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The Effectiveness of Healthy Lifestyle Education Combined with Yoga Therapy on Sedentary Behaviors and Social Well-Being Among Overweight Individuals at Risk of Developing Type 2 Diabetes

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ABSTRACT

The present study aimed to investigate the effectiveness of healthy lifestyle education combined with yoga therapy in reducing sedentary behaviors and improving social well-being among overweight individuals at risk of developing type 2 diabetes. A quasi-experimental method was employed using a pretest–posttest design with a two-month follow-up and a control group. The statistical population consisted of overweight individuals with a body mass index of 25 or higher who were at risk of developing type 2 diabetes and had attended healthcare and counseling centers in Tehran. Following screening and confirmation of the eligibility criteria, 40 participants were selected through purposive sampling and randomly assigned to an experimental group (n = 20), which received healthy lifestyle education and yoga therapy over 10 sessions, or a control group (n = 20), which received no intervention. Sedentary behavior was assessed using the Sedentary Behavior Questionnaire developed by Rosenberg et al. (2010), while social well-being was measured using Keyes's (2004) Social Well-Being Scale, which comprises five dimensions: social actualization, social integration, social coherence, social acceptance, and social contribution. The data were analyzed using repeated-measures analysis of variance in SPSS version 26. The findings indicated that the effects of time and the group-by-time interaction were statistically significant for both sedentary behavior, $F = 1186.201$, $p = .001$, $\eta^2 = .985$, and social well-being, $F = 397.400$, $p = .001$, $\eta^2 = .956$. Specifically, sedentary behavior decreased significantly and social well-being increased significantly in the experimental group, whereas no significant changes were observed in the control group. Bonferroni post hoc tests demonstrated significant differences between the pretest and both the posttest and follow-up assessments. However, the difference between the posttest and follow-up assessments was not statistically significant, indicating that the intervention effects were maintained throughout the follow-up period. Based on these findings, healthy lifestyle education combined with yoga therapy may be used as a complementary nonpharmacological intervention to reduce sedentary behaviors and enhance social well-being among individuals at risk of developing type 2 diabetes.

Keywords: yoga therapy, healthy lifestyle, sedentary behavior, social well-being, overweight, type 2 diabetes

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Introduction

Type 2 diabetes mellitus is one of the most consequential chronic metabolic disorders worldwide and is closely associated with excess body weight, physical inactivity, sedentary lifestyles, unhealthy dietary patterns, and psychosocial stress. The global growth of overweight and obesity has substantially increased the number of individuals exposed to metabolic abnormalities and the subsequent risk of developing type 2 diabetes. A large pooled analysis of population-representative studies documented a marked increase in obesity prevalence across children, adolescents, and adults between 1990 and 2022, indicating that excessive body weight has become a pervasive international public health concern rather than a problem confined to particular regions or socioeconomic groups (1). Parallel to this trend, the global prevalence of prediabetes has reached concerning levels, creating a large population of individuals who have not yet developed clinical diabetes but already demonstrate impaired glucose regulation and elevated cardiometabolic risk (2). Overweight individuals with glycated hemoglobin levels above the normal range therefore represent a particularly important target group for preventive interventions because metabolic deterioration may still be modifiable before the onset of established type 2 diabetes.

The transition from overweight and impaired glycemic regulation to type 2 diabetes is influenced by an interaction of biological, behavioral, environmental, and psychological determinants. Excess adiposity, particularly when accompanied by low energy expenditure, contributes to insulin resistance, systemic inflammation, impaired glucose utilization, and dysregulation of lipid metabolism. Nevertheless, the development of diabetes is not inevitable, and evidence has shown that structured lifestyle modification can substantially reduce the incidence of the disease among high-risk individuals. The landmark Diabetes Prevention Program demonstrated that intensive lifestyle intervention focusing on weight reduction, dietary improvement, and increased physical activity was more effective than metformin in preventing or delaying type 2 diabetes in people at elevated risk (3). These findings established lifestyle modification as a central component of diabetes prevention and highlighted the importance of interventions that help individuals adopt sustainable patterns of movement, nutrition, stress regulation, and self-management.

One of the most important behavioral risk factors in this context is sedentary behavior. Sedentary behavior is defined as any waking behavior characterized by an energy expenditure of 1.5 metabolic equivalents or less while an individual is sitting, reclining, or lying down (4). This concept is distinct from physical inactivity. An individual may meet recommended levels of moderate-to-vigorous physical activity while still spending many hours of the day sitting, and prolonged sedentary time may independently compromise metabolic health. Common sedentary activities include television viewing, computer use, prolonged telephone use, reading, driving, office work, and other seated tasks. Technological development, urban transportation, occupational automation, screen-based recreation, and changes in domestic routines have progressively increased the amount of time adults spend sitting, making sedentary behavior a major characteristic of contemporary lifestyles.

Accumulating evidence indicates that prolonged sedentary time is associated with an increased risk of type 2 diabetes, cardiovascular disease, premature mortality, and other adverse health outcomes. A systematic review and meta-analysis showed that adults with the highest levels of sedentary time had substantially greater risks of diabetes, cardiovascular events, cardiovascular mortality, and all-cause mortality than those with lower sedentary exposure (5). Similarly, a dose-response meta-analysis found that

increasing sedentary behavior was associated with higher risks of incident type 2 diabetes and mortality from cardiovascular disease, cancer, and all causes, demonstrating that the health consequences of sedentary behavior increase progressively as sitting time accumulates (6). More recent genetic evidence derived from Mendelian randomization analysis has also supported a potentially causal relationship between sedentary behavior and type 2 diabetes, while indicating a protective role for physical activity (7). These findings suggest that the reduction of sedentary time should be regarded as an independent preventive target rather than merely a secondary consequence of increasing exercise.

Sedentary behavior is particularly problematic among individuals with overweight or impaired glucose regulation because its metabolic effects may interact with existing insulin resistance and excess adiposity. Long periods of uninterrupted sitting reduce skeletal-muscle contractions, limit glucose uptake, impair lipoprotein lipase activity, and decrease total daily energy expenditure. Over time, these processes may worsen glycemic control and contribute to further weight gain. Accordingly, interventions designed for people at risk of diabetes should not focus exclusively on scheduled exercise sessions but should also teach participants to interrupt prolonged sitting, replace sedentary activities with light movement, and restructure daily routines. A systematic review and meta-analysis of interventions among adults with type 2 diabetes showed that behavioral programs can reduce sedentary time, although the magnitude of improvement varies according to intervention intensity, behavior-change techniques, monitoring procedures, and participant adherence (8). This variability emphasizes the need for multicomponent programs that combine education, self-monitoring, physical practice, motivational support, and feasible daily behavioral changes.

Healthy lifestyle education provides a framework through which individuals can acquire the knowledge and self-regulation skills needed to modify multiple diabetes-related behaviors simultaneously. Such education may include balanced nutrition, portion control, sleep regulation, stress management, physical activity planning, sedentary-time reduction, goal setting, self-monitoring, and relapse prevention. However, knowledge alone is often insufficient to produce sustained behavioral change. Individuals with overweight may experience physical discomfort, low exercise confidence, fatigue, negative body image, weight-related stigma, social withdrawal, and emotional distress, all of which can interfere with participation in conventional exercise programs. Timkova et al. showed that psychosocial distress among people with overweight and obesity is closely related to weight stigma and the availability of social support, indicating that metabolic risk cannot be fully addressed without considering individuals' interpersonal and psychological experiences (9). Therefore, lifestyle interventions may be more effective when they include an accessible mind-body activity capable of improving physical function while simultaneously reducing stress and supporting psychosocial well-being.

Yoga therapy represents one such complementary approach. Yoga is a multidimensional mind-body practice that typically combines physical postures, controlled breathing, relaxation, attentional regulation, and meditative awareness. Unlike exercise programs that emphasize high intensity or advanced physical performance, yoga can be adapted to participants' age, weight, flexibility, and health status. Its relatively low-impact nature may make it particularly suitable for overweight individuals who experience joint discomfort, reduced mobility, low exercise tolerance, or anxiety about participating in conventional fitness activities. Yoga may influence diabetes risk through several pathways, including increased energy

expenditure, improved muscular activity, enhanced flexibility and balance, reduced sympathetic activation, better sleep, improved emotional regulation, and greater awareness of eating and movement behaviors.

Evidence increasingly supports the cardiometabolic benefits of yoga among adults with overweight, obesity, prediabetes, or type 2 diabetes. A systematic review examining energy-balance outcomes found that yoga may contribute to improvements in body weight, body composition, physical activity, dietary behavior, and psychological factors associated with obesity, although the effects vary across intervention formats and study designs (10). A more recent systematic review and meta-analysis of randomized controlled trials reported beneficial effects of yoga on several cardiometabolic indicators among adults with overweight or obesity, strengthening the rationale for using yoga as part of comprehensive risk-reduction programs (11). These findings suggest that yoga may be particularly valuable when integrated into a broader healthy lifestyle intervention rather than delivered as an isolated physical practice.

Studies involving individuals at elevated risk of diabetes have also produced promising results. McDermott et al. found that a yoga intervention was feasible for reducing type 2 diabetes risk and showed favorable trends in weight-related and metabolic outcomes in a pilot randomized controlled trial (12). Ramamoorthi et al., in a systematic review and meta-analysis, concluded that yoga practice may improve glycemic control and other health parameters in individuals with prediabetes, although differences in intervention duration and methodological quality should be considered when interpreting the findings (13). Kaur et al. further demonstrated that a diabetes-specific yoga protocol improved glycemic, anthropometric, and lipid indicators among high-risk individuals, providing evidence that yoga can produce clinically relevant changes before the development of established diabetes (14). Similarly, the multicenter YOGA-DP feasibility trial indicated that a structured yoga program for people at high risk of type 2 diabetes was implementable across multiple settings and acceptable to participants, supporting the feasibility of larger preventive applications (15).

Evidence from people already diagnosed with type 2 diabetes provides additional support for the physiological and psychological effects of yoga. A systematic review and meta-analysis reported that yoga interventions were associated with improvements in glycemic control among adults with type 2 diabetes (16). Another meta-analysis found beneficial effects on blood glucose and lipid parameters, indicating that yoga may influence both carbohydrate and lipid metabolism (17). Singh and Khandelwal reported that yoga and exercise improved glycemic control and psychosocial outcomes among adults with type 2 diabetes, suggesting that the benefits of yoga extend beyond metabolic indices to psychological adjustment and quality of life (18). More recently, Subramani et al. reported improvements in the physical and mental health of adults with type 2 diabetes following yoga intervention, further reinforcing the value of mind-body approaches in comprehensive diabetes management (19). Taken together, these studies indicate that yoga may be relevant across the diabetes continuum, from high-risk states to established disease.

Although the metabolic implications of overweight, sedentary behavior, and yoga have received considerable attention, the social dimension of health has been less frequently examined in diabetes-prevention research. Social well-being refers to individuals' appraisal of their functioning and position within society and constitutes an essential component of positive mental health. Keyes conceptualized social well-being as comprising five dimensions: social integration, social acceptance, social contribution, social actualization, and social coherence (20). Social integration reflects a sense of belonging to a community;

social acceptance concerns positive attitudes toward other people; social contribution refers to the belief that one's activities are valuable to society; social actualization reflects optimism about the potential and development of society; and social coherence concerns the perception that the social world is understandable and meaningful. These dimensions extend the concept of health beyond the absence of psychiatric symptoms and emphasize the quality of individuals' relationships with their social environment.

Within the mental health continuum model, optimal mental health is characterized by flourishing, whereas low emotional, psychological, and social functioning is described as languishing (21). This framework challenges the assumption that the absence of mental illness is equivalent to positive health. An individual may have no diagnosable psychiatric disorder while still experiencing low social integration, limited perceived contribution, social distrust, and a lack of meaning in community life. The complete state model further proposes that mental illness and positive mental health are related but distinct dimensions, making it possible for individuals to experience various combinations of psychological symptoms and well-being (22). Descriptive epidemiological work has demonstrated that social well-being varies according to demographic, interpersonal, and social conditions and is meaningfully related to broader patterns of adult functioning (23).

Social well-being may be especially relevant among overweight individuals at risk of diabetes. Weight stigma and negative social evaluation can produce shame, avoidance of public exercise settings, reduced social participation, and reluctance to seek healthcare. Physical limitations and fatigue may further restrict engagement in recreational, occupational, and community activities. Over time, these experiences may reduce social integration and perceived social contribution while increasing isolation and distress. Conversely, supportive group-based interventions may provide opportunities for shared experience, interpersonal encouragement, behavioral modeling, and collective participation. When individuals engage in structured health-promoting activities within a respectful environment, they may experience greater social connectedness, self-efficacy, and confidence in their ability to participate meaningfully in daily life.

Yoga may contribute to social well-being through both direct and indirect mechanisms. Group yoga sessions create repeated opportunities for social contact, shared learning, and mutual support, while breathing and relaxation practices may reduce anxiety and facilitate interpersonal engagement. Improvements in physical comfort and energy may also make individuals more willing to participate in family, occupational, and community activities. Evidence from a randomized controlled trial of telehealth yoga among rural older adults showed that yoga-based participation may influence loneliness and social isolation, suggesting that yoga can have socially relevant benefits even when delivered remotely (24). Although older rural adults differ from overweight individuals at risk of diabetes, this evidence indicates that yoga can affect interpersonal and social dimensions of health rather than only physical outcomes.

Despite the growing literature, several gaps remain. Many previous studies have focused primarily on fasting glucose, glycated hemoglobin, lipid profiles, body mass index, or other biomedical outcomes. Fewer investigations have simultaneously examined sedentary behavior as a distinct behavioral outcome and social well-being as a positive psychosocial outcome. Moreover, interventions frequently evaluate yoga alone or lifestyle education alone, even though the combination of these approaches may produce complementary effects. Healthy lifestyle education can provide knowledge, behavioral strategies, and self-monitoring skills, whereas yoga therapy can offer an embodied method for increasing movement, reducing stress, improving

self-regulation, and fostering group engagement. The integration of these components may therefore be especially appropriate for overweight individuals who are at increased risk of type 2 diabetes but have not yet progressed to irreversible metabolic complications.

A further limitation of the existing literature is that many studies assess outcomes only immediately after intervention. Without follow-up assessment, it remains unclear whether reductions in sedentary behavior or improvements in psychosocial functioning persist after supervised sessions have ended. Maintenance is particularly important in diabetes prevention because short-term behavioral changes are unlikely to alter long-term disease risk unless they become incorporated into everyday life. A two-month follow-up can provide preliminary evidence regarding the stability of intervention effects and the extent to which participants continue using movement, relaxation, and lifestyle-management strategies independently.

Accordingly, the present study aimed to determine the effectiveness of healthy lifestyle education combined with yoga therapy in reducing sedentary behavior and improving social well-being among overweight individuals at risk of developing type 2 diabetes.

Methods and Materials

Study Design and Participants

The present study was applied in purpose and employed a quasi-experimental pretest–posttest design with a two-month follow-up and a control group. The statistical population consisted of overweight men and women who had glycated hemoglobin levels above the normal range and a body mass index of 25 kg/m² or higher and who attended healthcare clinics and counseling centers in different districts of Tehran. Potential participants were initially screened through a semi-structured clinical interview and an assessment of the study eligibility criteria. Individuals who met the inclusion criteria and provided informed consent were enrolled in the study. Using purposive sampling, 40 eligible participants were selected and subsequently assigned through random allocation to either the experimental group, which received healthy lifestyle education combined with yoga therapy (n = 20), or the control group, which received no intervention during the study period (n = 20). The mean age of participants was 47.40 years (SD = 6.72) in the experimental group and 47.70 years (SD = 7.71) in the control group. The mean age of the total sample was 47.55 years (SD = 7.14). Both groups completed the study measures at three assessment points: before the intervention, immediately after completion of the intervention, and two months after the intervention. All participants were informed about the objectives and procedures of the study, the voluntary nature of participation, the confidentiality of their information, and their right to withdraw from the study without adverse consequences.

Data Collection

Sedentary Behavior Questionnaire. Sedentary behavior was assessed using the Sedentary Behavior Questionnaire developed by Rosenberg et al. (2010) to estimate the amount of time adults spend engaging in common sedentary activities. The questionnaire evaluates nine frequently performed sedentary activities, including watching television, using a computer, playing video games, reading, talking on the telephone, completing paperwork or office-related tasks, and engaging in other seated activities. Participants report the amount of time spent performing each activity separately on weekdays and weekend days. The reported

durations are combined to calculate overall estimates of sedentary time, with higher scores indicating greater engagement in sedentary behavior. Rosenberg et al. (2010) reported two-week test–retest reliability coefficients of .85 for total weekday sedentary time and .77 for total weekend sedentary time. The construct validity of the questionnaire was supported by significant associations with body mass index and scores on the International Physical Activity Questionnaire. Although an independent psychometric evaluation of the exact Persian version of the questionnaire has not been widely reported among Iranian adults, conceptually comparable instruments have demonstrated satisfactory psychometric properties in Iranian populations. For example, the Persian version of the Seven-Day Sedentary Time Questionnaire demonstrated a Cronbach's alpha coefficient of .70 and a test–retest reliability coefficient of .90 in a sample of Iranian adults (Bakhtari Aghdam et al., 2022).

Keyes Social Well-Being Scale. Social well-being was measured using the Keyes Social Well-Being Scale (Keyes, 2004; Keyes & Shapiro, 2004). The scale contains 20 items and assesses five dimensions of social well-being: social actualization, social integration, social coherence, social acceptance, and social contribution. The items are rated on a Likert-type scale, and the relevant items are reverse-scored before the subscale and total scores are calculated. Higher scores indicate a more favorable level of perceived social well-being and more positive functioning within society. The measure was developed within Keyes's broader mental health continuum model, which conceptualizes flourishing as the presence of positive emotional, psychological, and social functioning rather than merely the absence of mental disorder (Keyes, 2002, 2005). The short Persian version of the scale has been validated among Iranian adults. Shayeghian et al. (2019), in a sample of 715 adults residing in Tehran, confirmed the five-factor structure of the scale using confirmatory factor analysis and reported acceptable model fit indices. They also reported a Cronbach's alpha coefficient of .72 for the total scale. In the present study, the internal consistency coefficient of the Social Well-Being Scale was .87, indicating satisfactory reliability.

Intervention

Participants in the experimental group received a 10-session healthy lifestyle education program combined with yoga therapy. The intervention was designed as a multicomponent program addressing behavioral, physical, nutritional, and psychological factors associated with overweight, sedentary behavior, and increased risk of type 2 diabetes. The educational component included information about the relationship among excessive body weight, physical inactivity, prolonged sitting, metabolic health, and diabetes risk; principles of balanced nutrition and portion control; regulation of eating patterns; reduction of high-calorie and highly processed foods; improvement of sleep routines; stress management; self-monitoring of health-related behaviors; goal setting; and the gradual replacement of sedentary activities with light or moderate physical activity. Participants were also trained to interrupt prolonged periods of sitting, incorporate brief movement breaks into daily routines, monitor daily sedentary time, and develop realistic plans for maintaining healthier behavioral patterns. The yoga therapy component included progressive instruction in gentle yoga postures, flexibility and balance exercises, controlled breathing techniques, body-awareness practices, relaxation exercises, and brief mindfulness-based attention to bodily sensations. The physical practices were adapted to participants' weight status and physical capacity and were introduced progressively to minimize discomfort and facilitate adherence. Each session integrated

educational discussion with supervised yoga practice, review of participants' experiences, correction of movement techniques, and assignment of home-based exercises. Participants were encouraged to practice the instructed yoga and lifestyle-management techniques between sessions and to record their adherence, sedentary periods, physical activity, and perceived barriers. The control group received no psychological, educational, or yoga-based intervention during the same period and continued its usual activities.

Data Analysis

Data were analyzed using IBM SPSS Statistics, version 26. Descriptive statistics, including means, standard deviations, frequencies, and percentages, were calculated to summarize the demographic characteristics and study variables. A mixed-design repeated-measures analysis of variance was used to examine changes in sedentary behavior and social well-being across the pretest, posttest, and two-month follow-up assessments and to compare the patterns of change between the experimental and control groups. In this analysis, assessment time was treated as the within-subject factor, and study group was treated as the between-subject factor. Before conducting the main analysis, the relevant statistical assumptions were evaluated. The normality of score distributions was examined using the Shapiro–Wilk test, homogeneity of covariance matrices was assessed using Box's M test, homogeneity of error variances was evaluated using Levene's test, and the sphericity assumption for repeated measurements was examined using Mauchly's test of sphericity. When the sphericity assumption was violated, the Greenhouse–Geisser correction was applied to adjust the degrees of freedom and significance levels for within-subject effects. Bonferroni-adjusted pairwise comparisons were conducted to determine whether significant differences existed between the pretest, posttest, and follow-up assessments. Effect sizes were reported using partial eta squared, and the statistical significance level was set at $p < .05$.

Findings and Results

The mean age of participants was 47.40 years (SD = 6.72) in the healthy lifestyle education and yoga therapy group, 47.70 years (SD = 7.71) in the control group, and 47.55 years (SD = 7.14) in the total sample. Of the 40 participants, 21 (52.5%) were men and 19 (47.5%) were women. In the experimental group, 11 participants (55%) were men and 9 (45%) were women, whereas the control group included 10 men (50%) and 10 women (50%). Regarding educational attainment, 5 participants (12.5%) had completed elementary or middle school education, 23 (57.5%) held a high school diploma, 10 (25%) held a bachelor's degree, and 2 (5%) held a master's degree. In terms of marital status, 25 participants (62.5%) were married, 8 (20%) were single, 5 (12.5%) were separated or divorced, and 2 (5%) were widowed. Furthermore, 9 participants (22.5%) had no children, 8 (20%) had one child, 17 (42.5%) had two children, and 6 (15%) had three children. Overall, the demographic distributions indicated that the two groups were reasonably comparable in terms of age, sex, marital status, and number of children.

Table 1. Means and Standard Deviations of Sedentary Behavior and Social Well-Being Scores by Group and Assessment Time

Variable	Group	Pretest, M (SD)	Posttest, M (SD)	Follow-Up, M (SD)
Sedentary behavior	Healthy lifestyle and yoga therapy	53.60 (5.63)	43.15 (4.98)	43.30 (5.01)
	Control	54.05 (3.84)	53.95 (3.87)	54.00 (3.89)

	Total sample	53.82 (4.76)	48.55 (7.02)	48.65 (7.00)
Social well-being, total score	Healthy lifestyle and yoga therapy	40.75 (5.59)	60.75 (5.29)	60.35 (5.39)
	Control	41.90 (5.04)	42.20 (5.31)	42.45 (5.68)
	Total sample	41.32 (5.29)	51.47 (5.75)	51.40 (5.58)
Social actualization	Healthy lifestyle and yoga therapy	8.20 (2.06)	12.35 (2.41)	12.30 (2.40)
Social integration	Healthy lifestyle and yoga therapy	5.90 (1.99)	9.05 (2.13)	9.00 (2.15)
Social coherence	Healthy lifestyle and yoga therapy	6.05 (1.98)	9.20 (2.16)	9.15 (2.20)
Social acceptance	Healthy lifestyle and yoga therapy	10.90 (2.63)	15.20 (3.03)	15.10 (2.98)
Social contribution	Healthy lifestyle and yoga therapy	10.70 (2.40)	14.95 (2.68)	14.80 (2.50)

As shown in Table 1, the mean sedentary behavior score in the experimental group decreased from 53.60 (*SD* = 5.63) at pretest to 43.15 (*SD* = 4.98) at posttest and remained relatively stable at the two-month follow-up, with a mean of 43.30 (*SD* = 5.01). In contrast, the mean scores in the control group remained nearly unchanged across the pretest, posttest, and follow-up assessments. The mean total social well-being score in the experimental group increased from 40.75 (*SD* = 5.59) at pretest to 60.75 (*SD* = 5.29) at posttest and remained high at follow-up, with a mean of 60.35 (*SD* = 5.39). No substantial changes in social well-being were observed in the control group. A similar pattern of improvement was found across all five social well-being dimensions in the experimental group, including social actualization, social integration, social coherence, social acceptance, and social contribution.

Before conducting the repeated-measures analysis of variance, the relevant statistical assumptions were examined. The normality of the distributions and homogeneity of error variances were assessed using the Shapiro–Wilk and Levene tests, respectively, and no issue precluding the use of parametric analysis was identified. For sedentary behavior, Box's *M* test was nonsignificant, Box's $M = 9.352$, $F = 1.318$, $p = .221$, indicating that the homogeneity of covariance matrices assumption was satisfied. Box's *M* test was also nonsignificant for social well-being, Box's $M = 5.200$, $F = 0.789$, $p = .575$. However, Mauchly's tests were statistically significant for both sedentary behavior, $\chi^2(2) = 29.476$, $p < .001$, and social well-being, $\chi^2(2) = 28.294$, $p < .001$, indicating that the sphericity assumption was violated. Therefore, the Greenhouse–Geisser correction was applied to the within-subject effects for both outcome variables.

Table 2. Greenhouse–Geisser-Corrected Repeated-Measures Analysis of Variance for Sedentary Behavior and Social Well-Being

Variable	Source	SS	df	MS	F	p	ηp^2
Sedentary behavior	Time	728.217	1.291	564.061	2107.023	< .001	.982
	Time × Group	707.317	1.291	547.872	2046.551	< .001	.982
	Error	13.133	49.059	0.268	—	—	—
Social well-being	Time	2727.117	1.303	2092.422	725.534	< .001	.950
	Time × Group	2504.717	1.303	1921.782	666.366	< .001	.946
	Error	142.833	49.527	2.884	—	—	—

As presented in Table 2, the Greenhouse–Geisser-corrected analysis revealed a statistically significant effect of time on sedentary behavior, $F(1.291, 49.059) = 2107.023$, $p < .001$, $\eta p^2 = .982$. More importantly, the time-by-group interaction was also statistically significant, $F(1.291, 49.059) = 2046.551$, $p < .001$, $\eta p^2 = .982$, indicating that changes in sedentary behavior across the three assessments differed significantly between the experimental and control groups. The very large effect size indicated that the intervention

accounted for a substantial proportion of the change in sedentary behavior. A statistically significant effect of time was similarly found for social well-being, $F(1.303, 49.527) = 725.534$, $p < .001$, $\eta p^2 = .950$. The time-by-group interaction for social well-being was also significant, $F(1.303, 49.527) = 666.366$, $p < .001$, $\eta p^2 = .946$. Considered alongside the descriptive findings, these results indicate that healthy lifestyle education combined with yoga therapy significantly reduced sedentary behavior and increased social well-being in the experimental group, whereas the scores of the control group remained relatively stable.

Table 3. Bonferroni-Adjusted Pairwise Comparisons of Sedentary Behavior and Social Well-Being Across Assessment Times

Variable	Assessment 1	Assessment 2	Mean Difference	SE	*p*
Sedentary behavior	Pretest	Posttest	5.275	0.105	< .001
	Pretest	Follow-up	5.175	0.112	< .001
	Posttest	Follow-up	−0.100	0.048	.132
Social well-being	Pretest	Posttest	−10.150	0.379	< .001
	Pretest	Follow-up	−10.075	0.332	< .001
	Posttest	Follow-up	0.075	0.167	1.000

The Bonferroni-adjusted pairwise comparisons indicated that sedentary behavior scores were significantly higher at pretest than at posttest, with a mean difference of 5.275 (SE = 0.105, $p < .001$), and significantly higher at pretest than at the two-month follow-up, with a mean difference of 5.175 (SE = 0.112, $p < .001$). The difference between the posttest and follow-up scores was not statistically significant, with a mean difference of −0.100 (SE = 0.048, $p = .132$), indicating that the reduction in sedentary behavior was maintained during the follow-up period. For social well-being, the pretest mean was significantly lower than both the posttest mean, with a mean difference of −10.150 (SE = 0.379, $p < .001$), and the follow-up mean, with a mean difference of −10.075 (SE = 0.332, $p < .001$). The difference between posttest and follow-up was not statistically significant, with a mean difference of 0.075 (SE = 0.167, $p = 1.000$). Thus, the improvement in social well-being was sustained for at least two months after completion of the intervention. Overall, the findings demonstrate that healthy lifestyle education combined with yoga therapy produced substantial and persistent reductions in sedentary behavior and improvements in social well-being among overweight individuals at risk of developing type 2 diabetes.

Discussion and Conclusion

The present study examined the effectiveness of healthy lifestyle education combined with yoga therapy in reducing sedentary behavior and improving social well-being among overweight individuals at risk of developing type 2 diabetes. The findings showed that the intervention produced significant changes in both outcomes across the pretest, posttest, and two-month follow-up assessments. Sedentary behavior decreased markedly in the experimental group, whereas no meaningful change was observed in the control group. Social well-being also increased substantially in the experimental group, while the control group remained relatively stable. The significant time-by-group interaction effects indicated that the observed changes were attributable to the intervention rather than to the passage of time alone. Furthermore, the very large effect sizes for sedentary behavior and social well-being demonstrated that the combined intervention had a strong practical impact. The nonsignificant differences between posttest and follow-up scores further indicated that the benefits were maintained for at least two months after completion of the intervention.

The first major finding was that healthy lifestyle education combined with yoga therapy significantly reduced sedentary behavior. This result is consistent with evidence indicating that sedentary time is a modifiable behavioral risk factor and that structured behavioral interventions can reduce prolonged sitting among adults with metabolic risk. Sedentary behavior is conceptually distinct from insufficient moderate-to-vigorous physical activity and refers to waking activities performed while sitting, reclining, or lying down with very low energy expenditure (4). Therefore, a person may technically meet exercise recommendations but still remain exposed to the metabolic consequences of spending many hours sitting. The intervention used in the present study directly addressed this distinction by teaching participants to monitor daily sitting time, interrupt prolonged sedentary periods, replace passive activities with light movement, and incorporate manageable physical activity into everyday routines.

The observed reduction in sedentary behavior is important because prolonged sitting has consistently been associated with adverse metabolic and cardiovascular outcomes. Previous meta-analytic evidence has shown that greater sedentary time is associated with elevated risks of type 2 diabetes, cardiovascular disease, cardiovascular mortality, and all-cause mortality (5). A dose-response meta-analysis similarly demonstrated that the risks of incident type 2 diabetes and mortality increase as sedentary exposure rises (6). In addition, Mendelian randomization evidence has supported a potentially causal relationship between sedentary behavior and type 2 diabetes, while indicating a protective effect of physical activity (7). The present findings therefore have preventive relevance because reducing sedentary time in overweight individuals with elevated diabetes risk may help interrupt a behavioral pathway through which insulin resistance and cardiometabolic deterioration progress.

The reduction in sedentary behavior also aligns with evidence from interventions specifically designed for adults with diabetes. A recent systematic review and meta-analysis found that behavioral interventions can successfully reduce sedentary behavior among adults with type 2 diabetes, particularly when they include self-monitoring, prompts, structured goal setting, and explicit strategies for breaking up sitting time (8). The current intervention incorporated several of these components through lifestyle education, behavioral planning, monitoring of sedentary periods, and home-based practice. This combination may have increased participants' awareness of habitual sitting and transformed a largely automatic behavior into a consciously regulated target. The significant maintenance of the reduction at follow-up suggests that participants did not merely reduce sitting during supervised sessions but may have integrated movement breaks and less sedentary routines into their daily lives.

Yoga therapy may have strengthened the behavioral effects of lifestyle education by providing a feasible and acceptable form of physical engagement. Individuals with overweight often experience fatigue, joint discomfort, embarrassment in public exercise settings, low exercise self-efficacy, or difficulty sustaining high-intensity programs. Yoga can be adapted to different physical capacities and can be performed with gradual progression, making it more accessible than some conventional exercise modalities. Evidence from a systematic review has indicated that yoga may positively influence several components of energy balance, including physical activity, body weight, eating behavior, and psychological regulation among adults with overweight or obesity (10). More recent meta-analytic evidence has also shown that yoga can improve cardiometabolic indicators among adults with overweight or obesity (11). Accordingly, the yoga component may have reduced sedentary behavior not only by increasing direct movement during sessions but also by

improving participants' physical confidence, bodily awareness, and willingness to remain active outside the intervention setting.

The present result is also consistent with studies involving individuals at elevated risk of diabetes. McDermott et al. reported that yoga was a feasible intervention for reducing type 2 diabetes risk and produced favorable changes in health-related outcomes among high-risk adults (12). Ramamoorthi et al. concluded that yoga practice may improve glycemic control and other health indicators in people with prediabetes (13). Similarly, a diabetes-specific yoga protocol was shown to improve glycemic, anthropometric, and lipid indices among high-risk individuals (14). The YOGA-DP multicenter feasibility trial further demonstrated that structured yoga-based prevention programs can be implemented among people at high risk of type 2 diabetes and can achieve acceptable participation and adherence (15). These findings support the interpretation that yoga can serve as a practical behavioral gateway to a more active lifestyle in populations who may face barriers to conventional exercise.

Another possible explanation for the reduction in sedentary behavior concerns the self-regulatory effects of the combined program. Lifestyle education provided participants with knowledge regarding diabetes risk, the consequences of prolonged sitting, and the importance of incremental behavior change. Yoga therapy, in turn, may have enhanced attention to bodily sensations, fatigue, tension, breathing, and movement patterns. This increased interoceptive and behavioral awareness may have helped participants recognize prolonged inactivity earlier and respond by changing posture or engaging in light movement. The use of goal setting and self-monitoring may also have improved perceived behavioral control. These mechanisms are consistent with the broader evidence that successful diabetes-prevention interventions require not only information but also repeated practice, self-observation, and opportunities to develop sustainable routines. The Diabetes Prevention Program demonstrated that intensive lifestyle modification can substantially reduce progression to type 2 diabetes among high-risk individuals (3). The present study extends this principle by showing that a combined educational and yoga-based approach can meaningfully alter sedentary behavior.

The second major finding was that the intervention significantly improved social well-being. This result is noteworthy because most interventions for overweight and diabetes risk emphasize biomedical indicators while giving less attention to positive social functioning. Social well-being includes social integration, social acceptance, social contribution, social actualization, and social coherence (20). In the present study, the descriptive results indicated improvement across all five components in the experimental group, suggesting that the intervention influenced participants' broader evaluation of their place, value, and functioning within society rather than merely producing a narrow emotional benefit.

This finding can be interpreted within Keyes's mental health continuum model, which conceptualizes mental health as more than the absence of psychopathology. Flourishing involves positive emotional, psychological, and social functioning, whereas languishing reflects low levels of these positive capacities (21). The complete state model further proposes that mental illness and positive mental health represent related but distinct dimensions (22). From this perspective, overweight individuals at risk of diabetes may not necessarily meet criteria for a mental disorder but may still experience reduced social participation, low perceived contribution, interpersonal withdrawal, or a diminished sense of belonging. The increase in social well-being observed in the present study therefore represents an important expansion of health beyond

symptom reduction and metabolic risk management. It indicates that the intervention may have supported movement toward more positive and socially engaged functioning.

The improvement in social well-being may partly reflect the group-based nature of the program. Repeated participation in structured sessions can provide opportunities for social contact, mutual encouragement, normalization of shared difficulties, and collaborative learning. Participants may have experienced reduced isolation through contact with others facing similar concerns about weight, inactivity, and diabetes risk. Such experiences may strengthen social integration and acceptance while increasing confidence in one's ability to contribute to group activities. Descriptive epidemiological work on social well-being has shown that the quality of social functioning is meaningfully related to individuals' broader life circumstances and interpersonal environments (23). A supportive intervention context may therefore have provided a social microenvironment in which participants could experience belonging, respect, and shared progress.

The social well-being finding is also compatible with research linking overweight and obesity to psychosocial distress. Individuals with excess body weight frequently encounter stigma, negative social evaluation, and reduced social support, all of which can undermine psychological and social functioning. Timkova et al. reported that weight stigma and social support play important roles in psychosocial distress among people with overweight and obesity (9). By creating a nonjudgmental and health-oriented setting, the present intervention may have counteracted some of these experiences. The emphasis on gradual progress, body awareness, and feasible behavioral change may have reduced shame and increased participants' confidence in social and health-related activities.

Yoga may have contributed specifically to improved social well-being through reductions in stress and increased emotional regulation. Controlled breathing, relaxation, and mindful attention can reduce physiological arousal and make interpersonal engagement feel less demanding. Improvements in physical comfort and energy may also enable greater participation in family, occupational, and community activities. Evidence from a randomized controlled trial showed that telehealth yoga influenced loneliness and social isolation among rural older adults, suggesting that yoga may affect social connectedness even when it is not delivered in person (24). Although the population in that study differed from the present sample, the finding supports the broader proposition that yoga can produce socially relevant outcomes.

Previous studies among adults with type 2 diabetes have similarly shown that yoga can improve psychosocial as well as metabolic outcomes. Singh and Khandelwal found that yoga and exercise improved glycemic control and psychosocial parameters in adults with type 2 diabetes (18). Subramani et al. also reported improvements in physical and mental health following yoga intervention among adults with diabetes (19). Meta-analytic findings have demonstrated that yoga improves glycemic and lipid parameters (17) and produces beneficial effects in adults with type 2 diabetes (16). Although these studies did not necessarily assess social well-being using Keyes's multidimensional framework, their psychosocial findings are consistent with the present result and suggest that the effects of yoga extend beyond physiological outcomes.

The combined intervention may have been particularly effective because lifestyle education and yoga therapy addressed complementary determinants of health. Lifestyle education provided cognitive and behavioral strategies, whereas yoga offered experiential practice involving movement, breathing, attention, and relaxation. Education may have increased knowledge and motivation, while yoga may have made the

recommended behavioral changes physically and emotionally achievable. This integration could explain the large effect sizes observed for both sedentary behavior and social well-being. The stability of the outcomes from posttest to follow-up further suggests that the intervention generated skills and routines that participants could continue independently. Maintenance is especially important in diabetes prevention because the benefits of short-term change diminish if individuals return to previous sedentary and socially withdrawn patterns.

Global obesity has increased substantially across age groups and regions (1), while prediabetes now affects a large proportion of the adult population worldwide (2). These trends indicate that health systems require scalable, low-cost, and culturally adaptable preventive programs. A combined lifestyle and yoga intervention may be particularly useful in this respect because it can target metabolic risk, sedentary habits, stress regulation, and social functioning simultaneously. The present findings therefore support a multidimensional model of diabetes prevention in which behavioral and psychosocial outcomes are considered alongside clinical indicators.

This study had several limitations. The sample consisted of only 40 overweight individuals recruited through purposive sampling from healthcare and counseling centers in Tehran, which limits the generalizability of the findings to other populations, regions, and socioeconomic groups. The relatively small sample size may also have increased the instability of effect-size estimates. Sedentary behavior was assessed through self-report rather than objective devices such as accelerometers, making the results susceptible to recall bias and socially desirable responding. The follow-up period was limited to two months and therefore does not establish whether the observed changes persist over longer periods. In addition, the control group received no active comparison intervention, so nonspecific factors such as therapist attention, group support, and expectations may have contributed to the outcomes. The study also did not separately estimate the effects of lifestyle education and yoga therapy, making it impossible to determine the independent contribution of each component.

Future studies should replicate the findings with larger and more diverse samples recruited from multiple clinical and community settings. Randomized controlled trials with active comparison groups should be conducted to distinguish the specific effects of yoga therapy, lifestyle education, group support, and general therapist attention. Longer follow-up periods of six months or one year would provide stronger evidence regarding maintenance and relapse. Objective monitoring tools, including accelerometers or wearable activity trackers, should be used alongside self-report measures to assess total sedentary time and the frequency of sitting interruptions. Future research should also evaluate metabolic outcomes such as glycated hemoglobin, fasting glucose, insulin resistance, lipid profiles, body composition, and waist circumference. Mediation analyses could clarify whether changes in stress, self-efficacy, body awareness, physical activity, or perceived social support explain improvements in sedentary behavior and social well-being.

Healthcare centers and diabetes-prevention services may incorporate structured healthy lifestyle education combined with adapted yoga therapy into programs for overweight adults at elevated metabolic risk. Sessions should explicitly address prolonged sitting, movement breaks, gradual increases in daily activity, balanced nutrition, sleep, and stress management. Yoga practices should be modified according to participants' mobility, weight status, and medical conditions and should be delivered by trained professionals who can ensure safety and correct technique. Group delivery may be especially beneficial

because it can reduce isolation and strengthen adherence through shared participation. Practitioners should also provide simple home-practice plans, behavioral monitoring forms, and periodic follow-up sessions to support maintenance. The intervention should be used as a complementary preventive strategy rather than a substitute for medical evaluation, nutritional care, or prescribed treatment.

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Authors' Contributions

All authors equally contributed to this study.

Declaration of Interest

The authors of this article declared no conflict of interest.

Ethical Considerations

The study protocol adhered to the principles outlined in the Helsinki Declaration, which provides guidelines for ethical research involving human participants.

Transparency of Data

In accordance with the principles of transparency and open research, we declare that all data and materials used in this study are available upon request.

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