

Research Article

The effects of eight weeks of aerobic exercise and NBS superfood supplementation on IL-1 β and SOD in elderly men with diabetes

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Abstract

Type 2 diabetes in older adults is characterized by chronic low-grade inflammation and oxidative stress, with elevated interleukin-1 β (IL-1 β) and reduced superoxide dismutase (SOD) activity playing central roles in disease progression. This study aimed to investigate the independent and combined effects of eight weeks of moderate-intensity aerobic exercise and NBS superfood supplementation on serum IL-1 β and SOD levels in elderly men with type 2 diabetes. Forty older men (aged 60–75 years) with type 2 diabetes were randomly allocated using stratified block randomization to four groups (n=10 each): control, exercise-only (TR), supplement-only (SUP), and exercise + supplement (TR+SUP). The exercise groups performed supervised cycling at 60–70% Wmax, 30 min/session, 3 sessions/week for 8 weeks. The supplementation groups received 10 g/day NBS superfood. Fasting serum IL-1 β and SOD were measured before and 48 hours after the intervention using ELISA. Two-way repeated-measures ANOVA revealed significant time \times group interactions for both IL-1 β ($p < 0.001$, $\eta^2 p = 0.372$) and SOD ($p < 0.001$, $\eta^2 p = 0.892$). Post-hoc tests showed the greatest reductions in IL-1 β and largest increases in SOD occurred in the TR+SUP group compared to all other groups ($p < 0.001$), indicating a synergistic effect. Eight weeks of moderate-intensity aerobic exercise combined with NBS superfood supplementation exerts potent synergistic anti-inflammatory and antioxidant effects in older men with type 2 diabetes, suggesting a promising non-pharmacological strategy for managing chronic inflammation and oxidative stress.

Key Words: Type 2 diabetes, Aerobic exercise, NBS superfood, IL-1 β , SOD

Introduction

Type 2 diabetes in older adults heightens the risk of neurodegenerative, cardiovascular, and cognitive disorders by triggering low-grade chronic inflammation and oxidative stress (Donath & Shoelson, 2011). Central to this process, interleukin-1 beta (IL-1 β), a key pro-inflammatory cytokine, amplifies reactive oxygen species (ROS) production through NLRP3 inflammasome activation (Dominic et al., 2022). The resulting ROS suppress the expression and function of antioxidant enzymes, notably superoxide dismutase (SOD), thereby perpetuating a vicious cycle in which reduced SOD activity exacerbates ROS accumulation and further elevates IL-1 β levels (Heneka et al., 2018). This reciprocal interplay between IL-1 β and SOD constitutes a core pathogenic mechanism in diabetes-affected tissues, including skeletal muscle, heart, and brain (Mao et al., 2012).

Moderate-intensity aerobic exercise is well-established as a potent non-pharmacological strategy for attenuating inflammation and bolstering antioxidant defenses in elderly diabetic individuals. Studies demonstrate that 8–12 weeks of aerobic training can decrease plasma IL-1 β by up to 30% and increase SOD activity by up to 45% (Abd El-Kader & Al-Jiffri, 2020; Gleeson et al., 2011), effects mediated via AMPK and SIRT1 signaling and suppression of NF- κ B activation (Petersen & Pedersen, 2005).

Recently, naturally derived dietary supplements have emerged as promising adjuncts or alternatives to pharmacotherapy. The NBS superfood supplement, an organic extract derived primarily from wheat, contains a comprehensive nutrient profile, including B vitamins (B1, B3, B5, B6, B9), vitamins C, D, and K, minerals (magnesium, potassium, phosphorus, sulfur, manganese, calcium, iron, boron, copper, zinc), and essential fatty acids (omega-3, omega-6, omega-9) (Kordi et al., 2025). This supplement has shown protective effects against oxidative stress by enhancing immune function, reducing inflammatory mediators, and optimizing energy metabolism. Mosadegh et al. (2022) reported that 1.5 g of NBS taken three times daily for 14

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days significantly lowered IL-1 β in COVID-19 patients. Additionally, Kordi et al. (2024) observed that combining aerobic exercise with NBS supplementation reduced IL-1 β and caspase-1 in cardiac tissue of diabetic rats. Shirinbayan et al. (2025) further demonstrated that post-exercise NBS administration with spinach substantially increased SOD activity in athletes.

Although robust evidence supports the independent benefits of moderate-intensity aerobic exercise in reducing plasma IL-1 β and enhancing SOD activity in elderly diabetic patients (Abd El-Kader & Al-Jiffri, 2020; Gleeson et al., 2011), and emerging data highlight the anti-inflammatory and antioxidant potential of NBS superfood (including reduced IL-1 β and caspase-1 in cardiac tissue (Kordi et al., 2024) and elevated SOD under high oxidative stress (Shirinbayan et al., 2025), no prior study has evaluated the combined effects of these interventions over an 8-week period in elderly men with diabetes. Accordingly, the primary aim of the present study was to examine the independent and combined effects of eight weeks of moderate-intensity aerobic exercise and NBS superfood supplementation on serum levels of IL-1 β and SOD activity in older men with type 2 diabetes.

Materials and methods

Participants

The study targeted men aged 60–75 years residing in Kermanshah, Iran (Rahimi et al., 2025). Forty elderly men with type 2 diabetes were recruited via purposive sampling and randomly allocated to four groups (n=10): control group (CONT), exercise group (TR), supplement group (SUP), and exercise + supplement group (TR+SUP).

To randomly assign subjects to four groups, a block randomization method (block size=4) was used to maintain a balance in the number of subjects in each group during the sampling process. Allocation was done in a 1:1:1:1 ratio using the reputable website [www. Randomization. Com](http://www.Randomization.Com). The allocation order list was prepared by an individual independent of the principal investigator (not involved in the screening and assessment process). Sealed Opaque Numbered Envelopes (SNOSE) were used to prevent selection bias. Each envelope contained a card identifying the assigned group and was only opened by the session facilitator upon entry into the study and after final verification of eligibility. This randomization and alloca-

-tion concealment method minimized the risk of selection bias and group prediction and ensured baseline balance between the four groups.

Inclusion criteria comprised confirmed type 2 diabetes, absence of active diabetic ulcers, no history of amputation or non-diabetic neurological/orthopedic conditions, no inflammatory arthropathies (e.g., rheumatoid arthritis), and no advanced diabetic retinopathy. Exclusion criteria included uncontrolled hyperglycemia, exercise-related musculoskeletal injuries, severe post-session fatigue, or persistent malaise. All participants completed health screening questionnaires and provided informed consent. The study complied with international ethical standards for human research, with ongoing health monitoring and the right to withdraw at any time.

Exercise protocol

Aerobic training was performed on a stationary cycle ergometer (Powermax, model K29100). Exercise intensity was personalized using an incremental workload test: participants began with 3 minutes of unloaded pedaling, followed by a 3-minute warm-up at 60 watts, after which workload increased by 40 watts every 3 minutes until volitional exhaustion determined maximum workload (Wmax). Training sessions were conducted at 60–70% Wmax for 30 minutes, three times per week, over eight weeks (Agustín et al., 2025). All sessions were supervised by a certified instructor to ensure adherence to prescribed timing, intensity, and frequency. The protocol is detailed in Table 1.

Supplementation protocol

Participants in the supplementation-only and combined groups received 10 g of NBS superfood daily, administered immediately before bedtime for eight consecutive weeks (Shirinbayan et al., 2025). This dosage was selected to optimize metabolic and immune support in elderly individuals with diabetes, leveraging the supplement's nutrient-dense, plant-based composition.

Blood sampling and biochemical analysis

Plasma levels of IL-1 β and SOD activity were assessed at baseline and 48 hours after the final intervention session. On each occasion, 10 mL of venous blood was collected from the antecubital vein following a 12-hour overnight fast, between 8:00 and 10:00 AM under standardized conditions. Samples were dra-

Table 1. Eight-week aerobic exercise protocol (three sessions per week)

Phase	Activity	Duration	Workload (watts)	Purpose
Incremental Test	Cycling on ergometer	3 min	0	Initial body preparation
Primary Warm-up	Fixed-load cycling	3 min	60	Gradual HR and blood flow increase
Secondary Warm-up/Increasing	+40 watts every 3 min until exhaustion	Variable	+40 every 3 min	Determine Wmax for intensity setting
Main Sessions	Continuous cycling at 60–70% Wmax	30 min	60–70% Wmax	Improve metabolism, reduce inflammation, enhance aerobic capacity

-wn into EDTA tubes (Pars Co., Iran), centrifuged at 3000 rpm for 10 minutes, and the resulting plasma was aliquoted into labeled microtubes and stored at -80°C until analysis. Concentrations of IL-1β and SOD activity were determined using commercially available ELISA kits (MyBioSource, China) specific to each biomarker.

Statistical analysis

Descriptive statistics, including means and standard deviations, were computed for all variables. The Shapiro-Wilk test was used to evaluate normality of the data within each group, and Levene’s test assessed homogeneity of variances. A two-way ANOVA was conducted to assess the main effects of the two interventions. Significant main effects were followed by Tukey’s post-hoc tests for pairwise group comparisons. All analyses were conducted using SPSS version 26, with statistical significance defined as p<0.05.

Results

Table 2 presents the characteristics of height, weight, age, body mass index, fat percentage, fasting glucose, insulin, hemoglobin A1C, and duration of diabetes in the study groups.

Data were normally distributed (Shapiro–Wilk p>0.05) and variances were homogeneous (Levene’s test p>0.05) (p<0.05). Given that the assumptions of normality, homogeneity of variance, and sphericity were satisfactorily met, a two-way repeated-measures analysis of variance (ANOVA) was performed to examine the main effects of time (pre-test vs. post-test) and group (control, exercise-only, supplement-only, and exercise + supplement), as well as the time × group interaction.

Two-way repeated measures ANOVA revealed significant main effects of time (F(1, 36)=84.33, p<0.001, η²p=0.539), group (F(3, 36)=22.28, p<0.001, η²p 0.481), and a significant time×group interaction (F(3,36)=14.19, p<0.001, η²p=0.36). Post-hoc Tukey HSD tests indicated that post-intervention serum interleukin-1β (IL-1β) concentration was significantly lower in the combined TR + SUP group compared to the TR (p<0.001), SUP (p=0.060), and CONT groups (p<0.001). Both TR and SUP groups also displayed significantly lower IL-1β levels than the control group (p<0.05). The greatest reduction in IL-1β was observed in the TR+SUP group, indicating a synergistic anti-inflammatory effect of exercise and supplementation (Table 2, Figure 1).

Two-way repeated measures ANOVA revealed significant main effects of time (F (1,36)=3124.58, p<0.001, η²p=0.987), group (F (3,36)=168.42, p<0.001, η²p=0.929), and a significant time × group interaction (F (3,36)=98.76, p<0.001, η²p=0.892). Post-hoc Tukey HSD tests indicated that in the post-test, serum SOD concentration was significantly higher in the TR+SUP group compared to all other groups (p<0.001). The SUP group also exhibited significantly higher SOD levels than both the CONT and TR groups (p<0.001 and p<0.05, respectively). The greatest increase in SOD was observed in the TR+SUP group, suggesting a synergistic effect of these two interventions (Table 2, Figure 2).

Discussion

The aim of the present study was to investigate the effects of eight weeks of moderate-intensity aerobic exercise combined with NBS superfood supplementation on serum interleukin-1β (IL

Table 1. Baseline data between study groups.

Factors	CONT group	TR group	SUP group	TR+SUP group
Age (year)	67.56± 1.45	66.87± 1.42	72.91± 2.6	70.50± 5.16
High (cm)	174.12± 3.18	174.87± 3.31	166.73± 7.50	167.09± 6.26
Weight (kg)	71.75± 3.05	73.62± 2.87	75.4± 12.67	72.74±14.54
BMI (kg/m²)	23.66± 0.67	24.10± 0.89	27.11± 4.52	26.33± 4.34
Fat (%)	25.50± 2.97	24.11± 0.88	28.17± 1.18	27.18± 1.78
FBS (mg/dl)	187.93± 5.41	184.75± 6.31	189.32± 1.98	188.56± 2.79
Insulin (mg/dl)	12.76± 1.25	12.80± 1.72	12.66± 1.82	12.80± 1.58
A1C (%)	7.35± 0.45	7.17± 0.57	7.17± 1.95	7.69± 1.31
Diabetic Time (year)	7.32± 1.57	7.56± 1.63	7.89± 1.28	7.42± 1.76

Table 2. Two-way ANOVA results for IL-1β and SOD levels

Factors	Source of Variance	df	F	p	Partial η²
IL-1β	Time	1	22.28	0.001*	0.481
	Group	3	48.33	0.001*	0.539
	Time* Group	3	14.19	0.001*	0.372
SOD	Time	1	3124.58	0.001*	0.987
	Group	3	168.42	0.001*	0.929
	Time* Group	3	98.76	0.001*	0.892

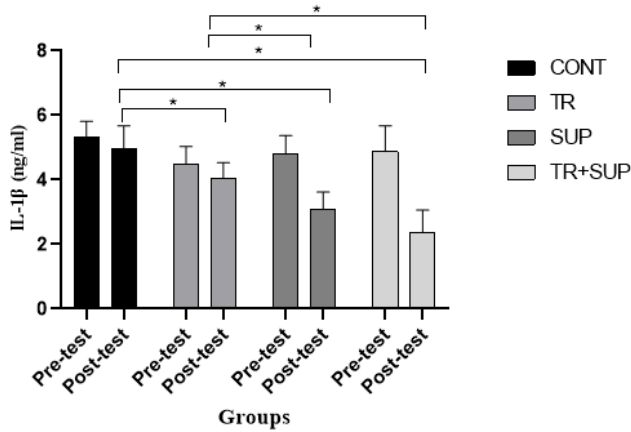


Figure 1. IL-1 β changes levels in the four groups before and after intervention. * indicate a significant difference between groups ($p < 0.05$).

-1 β) and superoxide dismutase (SOD) levels in older men with type 2 diabetes. The results revealed that both aerobic exercise and NBS superfood supplementation independently reduced IL-1 β and increased SOD concentrations.

In agreement with the current findings, previous research has reported a significant reduction in IL-1 β following aerobic training in men with diabetes (Nabilpour & Sadeghi, 2024.). Similarly, regarding the effect of NBS superfood, Kordi et al. (2024) demonstrated that six weeks of moderate-intensity aerobic exercise combined with NBS supplementation significantly decreased IL-1 β levels (Kordi et al., 2024).

In patients with type 2 diabetes, chronic hyperglycemia and elevated free fatty acids activate TLR2/4 receptors and increase mitochondrial ROS, thereby stimulating the NF- κ B pathway and upregulating pro-IL-1 β production. Concurrently, stimuli such as TXNIP, AGEs, and islet amyloid trigger NLRP3 inflammasome activation, leading to caspase-1 cleavage and maturation of IL-1 β (Rohm et al., 2022; Kelley et al., 2019). The secreted mature IL-1 β exacerbates insulin resistance and induces β -cell apoptosis via JNK and IKK β /NF- κ B signaling, establishing chronic low-grade inflammation in adipose tissue, pancreas, and liver that perpetuates the vicious cycle of diabetes (Jayaraman et al., 2021).

Aerobic exercise in older adults with diabetes primarily attenuates IL-1 β through inhibition of the NF- κ B pathway and activation of the SESN1-AMPK axis, suppressing p65 phosphorylation and IKK α degradation and consequently reducing pro-IL-1 β expression. Exercise-induced SESN1 upregulation activates AMPK, inhibits mTORC1, disrupts NLRP3 inflammasome assembly, and lowers serum and skeletal muscle IL-1 β (Osawa & Arai, 2025). These adaptations are accompanied by improved insulin sensitivity, reduced oxidative stress (via elevated SOD and GSH-Px), and suppression of chronic inflammation, ultimately

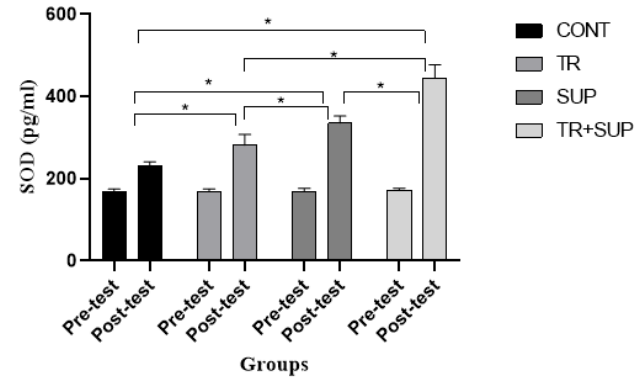


Figure 2. SOD changes levels in the four groups before and after intervention. * indicate a significant difference between groups ($p < 0.05$).

tely enhancing vascular and metabolic function in older patients with type 2 diabetes (Oliveira et al., 2012).

With respect to NBS superfood supplementation, cross-sectional and prospective studies indicate that regular whole-grain consumption is associated with reduced systemic inflammation (Kordi et al., 2024; Awika et al., 2018). The present study showed that NBS supplementation, either alone or combined with exercise, significantly decreased IL-1 β . This effect may be attributed to minerals, vitamins, and bioactive compounds in the supplement. Notably, apigenin (a flavonoid abundant in wheat) prevents NF- κ B activation and downstream proinflammatory gene expression, inhibits caspase-1, and suppresses IL-1 β production. Apigenin also blocks ERK1/2 phosphorylation and reduces mRNA stability of inflammatory mediators (Zhang et al., 2007). Furthermore, chronic hyperglycemia in type 2 diabetes upregulates cyclooxygenase-2 (COX-2) and prostaglandin E2 (PGE2) via ROS and NF- κ B activation in macrophages, adipocytes, and endothelial cells. PGE2 impairs IRS-1 phosphorylation through EP2/EP4 receptors and cAMP, aggravating insulin resistance and β -cell apoptosis. Wheat-derived compounds have been shown to inhibit arachidonic acid release, prostaglandin synthesis, and COX-2 gene expression (Zhang et al., 2007; Hurst & Hurst, 2012).

The present investigation demonstrated that both aerobic exercise and NBS superfood supplementation significantly increased SOD activity. These findings align with Piralai and Ismael (2024), who reported elevated SOD after eight weeks of aerobic training, and Shirinbayan et al. (2025), who observed a significant SOD increase in athletes after one week of NBS consumption (Shirinbayan et al., 2025). The significant increase in SOD activity observed in the present study is consistent with the adaptive antioxidant response to regular moderate-intensity aerobic exercise in older adults with type 2 diabetes. Chronic hyperglycemia and oxidative stress in diabetes initially upregulate

compensatory antioxidant enzymes, including SOD (Poblete Aro et al., 2015). Aerobic training, particularly when combined with NBS superfood supplementation, further enhances SOD activity through activation of Nrf2-ARE signaling, increased expression of mitochondrial SOD2, and improved redox homeostasis. This elevation reflects an augmented endogenous antioxidant defense capacity rather than a compensatory overexpression and is associated with reduced lipid peroxidation and inflammatory burden, as supported by previous studies in diabetic populations (Saydi et al., 2024).

The current findings suggest that NBS superfood supplementation may enhance SOD activity in older diabetic patients. Although limited data exist on wheat germ and ROS modulation, wheat germ (the by-product of grain milling) exhibits superior antioxidant capacity compared with other milled fractions due to its high content of phytic acid, polyphenols (lignans and phenolic acids), vitamins, and minerals. These phytochemicals confer protection against cancer and type 2 diabetes by scavenging free radicals, chelating metal ions, and activating endogenous antioxidant enzymes (Ciudad-Mulero et al., 2023). Observed changes in antioxidant enzyme activities likely arise from synergistic actions of antioxidant vitamins, fatty acids, phytosterols, and phenolic compounds in wheat germ (Higuchi, 2014; Karabacak et al., 2011). Dietary antioxidants are essential for preventing and delaying chronic diseases such as diabetes, with phenolic compounds acting as multitarget agents that modulate enzyme and receptor activity. Notably, 5-n-alkylresorcinols (ARs) (unique phenolic lipids abundant in wheat germ) display multiple bioactivities with potential to attenuate progression of chronic diseases (Fan et al., 2020).

Conclusion

The present study demonstrates that eight weeks of moderate-intensity aerobic exercise and NBS superfood supplementation, both independently and synergistically, significantly reduced serum IL-1 β levels and increased SOD activity in older men with type 2 diabetes. The most pronounced improvements occurred in the combined exercise and supplementation group, indicating a clear synergistic anti-inflammatory and antioxidant effect. These beneficial changes are mediated through inhibition of NF- κ B signaling and NLRP3 inflammasome activation, enhanced SESN1-AMPK and Nrf2-ARE pathways, and the bioactive compounds of NBS Superfood supplement that further suppress proinflammatory cytokines and bolster endogenous antioxidant defenses. Consequently, this combined non-pharmacological intervention effectively interrupts the vicious cycle of chronic low-grade inflammation and oxidative stress that drives diabetes progression in older adults. These findings support the integration of moderate-intensity aerobic exercise with NBS superfood supplementation as a safe, accessible, and potent therapeutic st-

-ategy to improve metabolic and inflammatory profiles in elderly patients with type 2 diabetes. Future large-scale, long-term trials are warranted to confirm these effects and explore clinical outcomes.

The present study is limited by its small sample size, which may have reduced statistical power for detecting moderate effects. Additionally, the lack of blinding for participants, supervisors, and assessors could have introduced performance and detection bias in this exercise and supplementation trial. Finally, dietary intake (beyond the supplement) and daily physical activity outside supervised sessions were not controlled, representing potential confounders that may have influenced the inflammatory and antioxidant markers.

What is already known on this subject?

Regular exercise in the daily routine of old age not only helps control the symptoms of diabetes but also increases the level of quality of life. Also, herbal supplements rich in antioxidants and nutrients have great potential to reduce inflammation and strengthen cellular defenses.

What this study adds?

Aerobic exercise, by enhancing metabolism and reducing inflammation, and NBS supplementation, with the potential to improve immunity and inhibit oxidative stress, are promising complementary strategies. By clarifying the interaction of these interventions on inflammatory and antioxidant markers, this study can help to develop policies for healthy aging, reduce healthcare costs, and empower communities to face the challenges of diabetes.

Organ Cross-Talk Tips:

- Moderate-intensity aerobic exercise stimulates skeletal muscle to release myokines and factors (e.g., irisin, beneficial IL-6) that suppress NF- κ B/NLRP3 signaling in remote organs, reducing systemic inflammation and enhancing antioxidant capacity (e.g., via Nrf2-ARE activation of SOD). NBS superfood, rich in bioactive compounds (e.g., flavonoids like apigenin), likely augments this by further inhibiting pro-inflammatory cytokine release from adipose tissue and supporting redox homeostasis, thereby interrupting pathological cross-talk between adipose, liver, muscle, and pancreas.

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Data availability

The data supporting the findings of this study are available within the article. This data can be provided by the corresponding author upon reasonable request.

Compliance with ethical standards

Conflict of interest the authors declare that there is no conflict of interest in the present research.

Ethical approval The ethics committee of Sport Sciences Research Institution of Iran approved the study protocol with the ethics code IR.IAU.KSH.REC.1404.081.

Informed consent Written informed consent was obtained from all participants.

Author contributions

Conceptualization: B.F., Methodology: S.H.D., Software: M.B., Validation: B.F.,; Formal analysis: S.H.D.,; Investigation: M.B.,; Resources: B.F.,; Data curation: S.H.D.,; Writing - original draft: S.H.D.,; Writing–review & editing M.B.,; Visualization: B.F.,; Supervision: S.H.D.,; Project administration: B.F.,; Funding acquisition: F.H.D.

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