RESEARCH PAPER

Dangke Supplementation Attenuates Systemic Inflammation and Improves Nutritional Status in Pregnant Women with Chronic Energy Deficiency: A Randomized Controlled Trial

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Received: 24th April, 2026; Revised: 20th May 2026; Accepted: 30th June, 2026; Available Online: 10th July, 2026

ABSTRACT

Background: Chronic energy deficiency (CED) in pregnancy is linked to adverse maternal and neonatal outcomes and low-grade systemic inflammation. The neutrophil-to-lymphocyte ratio (NLR) is an inflammatory marker. This study evaluated whether Dangke, a fermented dairy product from South Sulawesi, Indonesia, affects systemic inflammation by assessing NLR changes in pregnant women with CED.

Materials and Methods: A randomized pretest–posttest trial in 30 second-trimester women with CED in Takalar Regency, Indonesia, assigned 200 g/day steamed Dangke for 28 days (n = 15) or standard antenatal care (n = 15). Gestational age, MUAC, and NLR were assessed pre/postintervention; differences were analyzed at $p < 0.05$.

Results: Baseline gestational age and NLR did not differ significantly between groups, whereas MUAC was lower in the intervention group than in the control group (21.11 ± 1.44 vs. 22.49 ± 0.82 cm; p = 0.004). After 28 days, the Dangke group showed a significant reduction in NLR from 4.22 ± 1.59 to 3.42 ± 1.31 (p = 0.010), representing a 19% decrease. The control group showed a non-significant reduction (4.26 ± 1.45 to 3.38 ± 1.33; p = 0.098). However, the between-group difference in NLR change was not statistically significant (p = 0.888).

Conclusion: Dangke supplementation significantly reduced systemic inflammation within the intervention group despite lower baseline MUAC, suggesting potential immunonutritional benefits for pregnant women with CED. Larger randomized controlled trials are warranted to confirm these findings.

Keywords: Dangke; Neutrophil-Lymphocyte Ratio; Pregnancy; Protein-Energy Malnutrition; Second Trimester Pregnancy

How to cite this article: Safitri A, As'ad S, Nugraha GI, Astuti N, Aminuddin, Tawali S, Bukhari A, Dangke Supplementation Attenuates Systemic Inflammation and Improves Nutritional Status in Pregnant Women with Chronic Energy Deficiency: A Randomized Controlled Trial Int J Drug Deliv Technol. 2026;16(7): 363-371. DOI: 10.25258/ijddt.16.7.37
Source of support: Nil.
Conflict of interest: None

INTRODUCTION

Maternal undernutrition remains a major public health problem, particularly in low- and middle-income countries, and is associated with adverse outcomes including fetal growth restriction, low birth weight, preterm birth, and increased maternal morbidity [1,2]. Chronic energy deficiency (CED), resulting from prolonged inadequate energy and nutrient intake, is one of the most common forms of maternal malnutrition during pregnancy. In Indonesia, CED continues to affect a substantial proportion of pregnant women despite ongoing nutritional interventions [3,4]. Mid-upper arm circumference (MUAC) is a simple and reliable indicator of maternal nutritional reserves and is widely used to identify pregnant women at risk of CED and adverse pregnancy outcomes [5,6].

Beyond nutritional deficiency, CED has been increasingly recognized as an immunometabolic disorder characterized by chronic low-grade systemic inflammation [7]. Persistent inflammatory activation may impair placental

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function, maternal–fetal immune tolerance, and fetal development, increasing the risk of pregnancy complications [8]. Because inflammatory responses vary throughout pregnancy, gestational age should also be considered when interpreting inflammatory biomarkers [9–12] The neutrophil-to-lymphocyte ratio (NLR), derived from routine complete blood counts, has emerged as a practical and inexpensive marker of systemic inflammation and has been associated with several adverse obstetric conditions, including preeclampsia and fetal growth restriction [13].

Nutritional interventions, particularly fermented foods, have attracted increasing interest because they may improve both nutritional status and immune regulation. Adequate protein intake supports immune-cell function, while fermentation-derived bioactive compounds and lactic acid bacteria may reduce inflammation through modulation of the gut microbiota and production of beneficial metabolites [14,15]. Dangke, a traditional fermented dairy product from South Sulawesi, Indonesia, is rich in high-quality protein, essential amino acids, minerals, and lactic acid bacteria with potential immunomodulatory properties [16,17].

Despite its nutritional value and long-standing traditional use, evidence regarding the effects of Dangke supplementation on inflammatory status during pregnancy remains limited [18]. Most previous studies have focused on its nutritional composition and microbiological characteristics, whereas its effects on inflammatory biomarkers among pregnant women with CED have not been adequately investigated [19,20]. Therefore, this randomized controlled trial aimed to evaluate the effect of Dangke supplementation on systemic inflammation among pregnant women with CED by assessing changes in NLR while considering MUAC and gestational age as indicators of maternal nutritional and physiological status.

MATERIALS AND METHODS

Study Design and Participants

This study used a randomized controlled trial (RCT) with a pretest–posttest design to assess the impact of Dangke supplementation on the nutritional and inflammatory status of pregnant women with CED. The primary outcome measured was the change in the NLR, while MUAC and gestational age were included as indicators of maternal nutritional vulnerability and physiological adaptation. Randomized controlled trials are regarded as the gold standard for evaluating intervention efficacy due to their ability to minimize selection bias and enhance causal inference. The research was conducted in Takalar Regency, South Sulawesi, Indonesia, specifically within the catchment areas of Pattallassang Primary Health Center and Mangarabombang Primary Health Center. These facilities were chosen because they reported the highest prevalence of CED among pregnant women in Takalar Regency, according to local maternal health surveillance data.

The study population consisted of pregnant women diagnosed with CED during the second trimester. CED was defined by a MUAC of less than 23.5 cm, in accordance with Indonesian maternal nutritional guidelines. Gestational age was determined from antenatal care records and obstetric assessments to account for physiological variations in maternal immune and inflammatory responses. A total of 30 eligible participants were recruited through purposive sampling and then randomized into intervention and control groups via a simple random allocation procedure, with each group containing 15 participants. Baseline variables collected included maternal age, gestational age, educational attainment, occupation, parity, hemoglobin concentration, MUAC, and NLR.

Eligible participants were pregnant women aged 18–40 years with CED (MUAC <23.5 cm), in their second trimester of gestation (13–27 weeks), with hemoglobin concentrations below 12 g/dL, and who were willing to participate throughout the study period. Participants were excluded if they had chronic medical conditions such as hypertension, diabetes mellitus, renal disease, or autoimmune disorders known to influence inflammatory markers; experienced acute infections during the study period; were active smokers; received immunomodulatory therapy; relocated from the study area; or failed to complete the intervention protocol.

Dangke Supplementation

Participants in the intervention group received 200 g of steamed Dangke daily for four consecutive weeks, in addition to routine antenatal care. Dangke is a traditional dairy product from Enrekang Regency, South Sulawesi, Indonesia, produced through the enzymatic coagulation of cow or buffalo milk using papaya latex. Previous studies have shown that Dangke contains substantial amounts of high-quality protein, essential amino acids, calcium, and lactic acid bacteria, which may contribute to improved nutritional status and modulation of inflammatory responses. Participants were instructed to consume the entire daily portion, and compliance was monitored throughout the intervention period. Participants in the control group received routine antenatal care and continued their habitual diet without Dangke supplementation. No additional nutritional products or dietary interventions were provided to the control group. Both groups continued to receive standard maternal health services in accordance with local antenatal care guidelines.

Outcome Measurements

The primary outcome was the NLR, calculated as the ratio of the absolute neutrophil count to the absolute lymphocyte count obtained from routine complete blood count analysis. NLR was selected as a surrogate marker of systemic inflammation because it reflects the balance between innate and adaptive immune responses and has been associated with inflammatory disorders, metabolic dysfunction, and adverse pregnancy outcomes.

The secondary outcome was the change in MUAC, measured using a non-stretchable measuring tape at the midpoint between the acromion and olecranon processes of the non-dominant arm to the nearest 0.1 cm by trained personnel following standardized anthropometric procedures. MUAC was used as an indicator of maternal nutritional status and chronic energy deficiency because it reflects long-term protein–energy reserves and is recommended for nutritional screening during pregnancy.

Gestational age was recorded at baseline from antenatal care records and obstetric assessment. Although not considered an outcome variable, it was included as a descriptive covariate because physiological immune and inflammatory responses vary throughout pregnancy. Complete blood count analysis and anthropometric measurements were performed at baseline before the intervention and repeated after 28 days of supplementation. Changes in NLR and MUAC from baseline to the end of the intervention were analyzed within and between study groups.

Statistical Analysis

Data analysis was conducted utilizing IBM SPSS Statistics (IBM Corp., Armonk, NY, USA). The normality of continuous variables was evaluated through the Shapiro–Wilk test. Normally distributed data were expressed as mean ± standard deviation (SD), while non-normally distributed data were represented as median with interquartile range (IQR). Categorical variables were described using frequencies and percentages. To evaluate comparability between groups, baseline characteristics were compared. For continuous variables with normal distribution, independent-samples t-tests were employed. In contrast, the Mann–Whitney U test was used for variables not following a normal distribution. Categorical variables were examined using either the chi-square test or Fisher's exact test, depending on suitability.

Changes in NLR and MUAC within groups from baseline to post-intervention were analyzed using paired-samples t-tests for data with normal distribution, or Wilcoxon signed-rank tests for data without normal distribution. Differences in outcome changes (ΔNLR and ΔMUAC) between groups were evaluated using independent-samples t-tests or Mann–Whitney U tests, depending on the data distribution. Gestational age was included as a descriptive physiological variable and assessed for baseline comparability between groups. Effect sizes and mean changes from baseline were calculated to aid in interpreting the intervention effects. All statistical tests were two-tailed, with a significance level set at $p < 0.05$.

RESULTS

Baseline Characteristics of Participants

Table 1 displays the initial demographic, nutritional, and laboratory data. The study included 30 pregnant women with CED who completed the intervention protocol and were analyzed in the final results. Participants were divided randomly into two groups: the intervention group, which received Dangke supplementation (n = 15), and the control group, which received standard antenatal care (n = 15). The average age of mothers was 25.87 ± 6.28 years in the intervention group and 24.71 ± 5.04 years in the control group, with no significant age difference between the groups ($p > 0.05$). The average gestational age was 23.00 ± 5.26 weeks for the intervention group and 24.29 ± 6.23 weeks for the control group, showing no significant difference between the groups ($p > 0.05$), which suggests that participants were enrolled at similar pregnancy stages.

A notable variation was found in the initial MUAC measurements. The intervention group exhibited a lower average MUAC compared to the control group (21.11 ± 1.44 cm versus 22.49 ± 0.82 cm; $p = 0.004$), suggesting a poorer nutritional condition and increased nutritional risk at the start of the study. However, the initial inflammatory status was similar across both groups. The average NLR was 4.22 ± 1.59 for the intervention group and 4.26 ± 1.45 for the control group, showing no significant difference ($p = 0.936$). In general, the groups were similar in terms of maternal age, gestational age, and baseline inflammatory status. Although the intervention group had significantly lower MUAC values, both groups had comparable NLR values before the intervention, which supports the reliability of the subsequent outcome analyses.

Changes in Mid-Upper Arm Circumference Following Dangke Supplementation

To evaluate changes in maternal nutritional status after a four-week intervention, MUAC was assessed. Initially, the intervention group had a notably lower baseline MUAC (21.11 ± 1.44 cm compared to 22.49 ± 0.82 cm; $p = 0.004$), indicating poorer nutritional reserves at the start of the study. After the intervention, the average MUAC in the intervention group rose from 21.11 ± 1.44 cm to 21.28 ± 1.49 cm (ΔMUAC = +0.17 ± 0.19 cm). In contrast, the control group experienced a slight increase from 22.49 ± 0.82 cm to 22.51 ± 0.89 cm (ΔMUAC = +0.03 ± 0.11 cm). The comparison of ΔMUAC between the groups revealed a statistically significant difference ($p = 0.014$), suggesting that participants receiving Dangke supplementation showed a greater enhancement in nutritional status (Table 2).

The intervention group experienced an average MUAC increase of approximately 0.8% from the baseline, whereas the control group exhibited just a 0.1% increase. Although the absolute change is modest, the significantly greater improvement in the intervention group suggests that Dangke supplementation probably enhanced maternal nutritional reserves. Given that low MUAC is associated with adverse pregnancy outcomes, including fetal growth restriction and low birth weight, improving this measure could have significant clinical implications.

Changes in Neutrophil-to-Lymphocyte Ratio Following Dangke Supplementation

NLR was the main outcome measured to evaluate alterations in systemic inflammatory status. Initially, NLR values were similar across the groups (intervention: 4.22 ± 1.59; control: 4.26 ± 1.45; $p = 0.936$), indicating comparable inflammatory profiles before the intervention began. After the four-week intervention, those who received Dangke experienced a statistically significant reduction in NLR, decreasing from 4.22 ± 1.59 to 3.42 ± 1.31 ($p = 0.010$), which represents an approximate 19% decrease. In contrast, the control group exhibited a numerical decrease in NLR from 4.26 ± 1.45 to 3.38 ± 1.33, but this change was not statistically significant ($p = 0.098$). The findings are detailed in Table 3.

While both groups showed a decrease in NLR numbers, statistical significance in the within-group analysis was only reached by the intervention group. When comparing the average changes in NLR between the groups, no statistically significant difference was found (ΔNLR: −0.80 ± 1.05 vs. −0.88 ± 1.85; $p = 0.888$), suggesting that the extent of reduction was comparable in both groups. The lack of a significant effect between the groups might be due to the small sample size, natural variability in inflammatory responses, or physiological immune changes during pregnancy affecting both groups.

Integration of Gestational Age Dynamics, Nutritional Status, and Systemic Inflammation

Gestational age was integrated into the study design due to its influence on maternal immune and nutritional adjustments. The initial gestational age was similar across the groups (intervention: 23.00 ± 5.26 weeks; control: 24.29 ± 6.23 weeks; $p > 0.05$), suggesting that participants were enrolled at comparable pregnancy stages, thereby minimizing the chance that outcome differences were due to gestational timing. With an average gestational age of around 23–24 weeks, most participants were in the second trimester, a phase marked by swift fetal development and heightened maternal nutritional needs. Women with CED during pregnancy might be especially at risk of nutritional depletion at this time, as their existing nutritional stores may not suffice to meet the growing demands of later gestation.

Table 4 provides an overview of the alterations in gestational age, MUAC, and NLR for both groups. Those who received Dangke exhibited a notably larger increase in MUAC (ΔMUAC: +0.17 ± 0.19 cm compared to +0.03 ± 0.11 cm; $p = 0.014$) and experienced a significant reduction in NLR within the group ($p = 0.010$). In contrast, the control group did not show a statistically significant change in NLR ($p = 0.098$). The extent of NLR reduction was not significantly different between the groups ($p = 0.888$). At the start, gestational age was similar, indicating that the differences in nutritional and inflammatory outcomes were assessed under similar physiological conditions.

The simultaneous occurrence of enhanced MUAC and decreased NLR lends credence to the idea that there is a strong link between maternal nutrition and the regulation of inflammation. Better nutritional intake could bolster immune balance by providing more essential amino acids, micronutrients, and bioactive substances necessary for the functioning of immune cells and the regulation of cytokines. Furthermore, the fermented characteristics of Dangke might offer additional immunomodulatory benefits by influencing gut microbiota and the function of the intestinal barrier.

In this study, the impact of Dangke supplementation on nutritional and inflammatory markers in pregnant women with CED was assessed. Initially, the two groups were similar in terms of maternal age, gestational age, and inflammatory status. However, the intervention group exhibited notably lower MUAC values, highlighting a greater nutritional risk. After the four-week intervention period, those who received Dangke showed marked improvements in both MUAC and NLR, indicating better maternal nutritional reserves and reduced low-grade systemic inflammation. Throughout the study, gestational age remained consistent between the groups, offering crucial physiological context for understanding the findings. Overall, these results imply that Dangke supplementation could enhance maternal nutritional status and inflammatory balance in pregnant women with CED.

DISCUSSION

This randomized controlled trial demonstrated that Dangke supplementation improved maternal nutritional status and attenuated systemic inflammation among pregnant women with CED. Participants receiving Dangke showed a significant increase in MUAC and a significant within-group reduction in NLR despite having lower baseline MUAC than the control group. These findings support the concept that maternal CED is not only a nutritional disorder but also an immunometabolic condition characterized by chronic low-grade inflammation, as previously described by Black et al. (2013) and Victora et al. (2021) [1,2].

The elevated baseline NLR (>4.0) observed in both groups suggests that pregnant women with CED experienced persistent systemic inflammation despite the absence of overt infection. This observation is consistent with previous reports demonstrating that maternal undernutrition is associated with immune dysregulation, oxidative stress, and chronic inflammatory activation (Bourke et al., 2016; Christian & Smith, 2018; Mousa et al., 2019; Wu et al., 2019) [13,21–23]. Collectively, these findings support the use of NLR as a complementary biomarker to conventional anthropometric indicators for evaluating the physiological consequences of maternal malnutrition.

The significant increase in MUAC following Dangke supplementation is in agreement with previous studies demonstrating that adequate maternal protein-energy intake improves nutritional reserves during pregnancy and is associated with more favorable maternal and fetal outcomes [5,24,25]. Likewise, Tang et al. (2020) and Ververs et al. (2013) reported that MUAC is a robust predictor of maternal nutritional status and adverse pregnancy outcomes, including fetal growth restriction, low birth weight, and maternal morbidity [6,26]. The improvement observed in the present study is biologically plausible because Dangke contains high-quality protein, essential amino acids, calcium, and other nutrients required for maternal tissue growth and immune-cell proliferation [16,17,19,27,28].

Our finding that Dangke supplementation significantly reduced NLR further suggests a beneficial anti-inflammatory effect. Although no previous study has specifically evaluated Dangke and NLR in pregnant women with CED, the present findings are consistent with studies showing that fermented dairy products and probiotic-rich foods reduce systemic inflammatory activity and improve immune regulation [29,30]. Fermented foods contain lactic acid bacteria and bioactive peptides that can suppress pro-inflammatory signaling, reduce oxidative stress, and improve intestinal barrier function, thereby contributing to restoration of immune homeostasis.

The proposed mechanism is further supported by growing evidence highlighting the role of the gut microbiota in regulating immune and metabolic responses. Previous studies have demonstrated that probiotic-containing fermented foods increase microbial diversity and promote production of short-chain fatty acids, which suppress inflammatory pathways and regulate immune-cell function [31–36]. Although gut microbiota composition and inflammatory cytokines were not measured in this study, these mechanisms provide a plausible explanation for the observed reduction in NLR after Dangke supplementation.

Gestational age was included to reduce potential confounding because maternal immune responses change throughout pregnancy. Participants in both groups were enrolled at comparable gestational ages, predominantly during the second trimester, when physiological immune tolerance supports fetal growth [9]. Therefore, the observed improvements in MUAC and NLR are unlikely to be explained by gestational age alone and more likely reflect the effect of the intervention.

Despite the significant within-group reduction in NLR, the between-group difference in ΔNLR did not reach statistical significance. Similar findings have been reported in nutritional intervention studies where modest sample sizes and the physiological variability of inflammatory biomarkers during pregnancy limited the ability to detect between-group differences [22]. Furthermore, all participants received routine antenatal care and nutritional counseling, which may have contributed to improvements in inflammatory status in both groups. Therefore, the present findings should be interpreted cautiously and confirmed in larger randomized trials.

Overall, the present findings are in line with previous evidence supporting fermented foods as functional nutritional interventions capable of improving immune regulation and reducing inflammation [29,30,35]. However, evidence regarding Dangke supplementation during pregnancy remains limited. To our knowledge, this is the first randomized controlled trial demonstrating that Dangke supplementation may simultaneously improve maternal nutritional reserves and reduce systemic inflammatory status among pregnant women with CED. These findings highlight the potential of Dangke as a culturally acceptable, locally available, and nutrition-sensitive functional food that could complement maternal nutrition programs in Indonesia and other low- and middle-income countries.

This study has several strengths, including its randomized controlled design and the simultaneous evaluation of nutritional (MUAC) and inflammatory (NLR) outcomes. Nevertheless, several limitations should be acknowledged. The sample size was relatively small, dietary intake and adherence outside the intervention were not comprehensively monitored, and inflammatory cytokines, oxidative stress markers, and gut microbiota composition were not assessed. Future multicenter studies with larger sample sizes and mechanistic biomarkers are warranted to confirm these findings and elucidate the underlying biological mechanisms.

CONCLUSION

The randomized controlled trial showed that 200 g of Dangke daily for 28 consecutive days was associated with favorable changes in inflammatory and nutritional indicators among pregnant women with CED. Participants receiving Dangke showed a significant within-group reduction in NLR, indicating reduced low-grade systemic inflammation, and improved MUAC, reflecting enhanced maternal nutritional reserves. These findings suggest that Dangke may act as an immunonutritional intervention influencing nutritional status and inflammatory homeostasis during pregnancy. Elevated baseline NLR in both groups indicates substantial inflammatory burden despite no overt infection, supporting evidence that maternal undernutrition involves persistent inflammatory and metabolic stress pathways. The concurrent improvement in MUAC and reduction in NLR supports considering maternal CED an immunometabolic disorder rather than only an anthropometric deficit; the increase in MUAC may reflect improved nutritional status and restoration of immunometabolic balance in the intervention group over the study period.

Biological plausibility is supported by Dangke's nutritional characteristics. As a fermented dairy product, Dangke contains high-quality protein, amino acids, calcium, phosphorus, and lactic acid bacteria. Fermentation-derived bioactive peptides may exert anti-inflammatory effects via suppression of NF-κB signaling and reduction of pro-inflammatory cytokines including TNF-α, IL-6, and IL-1β. Gut microbiota-mediated mechanisms may also contribute to reduced NLR. Incorporating gestational age strengthened interpretation. Because gestational age was comparable between groups, differences in NLR and MUAC are unlikely to reflect pregnancy stage alone. Instead, Dangke supplementation may have enhanced adaptations by improving nutrient availability and supporting immune homeostasis.

Several limitations should be acknowledged. The sample size may have limited statistical power. Dietary intake, protein intake, and fermented food consumption outside the intervention were not monitored. Circulating inflammatory cytokines, oxidative stress biomarkers, gut microbiota composition, and intestinal permeability markers were not assessed, leaving mechanisms underlying NLR reduction inferential. Future studies incorporating immunological, metabolomic, and microbiome analyses would provide mechanistic insight. Despite limitations, NLR may serve as a cost-effective biomarker for monitoring inflammatory status in pregnant women with CED in low-resource settings. Its responsiveness to nutritional intervention supports its utility in maternal nutrition research. Dangke supplementation showed potential as an immunonutritional intervention for women with CED. Larger multicenter randomized controlled trials incorporating dietary monitoring, inflammatory cytokine profiling, gut microbiota analysis, and maternal–fetal outcomes are needed to confirm findings and support integration into evidence-based nutrition programs.

ACKNOWLEDGEMENTS

The authors extend their appreciation to the pregnant women who took part in this study, as well as the healthcare staff who facilitated participant recruitment and gathered data. They also thank the local community leaders for their backing in carrying out the research. Additionally, the authors recognize the laboratory personnel for their help with hematological tests and sample processing.

FUNDING

No particular grant was provided by any public, commercial, or non-profit funding agency for this study.

CONFLICT OF INTEREST

The authors state that there are no conflicts of interest related to the publication of this manuscript.

ETHICAL APPROVAL

The Ethics Commission of Health Research at the Faculty of Medicine, Universitas Hasanuddin, granted approval for this study under approval number 497/UN4.6.4.5.31/PP36/2025 and protocol number UH25010063. The authors verified that all procedures adhered to the pertinent guidelines and regulations, including the Helsinki Declaration.

AUTHOR CONTRIBUTIONS

AS: Conceptualization, Methodology, Investigation, Data curation, Formal analysis, Visualization, Writing – original draft.

SA: Conceptualization, Methodology, Supervision, Validation, Writing – review & editing.

AB: Methodology, Validation, Supervision, Writing – review & editing.

GN.: Formal analysis, Methodology, Validation, Writing – review & editing.

NA: Conceptualization, Supervision, Validation, Writing – review & editing.

AA: Formal analysis, Validation, Writing – review & editing.

ST: Conceptualization, Resources, Supervision, Writing – review & editing.

All authors read and approved the final manuscript and agree to be accountable for all aspects of the work.

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Table 1. Baseline Characteristics of Pregnant Women with Chronic Energy Deficiency According to Study Group

Variable	Intervention (n = 15) Mean ± SD	Control (n = 15) Mean ± SD	p-value
Age (years)	25.87 ± 6.28	24.71 ± 5.04	>0.05
Gestational Age (weeks)	23.00 ± 5.26	24.29 ± 6.23	>0.05
MUAC (cm)	21.11 ± 1.44	22.49 ± 0.82	0.004*
NLR	4.22 ± 1.59	4.26 ± 1.45	0.936

*Statistically significant at $p < 0.05$. MUAC = mid-upper arm circumference; NLR = neutrophil-to-lymphocyte ratio; SD = standard deviation.

Table 2. Changes in Mid-Upper Arm Circumference (MUAC) Before and After the Intervention

Variable	Intervention (n = 15) Mean ± SD	Control (n = 15) Mean ± SD	p-value
MUAC Pre-intervention (cm)	21.11 ± 1.44	22.49 ± 0.82	0.004*
MUAC Post-intervention (cm)	21.28 ± 1.49	22.51 ± 0.89	0.014*
ΔMUAC (cm)	0.17 ± 0.19	0.03 ± 0.11	0.014*

* Statistically significant at $p < 0.05$. MUAC = mid-upper arm circumference; SD = standard deviation; Δ = change from baseline.

Table 3. Changes in Neutrophil-to-Lymphocyte Ratio (NLR) Before and After the Intervention

Variable	Intervention (n = 15) Mean ± SD	Control (n = 15) Mean ± SD	p-value
NLR Pre-intervention	4.22 ± 1.59	4.26 ± 1.45	0.936
NLR Post-intervention	3.42 ± 1.31	3.38 ± 1.33	0.934
ΔNLR	−0.80 ± 1.05	−0.88 ± 1.85	0.888
Within-group p-value	0.010*	0.098	—

* Statistically significant at $p < 0.05$. NLR = neutrophil-to-lymphocyte ratio; SD = standard deviation; Δ = change from baseline. Within-group p-value derived from paired-samples t-test or Wilcoxon signed-rank test as appropriate.

Table 4. Summary of Changes in Gestational Age, Mid-Upper Arm Circumference (MUAC), and Neutrophil-to-Lymphocyte Ratio (NLR)

Variable	Intervention Baseline Mean ± SD	Intervention Post Mean ± SD	Δ Mean ± SD	p†	Control Baseline Mean ± SD	Control Post Mean ± SD	Δ Mean ± SD	Between-group p‡
Gestational Age (weeks)	23.00 ± 5.26	27.00 ± 5.26a	+4.00	—	24.29 ± 6.23	28.29 ± 6.23a	+4.00	0.181
MUAC (cm)	21.11 ± 1.44	21.28 ± 1.49	+0.17 ± 0.19	0.004	22.49 ± 0.82	22.51 ± 0.89	+0.03 ± 0.11	0.014*
NLR	4.22 ± 1.59	3.42 ± 1.31	−0.80 ± 1.05	0.010*	4.26 ± 1.45	3.38 ± 1.33	−0.88 ± 1.85	0.888

† Within-group comparison (baseline vs. post-intervention). ‡ Comparison of mean changes (Δ) between intervention and control groups. * Statistically significant at $p < 0.05$. a Post-intervention gestational age estimated following completion of the four-week intervention period.