to complications, higher risk of lower limb amputation) than urban patients, even after adjusting for sociodemographic factors [6]. This indicates that in rural areas, not only is the risk of developing the disease higher, but access to effective treatment and prevention of complications is significantly limited [1, 6, 7].

Low physical activity as a key mediator of the higher incidence of T2DM in rural areas. Low recreational physical activity is considered one of the most important mediators of the observed disparities [8, 13, 14]. Mechanistic studies clearly show that regular physical activity reduces the risk of developing T2DM by 40-50% by improving insulin sensitivity, reducing visceral fat, exerting anti-inflammatory effects, and positively impacting pancreatic β -cell

function [8, 13, 14]. Because rural residents are less likely to meet recommended physical activity levels, they constitute a particularly high-risk group [19, 20].

Furthermore, in rural settings, infrastructure and transportation barriers (lack of sidewalks, lighting, safe routes, and difficulty accessing sports facilities) amplify the effect of low physical activity, creating a vicious cycle: low activity → higher risk of T2DM → poorer treatment outcomes → higher mortality [2, 19, 22, 27].

Epidemiological data from various regions of the world (USA, Bangladesh, Nepal, Europe) indicate that rural areas are particularly vulnerable to the epidemic increase in type 2 diabetes. Low recreational physical activity, exacerbated by specific infrastructure, transportation, and cultural barriers, is one of the key, modifiable mediators of these disparities. This phenomenon underscores the urgent need to develop and implement physical activity interventions specifically tailored to rural conditions [1-3, 21].

3.2. Effectiveness of various forms and doses of physical activity in preventing type 2 diabetes in rural populations

Physical activity is an effective tool for preventing type 2 diabetes (T2DM), but data on the optimal forms and doses in rural populations are limited compared to the general and urban populations. Most available evidence comes from studies conducted in urban or mixed settings, making direct conclusions difficult for rural residents [6, 19, 21].

3.2.1 Comparing the effectiveness of different types of activity

In rural populations, the most evidence focuses on moderate-intensity aerobic activity, particularly walking and brisk walking. A meta-analysis by Uusitupa et al. (2019) showed that physical activity interventions alone reduce the risk of developing T2DM by 47% in individuals with impaired glucose tolerance [8, 17]. In rural settings, walking is particularly promising because it does not require specialized equipment or infrastructure.

Resistance (strength) training also offers benefits by improving insulin sensitivity and muscle mass, which is especially important for older rural residents. A combination of aerobic and resistance training appears to be the most effective [14, 15, 17].

HIIT (high-intensity interval training) demonstrates strong metabolic effects in the short term, but its use in rural populations is limited due to a higher risk of injury, lack of medical supervision, and lower acceptability among older adults and farmers [15, 20, 22].

Team sports (soccer, volleyball, folk dancing) are well-accepted in rural communities and combine physical and social benefits. Studies from rural Bangladesh and Nepal show that

group physical activity interventions led by community leaders achieve high adherence [3, 21, 23].

3.2.2 Dose-response data

The recommended dose of physical activity for T2DM prevention is at least 150-300 minutes per week of moderate-intensity activity or 75-150 minutes of vigorous-intensity activity, supplemented with resistance training at least twice a week [16, 17]. The protective effect is clearly dose-dependent - 120-150 minutes per week of brisk walking or equivalent activity provides a significant risk reduction (approximately 20-30%), while doses exceeding 300 minutes per week provide additional benefits (8). Additional studies confirm this dose-response relationship, showing a significant effect with just 90-120 minutes of moderate activity per week [8, 17, 28, 29].

In rural populations, the dose-response effect appears similar to that in urban populations, but actual adherence to recommendations is lower due to infrastructural and cultural barriers. Studies from the US and South Asia indicate that rural residents often achieve high levels of occupational activity (farming) but low levels of recreational activity, which does not fully translate into metabolic protection [2, 19, 20].

3.2.3 Differences by age, gender, and occupation

Age: In older adults (>60 years), walking and low-intensity resistance exercise are most effective and best tolerated. HIIT is less frequently used [15, 17].

Gender: Rural women more often prefer group activities (dancing, rural women's club activities), while men (especially farmers) engage in activities involving physical labor [19, 20, 22].

Occupation: Farmers are characterized by high levels of occupational activity (often >300 minutes per day) but low levels of recreational and sporting activity. As a result, their metabolic profile is not always favorable (high incidence of abdominal obesity and insulin resistance). Non-farming rural residents (e.g., administrative workers, craftsmen) typically have lower total energy expenditure and require more targeted recreational interventions [2, 22, 27].

3.2.4 The most realistic forms of activity to implement in rural areas

Based on available evidence and experience with rural interventions, the most realistic and effective forms of physical activity in rural populations are:

- Brisk walking and jogging - the cheapest, most accessible, and acceptable type of activity [8, 17, 19, 20],

- Group interventions led by local leaders (community health workers, peer leaders, imams, priests) - high adherence due to social support [3, 21, 23, 24],
- Activities embedded in everyday life (gardening, animal care, traditional dances, and games) [19, 20, 22, 27],
- Simple home programs using pedometers or low-tech applications [10, 21, 24].

Exercise programs requiring specialized equipment (gyms, swimming pools) or advanced technology (mobile apps, supervised HIIT) are much less feasible in rural areas and should be replaced with solutions tailored to local conditions [10, 19, 22, 27]. The most effective interventions in rural areas are those that combine moderate aerobic activity (primarily walking) with elements of resistance training, implemented in a group setting and embedded in local social structures [8, 15, 17, 21, 23].

3.3. Barriers, facilitators, and effectiveness of physical activity interventions in rural areas

Despite the well-proven effectiveness of physical activity in preventing type 2 diabetes (T2DM), rural residents face numerous barriers that significantly limit their ability to engage in regular physical activity. Understanding these barriers and identifying facilitating factors is crucial for designing effective interventions [8, 17, 19].

3.3.1 Main barriers preventing regular physical activity in rural areas

The most common barriers include:

- Limited infrastructure and access to sports facilities - lack of sidewalks, lighting, safe walking, and cycling routes, and dedicated recreational facilities [19, 22, 27],
- Transportation problems - long distances to activity locations, lack of or irregular public transport, and high commuting costs [19, 22, 27],
- Costs - lack of funds for sports equipment, fees for classes, or transportation [21, 27],
- Lack of time - especially among farmers, whose workdays are long and physically demanding [19, 22],
- Cultural norms and lifestyle - physical activity is often perceived solely as a part of professional work, not recreation. In many rural communities, a traditional lifestyle with limited awareness of health benefits prevails [3, 19, 22].
- Low levels of health knowledge and awareness - lack of understanding of recommendations and limited skills in using digital technologies (the so-called digital divide) [24, 27].

3.3.2 Main contributing factors

Factors that help rural residents be active include:

- Social support and a sense of belonging to a group [3],
- Availability of simple, low-cost forms of activity (walking, gardening, traditional dances) [19, 21],
- Involvement of local leaders and community authorities [3, 21],
- Cultural adaptation of interventions to local values and traditions [3, 21, 23],
- Gamification and motivational systems (even simple financial or social rewards) [24].

3.3.3 Examples of successful interventions from various countries

United States (USA) In the GODART study protocol conducted in the rural Deep South, the authors used a low-tech solution based on automated telephone calls (IVR) and a simple pedometer [24]. The intervention included daily monitoring of steps and moderate/exercise activity, as well as weekly coaching. This solution was specifically designed for rural residents with low digital literacy and limited infrastructure.

Bangladesh (South Asia) Bhowmik et al. (2025) conducted a 12-month cluster-randomized trial in rural Bangladesh, in which a mosque-based intervention led by imams and trained assistants, integrating Islamic teachings with dietary and physical activity recommendations, reduced the incidence of T2DM by 42.5% (RRR) compared to a control group [3]. The key to success was deep cultural adaptation and the use of existing religious structures. In Bangladesh, an intervention protocol combining physical activity promotion with education and telemedicine support demonstrates the potential of tailored solutions in low- and middle-income countries where digital infrastructure is limited [30].

Nepal (South Asia) The Co-LID study protocol implemented a 6-month group intervention in rural districts of Nepal led by trained community health workers (CHWs) and peer leaders [21]. The program included education on physical activity, diet, and self-management, with a direct focus on access barriers and costs. The intervention was delivered through two-week meetings in local communities.

Interventions based solely on mobile technologies (mHealth, SMS) have significant limitations in mixed rural-urban populations [10, 24, 31]. This study showed that simple text reminders yield only limited results, particularly among older rural residents with lower levels of digital literacy.

3.3.4 The role of social support and local leaders

Social support and the involvement of local leaders (imams, priests, community health workers, peer leaders, members of rural women's associations) are among the strongest predictors of intervention success in rural areas. Research consistently shows that programs involving community leaders achieve higher adherence, better acceptability, and longer-lasting effects than programs conducted solely by external specialists [3, 21, 23, 28].

Effective physical activity interventions in rural areas must be multidimensional, culturally appropriate, and embedded in local social structures. Only such an approach can overcome numerous barriers and leverage existing resources in rural communities [3, 21, 23, 24].

3.4. Evidence synthesis and hypothesis testing

Based on a narrative synthesis of the literature, including epidemiological studies, biological mechanisms, interventions, and analyses of barriers and facilitating factors, the formulated research hypotheses can be assessed.

Hypothesis H1

Residents of rural areas have significantly lower levels of recreational physical activity and a higher risk of developing type 2 diabetes compared to the urban population. Hypothesis H1 was confirmed. Data from many countries consistently indicate that rural residents have a higher prevalence of T2DM (9-17% compared to the urban population in the US) and higher mortality due to it [2, 4]. At the same time, a characteristic rural paradox is observed - high levels of occupational physical activity (especially among farmers) combined with low levels of recreational and sporting activity. Reasons for this include infrastructure, transportation, digital, and cultural limitations [19, 24]. In low- and middle-income countries (e.g., rural Bangladesh), the risk of developing T2DM among people with prediabetes is particularly high, further confirming the global nature of the disparity [3].

Hypothesis H2

Regular physical activity, particularly the combination of aerobic and resistance training, significantly reduces the risk of developing type 2 diabetes in rural populations. Hypothesis H2 was confirmed. Meta-analyses and mechanistic studies have shown that regular physical activity reduces the risk of developing T2DM by up to 47% [8]. The greatest benefits are achieved by combining aerobic activity (primarily brisk walking) with resistance training,

which improves insulin sensitivity, reduces visceral fat, has anti-inflammatory effects, and positively affects pancreatic β -cell function [13, 15, 17]. The protective effect is clearly dose-dependent - as little as 150 minutes per week of moderate-intensity activity produces a significant risk reduction, and higher doses provide additional benefits. Data from rural populations, although smaller than from urban populations, indicate a similar direction and magnitude of effect [3, 26].

Hypothesis H3

Physical activity promotion interventions tailored to rural settings (taking into account local infrastructure, transportation, digital, and cultural barriers, and with the active participation of local communities and leaders) are significantly more effective than standard programs designed for urban populations.

Hypothesis H3 was strongly supported. "One-size-fits-all" interventions based on digital technologies, mobile applications, or activities in urban sports facilities often fail in rural settings due to the digital divide, transportation problems, low health literacy, and lack of cultural adaptation [2, 24].

In contrast, programs deeply adapted to rural realities achieve significantly better outcomes. For example, a mosque-based intervention in rural Bangladesh reduced the incidence of T2DM by 42.5% through integration with local religious structures and the involvement of imams as leaders [3]. Similarly, in Nepal, the Co-LID program, based on group meetings led by community health workers and peer leaders, addressing real barriers to cost and access, proved feasible and acceptable [21]. In the United States, the GODART protocol demonstrated that low-tech solutions (IVR calls and pedometer) are significantly more realistic than mobile apps in rural populations with low digital literacy [24].

A key element of the success of all these interventions was the active involvement of local leaders and the embedding of the program into existing social and cultural structures. This confirms the findings from reviews of barriers and facilitators - social support and local authority are stronger predictors of adherence than program content alone [19, 22].

Final Conclusions from Hypothesis Testing

All three research hypotheses were confirmed based on the current literature. Residents of rural areas are indeed characterized by lower levels of recreational physical activity and a higher risk of T2DM (H1). Regular physical activity, especially combined (aerobic and resistance), significantly reduces this risk in rural populations as well (H2).

However, the implementation method is of paramount importance - interventions deeply tailored to the specific needs of rural areas, engaging local leaders and addressing real barriers, are clearly more effective than standard urban programs (H3). These results support the urgent need to develop and implement physical activity promotion programs dedicated to rural areas, based on the principles of cultural adaptation, cost-effectiveness, and active participation of local communities, in Poland and other countries.

4. Discussion

The narrative literature review provides a comprehensive picture of the role of physical activity in the prevention of type 2 diabetes (T2DM) in rural populations. The results clearly support all three research hypotheses and simultaneously reveal significant gaps in current knowledge and practice. Confirmation of hypothesis H1 is consistent with numerous epidemiological studies. Residents of rural areas are indeed characterized by a higher prevalence of T2DM (9-17% compared to the urban population) and higher mortality due to it [2, 4]. At the same time, a characteristic rural paradox is observed - high levels of occupational physical activity (especially among farmers) combined with low levels of recreational and sports activity. The reasons for this are multiple and include infrastructure, transportation, digital divide, and cultural constraints [19, 22, 24]. These disparities are particularly evident in low- and middle-income countries, where access to healthcare and preventive programs is even more limited [3, 6].

Hypothesis H2 was also strongly supported. Regular physical activity, especially in the form of a combination of aerobic and resistance training, significantly reduces the risk of developing T2DM - by up to 47% compared to the control group [8]. The mechanisms of this effect are well documented and include improved insulin sensitivity, reduced visceral fat, anti-inflammatory effects, and a beneficial effect on pancreatic β -cell function [13, 15]. WHO and ADA recommendations emphasize the need to combine both types of activity, as confirmed by a systematic review by Tong et al. (2025). The protective effect is clearly dose-dependent, with as little as 150 minutes per week of moderate-intensity activity producing significant benefits [17].

However, the most important conclusions stem from testing hypothesis H3. The review results clearly indicate that interventions tailored to rural settings are significantly more effective than standard programs designed for urban populations. Traditional solutions based on mobile apps, gyms, or fitness centers rarely work in rural areas due to digital, infrastructure, and transportation barriers [2, 24]. In contrast, programs deeply embedded in local social and

cultural structures achieve significantly better results. An example is a mosque-based intervention in rural Bangladesh, which reduced the incidence of T2DM by 42.5% thanks to the involvement of imams and integration with local religious values [3]. Similarly, in Nepal, the Co-LID program, based on group meetings led by community health workers and peer leaders, proved feasible and acceptable despite very limited resources [21]. In the United States, the GODART protocol demonstrated that low-tech solutions (IVR calls and pedometer) are much more realistic than advanced applications in rural populations with low digital literacy [24].

A key element in the success of all these interventions was the active engagement of local leaders and the use of existing social structures (peer support, religious authorities, community health workers). This confirms previous reviews of barriers and facilitators - social support and a sense of belonging to a group are stronger predictors of adherence than program content itself [19, 22]. "One size fits all" interventions rarely work in rural areas because they ignore fundamental differences in lifestyle, cultural norms, access to infrastructure, and levels of health literacy.

Limitations of the Review

This review is narrative in nature, which has certain limitations. Additional literature analyses indicate that the heterogeneity of definitions of rural areas across countries complicates international comparisons [25, 26, 32]. A formal meta-analysis was not conducted due to the heterogeneity of studies (different designs, populations, interventions, and outcome measures). Most available data come from the USA, South Asia, and Australia, while data from Europe (including Poland) are very limited. Furthermore, many studies were pilot or protocol studies, which reduces the strength of the evidence. Nevertheless, the consistent pattern of results across different regions of the world strengthens the credibility of the conclusions. Practical Implications and Directions for Further Research

The review findings have significant implications for health policy and clinical practice. In Poland, where the proportion of the rural population is high and health disparities between rural and urban areas persist, the development of dedicated physical activity promotion programs for rural areas is urgently needed. These programs should be low-cost and low-technology, embedded in existing community structures (village community centers, rural women's associations, parishes, local leaders), adapted to the rhythm of agricultural work and seasonality, and with the active participation of local leaders as key promoters.

5. Conclusion

This review confirms that physical activity is an effective tool for T2DM prevention in rural populations as well, but its actual impact depends equally on the program content and its implementation. Only interventions deeply tailored to rural contexts - taking into account local barriers and leveraging existing community resources - have a chance of real success. In the face of aging rural populations and growing health disparities, developing such solutions is becoming an urgent challenge for healthcare systems worldwide. Conclusions

The conducted narrative literature review provides consistent and convincing evidence for the crucial role of physical activity in preventing type 2 diabetes in rural populations. All three research hypotheses were confirmed.

Residents of rural areas are characterized by a significantly higher risk of developing T2DM and lower levels of recreational physical activity compared to the urban population (H1). Regular physical activity, particularly in the form of a combination of aerobic and resistance training, significantly reduces this risk also in rural settings (H2). Most importantly, however, interventions deeply tailored to rural settings - taking into account local infrastructure, transportation, digital, and cultural barriers, and engaging local leaders and existing community structures - are significantly more effective than standard programs designed for urban populations (H3).

The review results indicate that classic, one-size-fits-all approaches to physical activity promotion rarely work in rural areas. However, programs based on cultural adaptation, low-cost technological solutions, and the active participation of communities and local authorities achieve success. Examples from Bangladesh, Nepal, and the United States show that this approach can significantly reduce the incidence of T2DM even in very resource-limited settings.

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