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Research Article

Effects of Individualized Periodized Combined Training on Lipid Profile and Atherogenic Cardiovascular Risk in Sedentary Middle-aged Colombian Women

Arays Hernandez Garay[1,*], Alejandro Valero Inerarity[2], Ricardo Leonardo Perea Rodriguez[2], Monica Paola Murcia Doncel[1], Luis Fernando Cruz Quiroga[3], Eder Jair Sepulveda Molina[4], Marjorie Gissella Galofre Vasquez[4], Juan Pablo Garzon Sanchez[1], Jhoan David Romana Martinez[5]

[1]Research Department, Manuela Beltran University, Bogota, Colombia
[2]Research Department, Colombian School of Rehabilitation, Bogota, Colombia
[3]Research Department, Mental Health IPS, Bogota, Colombia
[4]Research Department, Autonomous University of the Caribbean, Barranquilla, Colombia
[5]Research Department, Diego Luis Cordoba Technological University, Choco, Colombia

Abstract

Background: Cardiovascular disease remains the leading cause of death among women, with cardiometabolic risk increasing during the menopausal transition due to adverse changes in lipid metabolism, body fat distribution, vascular function, and systemic inflammation. Although combined exercise is recommended for cardiovascular prevention, evidence on individualized periodized exercise regulated through internal monitoring of training load remains scarce in sedentary Latin American women. Objective: To evaluate the effects of a 20-week individualized periodized combined training program on body mass index, waist circumference, lipid profile, and atherogenic cardiovascular risk assessed by the Castelli Risk Indices in sedentary Colombian women aged 50 to 60 years. Methods: A single-group, pretest-posttest quasi-experimental study was conducted with 15 sedentary Colombian women (55.4 ± 3.2 years). Participants completed a supervised, individualized, 20-week periodized combined training program that included three weekly aerobic and strength training sessions (60 min/session) and two weekly unsupervised walking sessions. Exercise intensity was individualized using the TRIMP (Banister Training Impulse) model and the sRPE scale. Body mass index, waist circumference, lipid profile, and Castelli risk indices I and II were assessed before and after the intervention. Wilcoxon signed-rank tests, Rosenthal effect sizes, Hodges-Lehmann estimators, and Spearman correlation analysis were used to analyze the effects of the intervention. Results: Program adherence was 88.3%, and no exercise-related adverse events were reported. Significant improvements were observed in total cholesterol (−8.2%, $p < 0.001$), LDL cholesterol (−11.6%, $p < 0.001$), HDL cholesterol (+4.1%, $p < 0.001$), waist circumference (−3.8%, $p < 0.001$), Castelli risk index I (−11.7%, $p < 0.001$), and Castelli risk index II (−14.6%, $p < 0.001$). Triglycerides decreased, although the absolute magnitude of the change was small (−0.3%, $p = 0.005$). Large Rosenthal effect sizes ($r = 0.55$–0.94) were observed for all clinically significant outcomes. Greater reductions in waist circumference were associated with greater decreases in LDL cholesterol ($\rho = 0.672$, $p = 0.006$) and the Castelli Risk Index II ($\rho = 0.650$, $p = 0.009$). Conclusions: Individualized, periodized combined training regulated by internal

[*]Correspondence: Arays Hernandez Garay (hernandezgarayarays@gmail.com)

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monitoring of objective (TRIMP) and subjective (sRPE) training load resulted in clinically significant improvements in body mass index, waist circumference, lipid profile, and atherogenic cardiovascular risk in previously sedentary middle-aged Colombian women. These findings support individualized, periodized combined training with internal monitoring of training load as an effective community-based strategy for precision exercise medicine to improve cardiometabolic health and reduce cardiovascular risk in sedentary middle-aged women.

Keywords

Combined Exercise, Exercise Periodization, Internal Training Load Monitoring, Training Impulse (TRIMP), Session Rating of Perceived Exertion (sRPE), Dyslipidemia, Castelli Risk Index, Cardiovascular Diseases Prevention

1. Introduction

Cardiovascular disease (CVD) remains the leading cause of death and disability worldwide, and despite substantial progress in pharmacological therapy, diagnostic technology, and preventive cardiology, it continues to account for close to one-third of all global mortality [1, 2]. The World Health Organization identifies regular physical activity as one of the most cost-effective strategies available for reducing premature cardiovascular mortality and the broader burden of noncommunicable disease [3], a position reinforced by the 2021 European Society of Cardiology guidelines on cardiovascular disease prevention [4]. Population ageing, urbanization, sedentary behavior, and the accumulation of modifiable cardiometabolic risk factors have shifted the emphasis of cardiovascular medicine away from treating established disease and toward early, lifestyle-based prevention. Because these risk factors rarely act in isolation, but instead interact to progressively impair lipid metabolism and vascular function, contemporary prevention increasingly favors comprehensive, multi-factorial interventions over the management of single risk markers.

This epidemiological transition is particularly evident in Colombia and the broader Latin American region. National vital statistics indicate that cardiovascular disease remains among the leading causes of death among Colombian women [5, 6], while national activity surveys show that a substantial proportion of middle-aged Colombian adults fail to meet recommended physical activity levels [7]. Similar associations between physical activity, body composition and cardiometabolic health have been reported elsewhere in Latin America, including among older Chilean women [8], underlining the regional relevance of lifestyle-based prevention. Physical inactivity also represents a considerable economic burden through increasing healthcare expenditure and lost productivity [9], highlighting the urgency of scalable, evidence-based exercise interventions for populations at elevated cardiometabolic risk. Importantly, cardiovascular prevention in this region continues to rely largely on generalized recommendations that do not account for the substantial physiological heterogeneity observed among individuals, a limitation that becomes especially consequential when exercise is prescribed without regard to each participant's adaptive capacity.

Abdominal adiposity is a central contributor to this risk. Elevated waist circumference and unfavorable body fat distribution are independently associated with all-cause and cardiovascular mortality [10] and with incident cardiovascular events over the long term [11], and waist circumference itself performs comparably to other anthropometric indices in predicting metabolic disease [12]. Because visceral fat is metabolically active and closely associated with atherogenic dyslipidemia and insulin resistance, its measurement in conjunction with traditional lipid biomarkers offers a more complete picture of cardiometabolic risk than either measure alone [13]. This is especially relevant in the Colombian context, where the average age of menopause coincides with a demographic transition that renders women aged 50-60 years a priority target for preventive interventions.

Among women, the menopausal transition constitutes one of the most critical windows for the emergence of this risk. Declining ovarian estrogen production is associated with a cluster of unfavorable metabolic and vascular changes, and recent evidence links the menopausal transition itself to accelerated cardiovascular risk accumulation [14]. These hormonal changes are associated with less favorable lipid profiles, increased visceral adiposity and increased susceptibility of the vasculature, leading to recommendations for more individualized approaches to risk assessment and management during this time [15]. Exercise-based interventions have shown consistent, though variable, benefit for cardiometabolic health in postmenopausal women [16, 17], and reviews focused specifically on the effect of physical exercise on the lipid profile of women in the peri- and postmenopausal periods report generally favorable but heterogeneous outcomes across studies [18], while structured resistance training has additionally been associated with reductions in adiposity and inflammatory markers in this population [19]. This variability in response strengthens the argument that standardized, one-size-fits-all prescriptions are unlikely to fully capture the physiological diversity of menopausal women, and that individualized regulation of exercise dose may be needed to consistently translate exercise participation into clinically meaningful metabolic benefit.

Dyslipidemia sits at the center of this risk profile and remains one of the principal modifiable drivers of atherosclerotic cardiovascular disease, as reflected in current joint guideline recommendations for its clinical management [20]. While isolated lipid concentrations remain essential biomarkers, a growing body of evidence indicates that ratios combining proatherogenic and antiatherogenic lipoprotein fractions provide a more clinically informative measure of atherogenic burden than any single lipid value considered alone [21, 22]. Elevated total cholesterol/HDL-C and LDL-C/HDL-C ratios, commonly formalized as the Castelli Risk Indices I and II, have been associated with subclinical atherosclerosis and adverse vascular outcomes even among individuals whose isolated lipid values fall within conventional reference ranges [23], while lipoprotein(a) and related particle-level markers further illustrate how lipoprotein interactions, rather than isolated concentrations, drive atherogenic potential [24, 25]. Despite this recognized prognostic value, composite lipid ratios remain infrequently used as primary outcomes in exercise intervention research; consequently, most existing trials have reported changes in isolated lipid fractions without assessing whether these translate into a clinically meaningful reduction in atherogenic risk—a significant gap, as two individuals with similar LDL-C changes may experience markedly different overall risk reductions depending on their HDL-C response [21, 22]. Incorporating these indices into exercise physiology research therefore offers a more clinically relevant framework for evaluating preventive interventions, because they better reflect the balance between atherogenic and protective lipoprotein fractions that ultimately determines vascular risk.

Regular exercise remains one of the most effective non-pharmacological strategies for cardiovascular prevention, consistently improving lipid metabolism, reducing adiposity, and lowering overall cardiovascular risk across diverse populations [26-28]. Among exercise modalities, combined training that integrates aerobic and resistance components has repeatedly shown superior or complementary benefit relative to either modality alone: aerobic work principally improves cardiorespiratory fitness and lipid oxidation, while resistance training contributes to lean mass, glucose regulation, and resting metabolic rate, so their combination promotes broader physiological adaptation. This benefit has been documented specifically in middle-aged and postmenopausal women, including reductions in body fat and improvements in lipid profile following combined aerobic-resistance programs [29-31], sustained metabolic benefit from long-term aerobic-based interventions [32], and favorable hemodynamic and lipid adaptations from multicomponent programs sustained over periods as long as two years [33, 34]. Large randomized evidence, such as the CardioRACE trial, has further confirmed meaningful improvements in cardiovascular risk profile from both aerobic and combined training in adults with elevated cardiometabolic risk [35], and comparable benefits have been reported in occupational and community-based cohorts of perimenopausal women [36], and in systematic reviews and meta-analyses evaluating the effect of aerobic and resistance training on lipid profile in women more broadly [37]. Nevertheless, the magnitude of these adaptations varies considerably across studies, suggesting that exercise modality alone does not fully explain the heterogeneity of outcomes; differences in prescription, progression, and individualization of training load likely account for a substantial share of this variability, and future research should focus as much on how exercise is dosed and adjusted as on which modality is selected.

Periodization, understood as the systematic manipulation of training variables through planned variation in intensity, volume, and recovery, offers one established strategy for managing this variability and sustaining physiological adaptation while limiting excessive fatigue [38]. Although developed originally within athletic performance, periodization principles are increasingly incorporated into clinical and community-based exercise prescription because of their potential to improve adherence and long-term safety, consistent with current recommendations for individualized exercise prescription across clinical populations [39, 40]. Additionally, periodization contributes to sustained engagement by preventing monotony and boredom, factors that are particularly critical in previously sedentary populations where adherence is a primary determinant of intervention success. Comparative evidence further suggests that interventions individualized to participant characteristics may outperform generic, group-based programming across a range of functional and health outcomes [41], reinforcing the rationale for applying periodization principles beyond elite sport and into preventive, community-based cardiovascular health programs such as the one evaluated here [42].

A parallel and complementary strategy involves the direct monitoring of internal training load, which captures the physiological stress actually experienced by an individual in response to a given exercise stimulus, as distinct from the external work performed [43]. Heart-rate-based models such as Banister's Training Impulse (TRIMP) [44] and the session Rating of Perceived Exertion (sRPE) provide complementary objective and subjective measures of this internal dose, and their combined use allows exercise prescription to be adjusted dynamically according to each participant's demonstrated response rather than a fixed, predetermined schedule. Unlike heart rate-derived measures, which mainly reflect cardiovascular stress, sRPE includes afferent feedback from peripheral muscles, the respiratory system and central nervous system and provides a more holistic measure of the global physiological and perceptual strain during exercise. This is particularly relevant in sedentary populations where psychological and motivational factors are important in exercise tolerance and adherence. This approach aligns with a broader recognition that individual variability in exercise responsiveness is physiologically meaningful and clinically relevant, and that personalized activity prescription, accounting for factors that shape how a given stimulus is metabolized and tolerated, may be necessary to consistently achieve the intended cardiometabolic benefit [45, 46]. Framed this way, internal load monitoring is not simply a quantification tool but a mechanism for delivering exercise with a degree of individualization more typically associated with pharmacological therapy, consistent with an emerging precision-medicine approach to physical activity prescription in cardiovascular prevention [47].

Taken together, the evidence reviewed above indicates that the central question in exercise-based cardiovascular prevention is no longer whether exercise is beneficial, but how it should be prescribed, progressed, and individually regulated to maximize benefit under real-world conditions. Combined training, periodization, and internal training load monitoring have each been studied on their own, but their simultaneous integration within a single, community-based intervention remains uncommon, and comprehensive assessment of atherogenic risk through composite lipid indices is rarely included as an outcome in this type of research. To our knowledge, no published community-based study has combined individualized periodized combined training with complementary objective and subjective monitoring of internal training load and simultaneous evaluation of conventional lipid biomarkers and Castelli-type atherogenic indices in sedentary, middle-aged Colombian women—a population that remains markedly underrepresented in the exercise physiology literature despite its elevated and rising cardiometabolic risk [6-8].

The present study addresses this gap through four complementary components: (i) individualized periodized combined training; (ii) continuous regulation of training dose through complementary objective (TRIMP) and subjective (sRPE) monitoring of internal training load; (iii) comprehensive assessment of lipid metabolism and atherogenic cardiovascular risk using conventional lipid biomarkers together with the Castelli Risk Indices; and (iv) implementation in a community-based sample of sedentary Colombian women. Accordingly, the aim of this study was to evaluate the effects of a 20-week individualized periodized combined training program, monitored through complementary objective and subjective internal training load, on lipid profile, waist circumference, and atherogenic cardiovascular risk in sedentary middle-aged Colombian women. We hypothesized that individualized periodized combined training monitored through complementary objective (TRIMP) and subjective (sRPE) internal training load would produce clinically meaningful improvements in waist circumference, lipid profile, and Castelli Risk Indices after 20 weeks of intervention.

The present study shows that individualized periodized combined training with complementary objective (TRIMP) and subjective (sRPE) internal training load monitoring resulted in clinically meaningful cardiometabolic health and atherogenic cardiovascular risk improvements. These findings support the clinical applicability of precision exercise medicine as an effective community-based strategy for cardiovascular prevention in sedentary middle-aged women.

2. Materials and Methods

2.1. Study Design

This study employed a community-based quasi-experimental pre--post intervention design to evaluate the effects of a 20-week periodized combined training program on lipid profile, waist circumference, and atherogenic cardiovascular risk in sedentary Colombian women aged 50-60 years. The intervention was conducted under real-world community conditions to maximize ecological validity and facilitate the translation of evidence into public health practice. Owing to the preventive nature of the intervention and ethical considerations related to withholding exercise from sedentary women at elevated cardiometabolic risk, all eligible participants received the intervention, and no non-exercising control group was included. This decision, while ethically appropriate, introduces a potential selection bias and limits our ability to attribute the observed changes exclusively to the intervention, as we cannot rule out the influence of confounding variables or regression to the mean. The study was conducted in accordance with the Declaration of Helsinki and followed the recommendations of the TREND Statement for reporting non-randomized intervention studies.

A waiting-list control group was considered during study planning. However, because the intervention was implemented as part of a community health promotion program targeting sedentary women at elevated cardiometabolic risk, withholding structured exercise for 20 weeks was considered ethically inappropriate by the institutional ethics committee. Consequently, the findings should be interpreted with caution, and the results are considered preliminary evidence supporting the potential effectiveness of the intervention.

Prospective registration is not mandatory for non-randomized community-based interventions; however, the study adhered to the TREND Statement to maximize transparency and reproducibility. The study was approved by the Institutional Review Board of Autonomous University of the Caribbean (Protocol No. 20259) and performed in accordance with the Declaration of Helsinki.

2.2. Participants

The participants were selected through community outreach activities that were conducted in the municipality of Engativa, Bogota, Colombia, during the period of January to February 2025. Recruitment strategies included informational meetings at community centers, primary healthcare facilities, and local media announcements inviting sedentary women to participate in a supervised cardiovascular health promotion program.

Women were eligible if they met the following inclusion criteria: age between 50 and 60 years; sedentary lifestyle according to the International Physical Activity Questionnaire (IPAQ) short form, which was administered by trained interviewers in a face-to-face format to minimize comprehension errors and ensure accurate classification of physical activity levels, defined as engaging in less than 150 minutes of moderate-to-vigorous physical activity per week; absence of diagnosed cardiovascular, metabolic, renal, or musculoskeletal disorders that could contraindicate exercise participation; medical authorization to perform moderate-intensity physical exercise; willingness to attend all assessments and supervised training sessions; and being willing to provide signed informed consent.

Exclusion criteria were current participation in structured exercise programs, hormone replacement therapy initiated within the previous 6 months, use of lipid-lowering medication, uncontrolled hypertension, uncontrolled diabetes mellitus, orthopedic limitations preventing exercise participation, or any medical condition that required interruption of physical training during the intervention period.

All eligibility criteria were confirmed before baseline assessment by trained research personnel and all participants provided written informed consent prior to enrollment. The study protocol was approved by the Institutional Research Ethics Committee in accordance with the Declaration of Helsinki.

Menopausal status was defined by the Stages of Reproductive Aging Workshop (STRAW+10) classification system based on menstrual history and clinical characteristics. The use of the STRAW+10 classification enhances comparability with international studies investigating exercise interventions in peri- and postmenopausal women, thereby improving methodological consistency across studies.

Sample size calculation

The required sample size was determined a priori using G*Power 3.1.9.7 (Heinrich Heine University, Düsseldorf, Germany) for paired comparisons. Based on previous exercise intervention studies in postmenopausal women [19, 26, 28, 32], the minimum required sample was estimated at 12 participants for the primary outcome of LDL cholesterol using a two-tailed α level of 0.05, 80% statistical power, and a large expected effect size (Cohen's d = 0.8). To account for an anticipated attrition rate of approximately 20%, a target sample of 15 women was established.

The participant recruitment process, eligibility assessment, allocation, follow-up, and final analysis are summarized in the study flow diagram (Figure 1), prepared according to the recommendations of the TREND Statement for non-randomized intervention studies.

Initially, twenty-three women were assessed for eligibility. After applying the inclusion criteria, eight women were excluded (five for not meeting the inclusion criteria, two for declining to participate, and one for medical reasons). Consequently, fifteen women met all eligibility criteria, provided written informed consent, and completed the intervention (Figure 1).

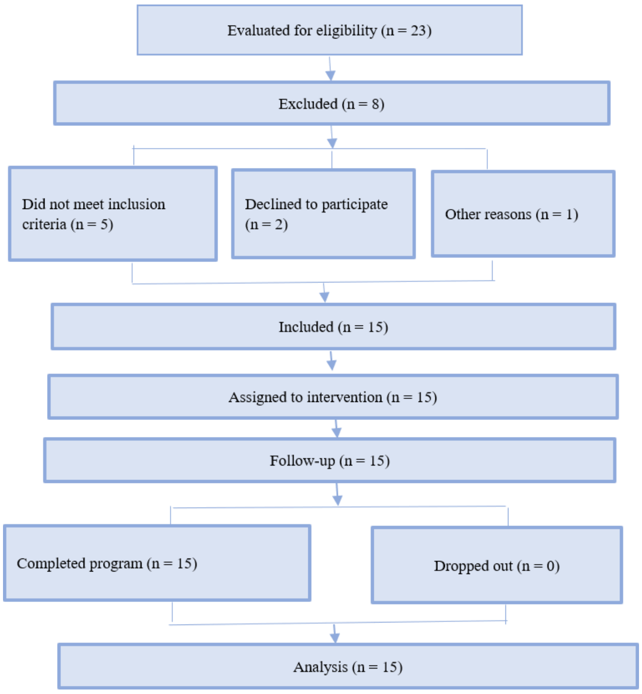

Figure 1. *Participant recruitment, enrollment, and analysis flow diagram (adapted TREND for quasi-experimental studies).*

All participants were classified as postmenopausal according to the STRAW+10 criteria, having experienced at least 12 consecutive months of spontaneous amenorrhea. Menopausal status was used to characterize the study population but was not included as a covariate in the statistical analyses because of the limited sample size.

2.3. Variables Under Study

The variables were measured by trained personnel at two points of the research (pretest and posttest). The variables and the controlled dimensions in the study are as follows.

2.3.1. Anthropometric Variables

Anthropometric measurements included weight, height, body mass index (BMI), and waist circumference (WC). Weight was measured using a SECA 274 digital scale with an accuracy of 0.1 kg. Height was measured with an accuracy of 0.1 cm using a SECA 274 stadiometer. Waist circumference (WC) was measured using a non-elastic measuring tape (SECA 201). The measurement was taken from the midpoint between the lower edge of the ribs and the iliac crest, following World Health Organization (WHO) standardization protocols. Body mass index (BMI) was calculated using the following formula:

$$\text{BMI} = \frac{\text{Body mass (kg)}}{\text{Height squared (m2).}} \quad (1)$$

Body mass index (BMI) was calculated by dividing body weight (kg) by height (m^2). It is classified according to World

Health Organization (WHO) criteria as underweight (<18.5 kg/m^2), normal weight (18.5–24.9 kg/m^2), overweight (25.0–29.9 kg/m^2), and obese (≥30.0 kg/m^2).

2.3.2. Biochemical Variables

Variables for determining lipid profile were total cholesterol (TC), low-density lipoprotein cholesterol (LDL) high density lipoprotein cholesterol (HDL) and triglyceride (TG). Venous blood samples were taken from fasting subjects (12-h fast) between 7:00 and 9:00 a.m. by a standard protocol to minimize circadian variability. Biochemical analyses were carried out in a fully accredited clinical laboratory, using the enzymatic colorimetric method (Cobas c111, Roche Diagnostics, Basel, Switzerland) to ensure the precision and reproducibility of the results. According to the manufacturer's specifications, the analytical sensitivity and specificity of the assays were as follows: total cholesterol (coefficient of variation [CV] < 2.0%), LDL cholesterol (CV < 3.0%), HDL cholesterol (CV < 2.5%), and triglycerides (CV < 3.0%). All assays were carried out according to the standardized protocols of the manufacturer (Roche Diagnostics, Method No. 20767107322). To minimize inter-lot variability, all samples from each participant (pre- and post-intervention) were processed in the same analytical batch. Internal quality controls were run with each batch, and all values fell within the acceptable ranges specified by the manufacturer.

2.3.3. Atherogenic Indices

Castelli Risk Index I (TC/HDL-C) and Castelli Risk Index II (LDL-C/HDL-C) were calculated because these composite lipid ratios provide a more comprehensive estimate of atherogenic cardiovascular risk than isolated lipid variables.

The cardiovascular risk was assessed using the atherogenic indices of Castelli:

$$\text{Castelli I} = \frac{TC}{HDL} \quad (2)$$

$$\text{Castelli II} = \frac{LDL}{HDL} \quad (3)$$

2.3.4. Training Load Monitoring

Internal training load was monitored using two complementary methods to capture both the objective physiological response to exercise and the participant's subjective perception of effort. The combined use of the Banister Training Impulse (TRIMP) model and session Rating of Perceived Exertion (sRPE) has been widely recommended because these methods provide complementary information regarding cardiovascular stress and perceived exertion, thereby facilitating individualized regulation of exercise intensity in both athletic and clinical settings [34, 43, 44].

Objective quantification of the internal load was performed using the Banister Training Impulse (TRIMP) model, which combines the duration of exercise and the exercise intensity (based on heart rate) into a single physiological indicator of cardiovascular stress. Continuous heart rate was recorded during each training session using a Polar H10 heart rate sensor (Polar Electro Oy, Kempele, Finland) synchronized with the Polar Team Pro monitoring system. The relative heart rate reserve (HRr) was calculated according to the following equation:

$$HRr = \frac{HRexercise - HRrest}{HRmax - HRrest} \quad (4)$$

where HR exercise is the average heart rate recorded during the exercise session, HR rest is the resting heart rate measured under standardized conditions after 5 min of rest in supine position and measured on three different days before the intervention and averaged to improve precision and reduce day-to-day variability, and HR max is the age-predicted maximal heart rate estimated using the Tanaka equation. The TRIMP was then calculated following the original formulation of Banister, validated specifically in women [43]:

$$TRIMP = D \times HRr \times 0.64 \times e\hat{}(1.92 \times HRr) \quad (5)$$

where D is the duration of exercise (minutes), HRr is the relative heart rate reserve and the exponential coefficient (0.64 × e^1.92 × HRr) takes into account the non-linear relationship between heart rate and blood lactate accumulation. The original formula and its gender-specific adaptation are described in detail by Banister [43].

Subjective internal training load was assessed using the session Rating of Perceived Exertion (sRPE) method pro-posed by Foster et al. Approximately 30 minutes after each training session, participants rated their perceived exertion using the Borg CR-10 scale. Session training load was determined by:

$$\text{sRPE Training Load} = \text{Session Duration (min)} \times \text{sRPE} \quad (6)$$

The session Rating of Perceived Exertion (sRPE) was incorporated because subjective perception of effort reflects the integrated physiological and perceptual response to exercise. Unlike heart rate-derived measures alone, sRPE captures the cumulative internal load experienced by the participant, integrating cardiovascular, metabolic, neuromuscular, and perceptual responses into a single practical measure of exercise stress [34, 43, 44, 48]. The complementary use of TRIMP and sRPE provides a more comprehensive assessment of internal training load than either method alone and is currently recommended for individualized exercise prescription and monitoring of training adaptations across both athletic and clinical populations [33, 34, 43, 44, 48].

Weekly internal load was quantified using Training Impulse (TRIMP). Acute Training Load (ATL) was defined as the total weekly TRIMP accumulated during the current week. Whereas Chronic Training Load (CTL) was calculated as the rolling four-week average of ATL values. The acute:chronic workload ratio (ACWR) was subsequently calculated as:

$$\mathrm{ACWR} = \frac{\mathrm{ATL}}{\mathrm{CTL}} \quad (7)$$

Although the ACWR has primarily been validated as an indicator of injury risk in team sports, its application in the present study was restricted to monitoring progressive overload and maintaining an appropriate balance between training stimulus and recovery throughout the intervention. Accordingly, ACWR values between 0.80 and 1.30 were considered indicative of an adequate progression of training load during the intervention, consistent with recommendations for exercise prescription in clinical populations [38, 39].

2.3.5. Covariates

Variables such as age, level of education, civil status, socioeconomic status, medical history, family background, and level of physical activity were also controlled at baseline and end of study using validated questionnaires such as the IPAQ. However, due to the small sample size, formal statistical adjustment for these variables was not performed; instead, descriptive analysis was used to characterize the sample.

Menopausal status was recorded at baseline as a biological characteristic because hormonal changes occurring during the menopausal transition are known to influence lipid metabolism, fat distribution, and cardiovascular risk. Although this variable was not incorporated into the statistical models because of the limited sample size, it was considered during the clinical interpretation of the intervention outcomes.

2.4. Intervention Fidelity

All sessions were supervised by nine professionals, who followed a standardized protocol to ensure the fidelity of the intervention. Attendance at each session was recorded and the exercise intensity was monitored during every supervised session using heart rate-derived TRIMP together with session Rating of Perceived Exertion (sRPE), allowing simultaneous objective and subjective evaluation of internal training load.

2.5. Statistical Analysis

The research data were processed using IBM SPSS Statistics version 31.0.1.0. Descriptive statistical analysis was performed using mean, standard deviation (SD), 95% confidence intervals (95% CI), median, and range.

The Shapiro-Wilk test was used to assess normality. HDL cholesterol and triglycerides did not meet the normality assumption. To maintain methodological consistency across all pairwise comparisons, and given the small sample size ($n = 15$), a uniform non-parametric analytical approach was selected a priori, and the Wilcoxon signed-rank test was applied to all outcomes regardless of individual normality findings, thereby avoiding distribution-specific analytical decisions in a small sample. Therefore, all pre-post comparisons were analyzed using the Wilcoxon signed-rank test as a robust and conservative non-parametric approach, with a significance level of 0.05. The assumptions of the Wilcoxon signed-rank test (i.e., symmetry of the differences around the median) were verified through visual inspection of boxplots and Q-Q plots of the paired differences, as well as by applying the sign test as a supplementary check. These assessments confirmed that the assumptions were adequately met for all primary outcomes.

Given the exploratory nature of this community-based study and the limited sample size, we did not adjust for multiple comparisons (e.g., Bonferroni correction) to avoid an excessive risk of Type II error (i.e., failing to detect clinically meaningful changes) [41, 49]. However, to reduce the risk of Type I error, we stress the importance of interpreting results in terms of effect sizes (Rosenthal’s r), confidence intervals, and clinical relevance, rather than focusing exclusively on p-values [50, 51]. This is consistent with current recommendations for the analysis of small-sample pilot and feasibility studies in exercise science [52, 53]. Thus, the findings should be regarded as preliminary and hypothesis-generating and need to be validated in larger confirmatory randomized controlled trials.

The effect size was estimated using Rosenthal's coefficient (r), calculated from the standardized Wilcoxon statistic, as:

$$r = \frac{Z}{\sqrt{N}} \quad (8)$$

Where Z is the standardized Wilcoxon test value and N is the number of observed pairs ($n = 15$). The magnitude of Rosenthal's effect size (r) was interpreted according to Cohen's recommendations, with values of approximately 0.10 are considered a small ≈ 0.10; medium ≈ 0.30; large ≥ 0.50 indicate large effects.

Effect size interpretation followed Cohen's recommendations, with Rosenthal's r values of approximately 0.10, 0.30, and ≥ 0.50 interpreted as small, medium, and large effects, respectively. To complement null-hypothesis significance testing and facilitate the clinical interpretation of the intervention, Hodges–Lehmann median difference estimators together with their corresponding 95% confidence intervals were calculated for all primary outcomes. Accordingly, statistical inference was based not only on p-values but also on the magnitude, precision, and potential clinical relevance of the observed effects, consistent with current recommendations for reporting exercise intervention studies.

To improve the clinical interpretation of treatment effects, absolute mean differences (Δ = post − pre) together with their 95% confidence intervals (95% CI) were calculated for all primary outcomes.

$$\Delta = \mathrm{post} - \mathrm{pre} \quad (9)$$

In addition to *p* values and effect sizes, the Hodges–Lehmann estimator with its corresponding 95% confidence interval (95% CI) was calculated to quantify the median paired difference and provide a robust estimate of the magnitude and clinical relevance of the intervention effects.

Training response was measured and individual differences were characterized by means of percentage changes and personal response ranges, respectively.

Associations between training load variables and cardiometabolic variables were analyzed using Spearman's rank correlation coefficient. Correlation analyses and sub-group comparisons were considered exploratory due to the limited sample size.

Finally, the participants were ranked according to their cumulative TRIMP score (High-Volume vs. Low-Volume) to investigate possible dose–response relationships between internal training load and cardiometabolic adaptations. These subgroup analyses were exploratory and should not be interpreted as confirmatory evidence of dose-response relationships. Owing to the exploratory nature of these subgroup analyses and the limited sample size, these findings should be interpreted with caution.

3. Results

3.1. Pretest Results

At the beginning of the research, a diagnosis (pretest) was conducted on the 15 women participating in the study. This measurement was carried out with the aim of understanding the results of each of the variables (Table 1). These variables are described below.

The following results of the anthropometric variables of the participants show an average weight of 76.0 ±7.4 kg, an average height of 1.61 ±0.05 m and an average body mass index of 29.3 ±1.2 kg/m2. These results indicate that the women in the study are overweight. The average waist circumference was 94.5 ±7.1 cm. This circumference exceeded the WHO threshold for central obesity.

Regarding the lipid profile levels of the participants, the average level of total cholesterol was 218.4 ±26.4 mg/dL, which is above the desirable level (<200 mg/dL). The mean serum LDL cholesterol level was 138.7 ±21.5 mg/dL, which is above the optimal level (<100 mg/dL) and borderline high. The mean HDL cholesterol level was 44.2 ± 7.5 mg/dL, which is below the recommended level for women (>50 mg/dL), and indicates increased cardiovascular risk. The mean tri-glycerides level was 156.3 ±30.5 mg/dL, which is in the borderline high range (150-199 mg/dL).

Table 1. *Baseline anthropometric and cardiometabolic characteristics of sedentary middle-aged Colombian women (n = 15).*

Variable	Mean	SD	95% CI	Minimum	Maximum
Age (years)	55.4	3.2	53.8–57.0	50	60
Anthropometric Variables					
Body weight (kg)	76.0	7.4	71.9–80.1	66.0	92.0
Height (m)	1.61	0.05	1.58–1.64	1.53	1.70
Body Mass Index (kg/m^2)	29.3	1.2	28.6–30.0	27.0	31.8
Waist circumference (cm)	94.5	7.1	90.6–98.5	85.0	112.0
Cardiometabolic Variables					
Total Cholesterol (mg/dL)	218.4	26.4	203.8–233.0	170.0	275.0
LDL Cholesterol (mg/dL)	138.7	21.5	126.8–150.6	100.0	181.0
HDL Cholesterol (mg/dL)	44.2	7.5	40.0–48.4	34.0	65.0
Triglycerides (mg/dL)	156.3	30.5	139.5–173.2	80.0	236.0

Note: SD. Standard deviation; CI = 95%, confidence interval; BMI, body mass index; LDL, low-density lipoprotein cholesterol; HDL, high-density lipoprotein cholesterol.

3.2. Test of Normality

The Shapiro–Wilk test indicated that HDL cholesterol (W = 0.847; p = 0.016) and triglycerides (W = 0.758; p = 0.001) did not follow a normal distribution (Table 2). Consequently, pre–post comparisons were performed using the Wilcoxon signed-rank test.

Table 2. *Shapiro–Wilk normality test for baseline variables (n = 15).*

Variable	W	p-value	Distribution	Statistical approach
Age (years)	0.974	0.918	Normal	Descriptive analysis
Body weight (kg)	0.937	0.346	Normal	Wilcoxon signed-rank test*
Height (m)	0.982	0.982	Normal	Descriptive analysis
Body Mass Index (kg/m^2)	0.936	0.331	Normal	Wilcoxon signed-rank test*
Waist circumference (cm)	0.937	0.342	Normal	Wilcoxon signed-rank test*
Total Cholesterol (mg/dL)	0.992	1.000	Normal	Wilcoxon signed-rank test*
LDL Cholesterol (mg/dL)	0.994	1.000	Normal	Wilcoxon signed-rank test*
HDL Cholesterol (mg/dL)	0.847	0.016	Non-normal	Wilcoxon signed-rank test
Triglycerides (mg/dL)	0.758	0.001	Non-normal	Wilcoxon signed-rank test

Note: W, Shapiro–Wilk statistic; LDL, low-density lipoprotein cholesterol; HDL, high-density lipoprotein cholesterol.

Although most variables met the normality assumption, the Wilcoxon signed-rank test was used for all pairwise comparisons due to the small sample size (n = 15) and the fact that two variables (HDL cholesterol and triglycerides) did not meet the normality assumptions. This conservative, nonparametric approach allowed for a consistent methodology across all analyses.

3.3. Intervention Program

3.3.1. Program Title

A combined periodized program of training for the improvement of lipid profile and cardiovascular risk reduction in sedentary women aged 50 to 60 years.

3.3.2. General Program Design

The intervention consisted of a 20-week supervised training program, with three 60-minute sessions per week (Monday, Wednesday, and Friday), under the supervision of a qualified professional certified by the Colombian College of Sports Training (COCED). The program included 2 days of unsupervised walking (Tuesday and Thursday), 45 min at moderate intensity (a pace at which conversation is possible but singing is not, equivalent to an RPE of 3-5 on the Borg scale or 50-60% of estimated maximum heart rate). Adherence to the unsupervised walking sessions was monitored by weekly self-report diaries on which participants noted the duration, perceived exertion and any problems experienced during each walking session. These diaries were discussed with the supervising professionals during the weekly supervised sessions to monitor compliance and to identify any barriers to adherence.

All sessions were supervised by nine trained professionals who followed a standardized protocol to ensure the reliability of the intervention and the data obtained for the study variables.

The exercise prescription followed the FITT (Frequency, Intensity, Time, and Type) principle recommended by the American College of Sports Medicine (ACSM) for exercise interventions aimed at reducing cardiovascular risk in middle-aged adults. The main characteristics of the intervention are summarized in Table 3.

Table 3. *FITT-based individualized exercise prescription and internal training load regulation during the 20-week periodized combined training program.*

FITT Component	Exercise Prescription	Individualization and Monitoring	Progression Strategy
Frequency	Three supervised sessions per week (Monday, Wednesday, Friday), complemented by two unsupervised walking sessions (Tuesday and Thursday).	Attendance was recorded at every supervised session. Overall adherence reached 88.3% throughout the intervention	Maintained throughout the intervention

FITT Component	Exercise Prescription	Individualization and Monitoring	Progression Strategy
Intensity	Aerobic exercise intensity progressed from 50–60% HRmax (40–50% HRR) during the adaptation phase to 60–70% HRmax (50–60% HRR) during the development phase and finally to 70–80% HRmax (60–70% HRR) during the optimization phase.	Exercise intensity was individualized using continuous heart-rate monitoring (TRIMP) together with session Rating of Perceived Exertion (sRPE) to integrate objective cardiovascular responses with participants' perceived effort.	Weekly individualized adjustment based on TRIMP, heart rate responses, and sRPE.
Time	Each supervised session lasted 60 minutes (10-minute warm-up, 40-minute combined training, 10-minute cool-down). Walking sessions lasted approximately 45 minutes.	Exercise duration remained constant, whereas exercise intensity and physiological load were progressively individualized.	Constant session duration
Type	Individualized periodized combined training including aerobic exercise (walking and rhythmic aerobic activities) together with progressive resistance exercises using elastic bands, body-weight exercises, and multi-joint functional movements.	Exercise selection and progression followed ACSM recommendations and were adapted to each participant's physiological response and tolerance throughout the intervention.	Progressive periodization across adaptation, development and optimization phases

Note: HRmax = maximum heart rate; HRR = heart rate reserve; TRIMP = Banister Training Impulse; sRPE = session Rating of Perceived Exertion; ACSM = American College of Sports Medicine. The intervention followed ACSM recommendations and employed continuous internal training load monitoring to optimize progression and participant safety.

The FITT framework enabled a standardized but individualized exercise prescription throughout the intervention. The exercise intensity was progressively adjusted according to participants' physiological responses, assessed through heart rate-derived TRIMP values and session ratings of perceived exertion, enabling safe progression and minimization of excessive fatigue.

3.3.3. Structure of the Supervised Session (60 Minutes)

The structure of each supervised session was as follows:

1) Warm-up (10 minutes): joint mobility exercises, dynamic stretches and light cardiovascular activation (e.g. marching in place, light jogging).
2) Main Work (40 minutes): Combined training (aerobic + strength), with a different time distribution according to the periodization phase.
3) Cool Down (10 minutes): Breathing exercises, static stretching of the major muscle groups worked, flexibility exercises.

3.3.4. Training Periodization

The program consisted of three phases (adaptation, development, and optimization) to maximize physiological adaptations, decrease the risk of injury and prevent overtraining (Table 4). The intensity of aerobic exercise was determined using the Karvonen Formula:

$$\text{Target HR} = ((\text{Max HR - Resting HR}) \times \%\ \text{Intensity}) + \text{Resting HR} \quad (10)$$

To estimate the maximum heart rate (HRmax), the Tanaka formula was used:

$$\text{HRmax} = 208 - (0.7 \times \text{Age}) \quad (11)$$

Table 4. *Twenty-week periodized combined training progression according to the FITT principle.*

Phase	Weeks	Main objective	Aerobic training	Strength training progression	Monitoring
Adaptation	1 - 6	Develop exercise tolerance and movement	Duration: 20-30 min. Intensity: 50-60% HRmax (40-50%	Exercises: Basic exercises with body weight and elastic bands with low resistance	TRIMP and session Rating of Perceived Exertion (sRPE) were

Phase	Weeks	Main objective	Aerobic training	Strength training progression	Monitoring
		competency.	HRR)	Sets/Reps: 1-2 x 12-15 repetitions. Intensity: 40-50% of the estimated one-repetition maximum (1RM).	monitored after each supervised session in an effort to individualize progression and avoid excessive physiological stress.
Development	7 - 14	Increase cardiovascular fitness, muscular strength and metabolic capacity.	Duration: 30-40 min. Intensity: 60-70% HRmax (50-60% HRR)	Exercises: Multi-joint exercises (squats, press, rows, deadlifts) with medium resistance bands Sets/Reps: 2-3 x 8-12 reps. Intensity: 50-65% of the estimated one-repetition maximum (1RM).	Weekly TRIMP adjustment
Optimization	15 - 20	Maximize and consolidate metabolic and cardiovascular adaptations.	Duration: 40-50 min Intensity: 70-80% HRmax (60-70% HRR)	Exercises: The same multi-joint exercises with high-resistance bands. Sets/Reps: 3 x 8-10 reps. Intensity: 65-75% of the estimated one-repetition maximum (1RM).	TRIMP and sRPE stabilization with fatigue monitoring

Note: The load of the strength training was progressed by increasing the resistance of the elastic bands or modifying the lever of the exercise (e.g., from squat to lunge), always ensuring correct technical execution. The intensity was regulated through the subjective perception of effort (RPE).

3.3.5. Program Validation

The periodized combined training program was validated in a two-stage process to ensure its scientific quality, safety, and feasibility before implementation. Content validity was assessed by a panel of five experts in exercise physiology, sports training, and physical activity for health, consisting of three university researchers and two clinicians. These experts evaluated the suitability of the exercises for the target population, the coherence of the periodization model, the progression of intensity and training volume, participant safety, and the feasibility of implementing the program in a com-munity setting. A four-point Likert scale (1 = not suitable to 4 = very suitable) was used for this evaluation. The final content validity index (CVI) was 0.91, which suggests an excellent agreement between the agencies and confirms the adequacy of the intervention design.

The second stage of the training program consisted of a pilot test of four weeks with the participation of three sedentary women who met the eligibility criteria of the study but were not included in the final sample. The experimental evaluation allowed the training methodologies to be refined, the guidelines of the Borg scale to be refined and the feasibility of the one-hour activity to be confirmed. Observations of the study participants allowed minor changes to be made to the pre- and post-exercise routines. The pilot test demonstrated the safety and practicality of the program for the target population.

3.4. Post-intervention Results

3.4.1. Clinical Outcomes and Anthropometry

Following the 20-week intervention, all 15 participants completed the program with a mean adherence rate of 88.3% (range: 82–95%), indicating high compliance with the supervised training program. No adverse cardiovascular events were recorded during the intervention. Analysis of individual response revealed consistent improvements among participants, with statistically significant reductions in total cholesterol (-8.2%; $p < 0.001$) and LDL cholesterol (-11.6%; $p < 0.001$), as well as a significant increase in HDL cholesterol (+4.1%; $p < 0.001$). Triglycerides showed a statistically significant but clinically negligible change (-0.3%; $p = 0.005$) (Table 5).

A reduction in body weight of 2.8% (from 76.0 ± 7.4 kg to 73.9 ± 6.6 kg) and in BMI of 2.7% (from 29.3 ± 1.2 kg/m^2 to 28.5 ± 1.0 kg/m^2) was observed. Waist circumference decreased significantly by 3.8% (from 94.5 ± 7.1 cm to 90.9 ± 6.7 cm; $p<0.001$).

The Castelli I index (total cholesterol/HDL) decreased by 11.7% ($p < 0.001$) and the Castelli II index (LDL/HDL) decreased by 14.6% ($p < 0.001$), indicating a substantial reduction in atherogenic cardiovascular risk (Table 5). In addition to statistical significance, important changes in health were measured by calculating mean absolute differences, 95% confidence intervals, median Hodges-Lehmann differences, and percentage changes for all study outcomes.

Table 5. Anthropometric and lipid profile variables pre- and post-intervention (n=15).

Variable	Pre-Mean (95% CI)	Post-Mean (95% CI)	Absolute Mean Difference (Post–Pre) (95% CI)	Hodges–Lehmann Median Difference (95% CI)	% Change	p-value
Body Weight (kg)	76.0 ±7.4 (71.9–80.1)	73.9 ±6.6 (70.2–77.5)	−2.13 (−3.22 to −1.05)	−2.00 (−3.00 to −1.00)	−2.8	<0.001
Height (m)	1.61 ±0.05 (1.58–1.64)	1.61 ±0.05 (1.58–1.64)	0.00 (0.00 to 0.00)	0.00 (0.00 to 0.00)	0.0	1.000
Body Mass Index (kg/m^2)	29.3 ±1.2 (28.6–30.0)	28.5 ±1.0 (28.0–29.1)	−0.79 (−1.15 to −0.43)	−0.80 (−1.20 to −0.40)	−2.7	<0.001
Waist circumference (cm)	94.5 ±7.1 (90.6–98.5)	90.9 ±6.7 (87.1–94.6)	−3.67 (−4.07 to −3.27)	−4.00 (−4.00 to −3.00)	−3.8	<0.001
Total Cholesterol (mg/dL)	218.4 ±26.4 (203.8–233.0)	200.5 ±22.1 (188.3–212.8)	−17.87 (−21.32 to −14.41)	−17.00 (−20.00 to −14.00)	−8.2	<0.001
LDL Cholesterol (mg/dL)	138.7 ±21.5 (126.8–150.6)	122.6 ±12.3 (115.8–129.4)	−16.13 (−22.16 to −10.10)	−16.00 (−20.00 to −10.00)	−11.6	<0.001
HDL Cholesterol (mg/dL)	44.2 ±7.5 (40.0–48.4)	46.0 ±7.2 (42.0–50.0)	+1.80 (+1.57 to +2.03)	+2.00 (+1.00 to +2.00)	+4.1	<0.001
Triglycerides (mg/dL)	156.3 ±30.5 (139.5–173.2)	155.8 ±30.2 (139.1–172.6)	−0.53 (−0.82 to −0.25)	−1.00 (−1.00 to 0.00)	−0.3	0.005
Castelli Index I (TC/HDL)	4.94 ±0.82 (4.49–5.39)	4.36 ±0.70 (3.97–4.75)	−0.58 (−0.628 to −0.544)	-0.58 (−0.72 to −0.45)	−11.7	<0.001
Castelli Index II (LDL/HDL)	3.14 ±0.61 (2.80–3.48)	2.68 ±0.49 (2.41–2.95)	−0.46 (−0.539 to −0.377)	−0.47 (−0.55 to −0.29)	−14.6	<0.001

Note: CI = Confidence Interval. 95% CI calculated as Mean ±(t-value × SEM).

The effect size analysis showed a strong cardiometabolic adjustment with large effect sizes in body weight, body mass index, waist circumference, total cholesterol, LDL cholesterol, HDL cholesterol and Castelli Risk Indices, after the intervention. These changes were not only statistically significant but also clinically meaningful. In contrast, although triglycerides decreased significantly, the corresponding clinical effect was modest, suggesting that exercise alone may have a limited influence on this variable in previously sedentary middle-aged women (Table 6).

Table 6. Effect size and clinical interpretation of the intervention outcomes (n = 15).

Outcome Variable	% Change	Rosenthal's r	Effect Magnitude	Clinical Relevance	Practical Implication
Body weight (kg)	−2.8	0.91	Large	Clinically meaningful reduction in body weight, consistent with improved energy balance and cardiometabolic health.	Individualized combined treatment is a powerful non-pharmacological approach for weight management in sedentary middle-aged women.
Body Mass Index (kg/m^2)	−2.7	0.85	Large	Clinically significant reduction in total adiposity, im-	Confirms the effectiveness of periodized combined training for the

Outcome Variable	% Change	Rosenthal's r	Effect Magnitude	Clinical Relevance	Practical Implication
				provement in body composition.	prevention of obesity and healthy aging.
Waist circumference (cm)	−3.8	0.94	Large	Significant reduction in central adiposity, meaning lower levels of visceral fat accumulation and lower cardiometabolic risk.	Supports waist circumference as a primary clinical indicator for monitoring exercise-induced cardiometabolic adaptations.
Total Cholesterol (mg/dL)	−8.2	0.88	Large	Clinically relevant reduction in circulating cholesterol concentrations, reflecting improved lipid metabolism.	May improve management of cardiovascular risk through structured exercise.
LDL Cholesterol (mg/dL)	−11.6	0.88	Large	Significant reduction in atherogenic lipoproteins, consistent with a clinically relevant improvement in cardiovascular risk profile.	Recommends individualized exercise prescription as a useful strategy to improve lipid control in primary cardiovascular prevention.
HDL Cholesterol (mg/dL)	+4.1	0.94	Large	Clinically meaningful increase in HDL cholesterol, consistent with a more favorable lipid profile.	Supports the beneficial effect of regular combined exercise on protective lipid metabolism.
Triglycerides (mg/dL)	−0.3	0.73	Large	Despite the large statistical effect size, the absolute reduction (−0.3%) was clinically negligible.	Exercise may have only a limited effect on triglyceride concentrations, but additional nutritional interventions may enhance this response.
Castelli Index I (TC/HDL)	−11.7	0.55*	Large	Improvement in total cholesterol/HDL ratio indicates lower global atherogenic burden.	Proposes the use of composite lipid index measures to monitor exercise-induced reductions in cardiovascular risk.
Castelli Index II (LDL/HDL)	−14.6	0.61*	Large	Improvement in the LDL/HDL ratio reflects a clinically meaningful reduction in atherogenic cardiovascular risk.	Reinforces individualized periodized exercise as an effective community-based strategy for improving cardiometabolic health.

Note: Rosenthal's effect size (r) was calculated using the standardized Wilcoxon signed-rank statistic. Effect size was interpreted using Cohen's conventions (small ≈ 0.10; medium ≈ 0.30; large ≥ 0.50).

Exploratory Spearman correlation analyses were performed to examine associations between intervention-induced changes in anthropometric variables, internal training load, and cardiometabolic outcomes (Table 7).

There was a significant positive correlation between waist circumference reduction and LDL cholesterol reduction ($\rho = 0.672$, $p = 0.006$), indicating that the greater the reduction in central adiposity the greater the improvement in LDL levels. A similar positive correlation was observed between the reduction of waist circumference and improvement of Castelli Index II (ρ=0.650, p=0.009) while no significant correlation was found between the reduction of waist circumference and Castelli Index I (ρ=0.207, p=0.459). These correlations suggest that the reduction of visceral adiposity may be an important mediatory factor for the lipid profile improvements observed in this study.

No significant correlations were observed between accumulated TRIMP and changes in the lipid profile (all $p > 0.05$), suggesting that cardiometabolic adaptations may depend not only on total internal training load but also on individual physiological responsiveness, baseline cardiometabolic status, and exercise adherence.

Table 7. *Spearman correlations between changes in waist circumference and cardiometabolic outcomes following the 20-week intervention.*

Comparison	Spearman's ρ	Bootstrap 95% CI	*p*	Strength	Clinical Interpretation
Δ Waist Circumference vs. Δ LDL Cholesterol	0.672	0.29 to 0.88	0.006	Strong	Greater reductions in central adiposity were associated with larger decreases in LDL cholesterol.
Δ Waist Circumference vs. Δ Castelli Index I*	0.207	−0.35 to 0.66	0.459	Weak	No statistically significant association was observed.
Δ Waist Circumference vs. Δ Castelli Index II*	0.650	0.25 to 0.87	0.009	Strong	Greater reductions in waist circumference were associated with larger improvements in the LDL/HDL ratio.

Analysis of the internal load showed a progressive increase through the three periodization phases (Table 8). Weekly TRIMP values increased from 360 to 600 AU min during the adaptation phase, from 600 to 960 AU min during the development phase, and from 960 to 1080 AU min during the optimization phase. The progressive increase in training load and stabilization of the load-rest ratio is indicative of positive physiological adaptation over the intervention period.

The Session Rating of Perceived Exertion (sRPE) using the Borg CR-10 scale increased progressively across the adaptation (3.2 ± 0.7), development (5.1 ± 0.6) and optimization phases (6.8 ± 0.8) reflecting the planned increase in exercise intensity throughout the periodized program. The higher perceived effort associated with progressive overload was not associated with adverse effects, as ACWR values remained within the recommended range, no exercise-related adverse events occurred and adherence was 88.3%, indicating that the individualized progression was well tolerated and achieved without evidence of excessive fatigue or maladaptation.

Overall, the progressive increase in internal training load was accompanied by stable ACWR values, high adherence (88.3%), and the absence of exercise-related adverse events, indicating successful physiological adaptation and appropriate tolerance to the progressively increasing training stimulus throughout the intervention.

Table 8. *Progression of internal training load across the three periodization phases.*

Phase	Weeks	TRIMP Initial	TRIMP Final	Increase (%)	Borg CR-10	Aerobic Effect (AU)	Objective
Adaptation	1-6	360	600	+66.7%	3.2 ±0.7 (Moderate)	2.5 → 3.8	Familiarization
Development	7-14	600	960	+60.0%	5.1 ±0.6 (Hard)	4.0 → 5.7	Progressive overload
Optimization	15-20	960	1080	+12.5%	6.8 ±0.8 (Very hard)	6.0 → 7.2	Performance consolidation

Note: Values correspond to the mean session Rating of Perceived Exertion recorded approximately 30 minutes after each supervised exercise session according to Foster's method.

The smaller increase in TRIMP during the optimization phase may reflect a strategic stabilization of training volume while intensity increased, favoring consolidation of physiological adaptations and reducing excessive fatigue (Figure 2 and 3).

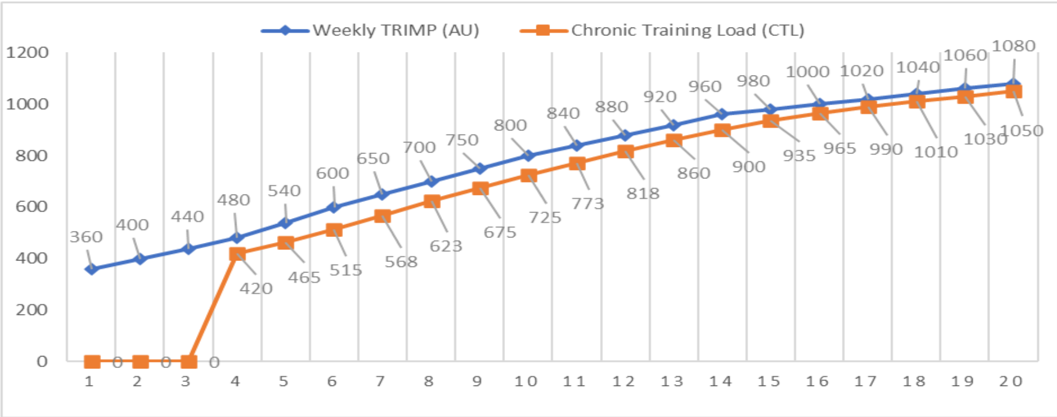

Figure 2. *Weekly evolution of internal training load showing weekly Training Impulse (TRIMP) and chronic training load (CTL) throughout the 20-week periodized intervention.*

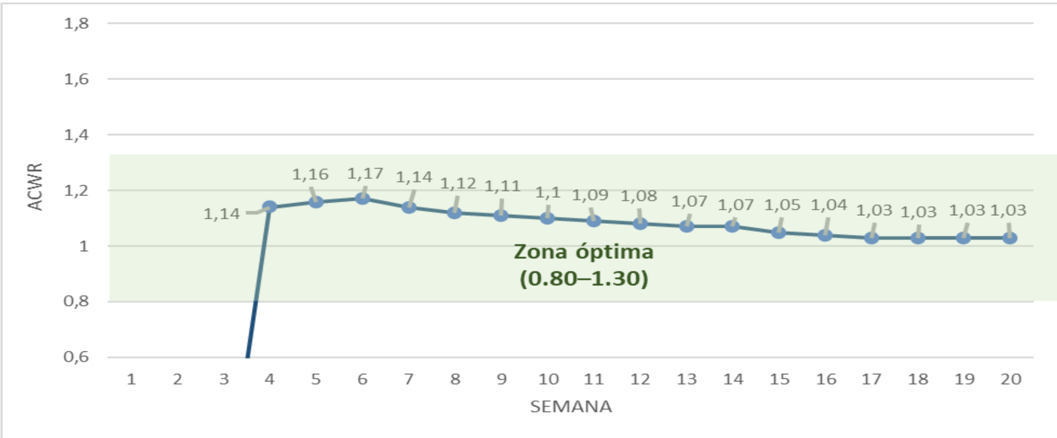

Figure 3. *Weekly evolution of the acute: chronic workload ratio (ACWR) throughout the 20-week periodized intervention.*

Figure 2 and Figure 3 show the progressive increase in internal training load throughout the intervention. Acute Training Load (ATL) increased progressively in parallel with Chronic Training Load (CTL), whereas the Acute:Chronic Workload Ratio (ACWR) remained within the recommended range (0.80–1.30) during most weeks, indicating an appropriate balance between overload and recovery and suggesting successful physiological adaptation without evidence of excessive fatigue.

3.4.2. Training Load

To examine whether participants with higher training loads experienced greater improvements, we divided the sample into two groups based on the median accumulated TRIMP (total TRIMP across 20 weeks: 14,400 AU·min). Participants above the median (High-Volume group, n=8, mean TRIMP: 15,840 ±1,200 AU·min) and below the median (Low-Volume group, n=7, mean TRIMP: 13,200 ±960 AU·min) were compared.

The High-Volume group showed a greater reduction in LDL cholesterol (−13.8% vs. −9.2%, p = 0.041) and a larger improvement in Castelli index II (−17.2% vs. −12.4%, p = 0.048) than the Low-Volume group. These findings suggest that training volume is associated with improved lipids in a dose-response fashion. No significant differences were found for other outcomes. Although these findings suggest a potential dose–response relationship between accumulated internal training load and improvements in LDL cholesterol and Castelli Index II, they should be interpreted as exploratory because of the limited sample size and the non-randomized design of the study.

4. Discussion

The principal finding of the present study is that individualized periodized combined training regulated through complementary objective (TRIMP) and subjective (sRPE) internal training load produced clinically meaningful improvements in lipid profile and atherogenic cardiovascular risk while maintaining high adherence and an appropriate physiological training load throughout the intervention.

The present study demonstrated that the 20-week individualized periodized combined training program, regulated through objective (Training Impulse [TRIMP]) and subjective (session Rating of Perceived Exertion [sRPE]) monitoring of internal training load, was associated with clinically meaningful improvements in cardiometabolic health among previously sedentary middle-aged Colombian women. The intervention produced significant reductions in total cholesterol, LDL cholesterol, waist circumference, and both Castelli Risk Indices, accompanied by an increase in HDL cholesterol, high program adherence, and the absence of exercise-related adverse events.

Session Rating of Perceived Exertion (sRPE) was added to complement heart rate-derived TRIMP in an attempt to capture the integrated psychophysiological perception of effort of the participants. The complementary use of objective and subjective internal load measures has been suggested to allow a more comprehensive characterization of exercise-induced stress than either method alone and to optimize individualized exercise prescription and monitor training adaptations, particularly in heterogeneous community-based populations where physiological responses may vary despite similar external workloads [33-35, 43, 44, 50].

The complementary use of objective (TRIMP) and subjective (sRPE) internal load measures may have contributed to the consistent adherence observed throughout the intervention by allowing exercise intensity to remain individualized according to each participant's physiological and perceptual responses.

The favorable changes in the lipid profile and atherogenic cardiovascular risk found are biologically plausible and can be explained by several complementary physiological mechanisms induced by periodized combined training. Regular aerobic and resistance exercise increases skeletal muscle lipoprotein lipase (LPL) activity to help hydrolyze and clear triglyceride-rich lipoproteins and promote HDL maturation and reverse cholesterol transport. Furthermore, regular physical activity activates AMP-activated protein kinase (AMPK), a key enzyme in the regulation of cellular energy balance that activates fatty acid oxidation and inhibits hepatic lipogenesis. Exercise increases the expression of peroxisome proliferator-activated receptor gamma coactivator-1 alpha (PGC-1α), which increases mitochondrial biogenesis and oxidative capacity, increasing β-oxidation and decreasing lipid accumulation. Together these adaptations may contribute to reductions in LDL cholesterol, improvements in HDL cholesterol, and lower Castelli Risk Indices, supporting the biological plausibility of the cardiometabolic benefits observed in the present study [26, 29, 32, 36, 43, 48, 53, 54].

Collectively, these findings support the hypothesis that individualized exercise prescription based on progressive periodization and continuous internal load regulation may optimize lipid metabolism and reduce atherogenic cardiovascular risk in women undergoing the menopausal transition. Given that menopause is characterized by accelerated metabolic deterioration and increased cardiovascular risk, these results reinforce current recommendations advocating structured exercise as a cornerstone of primary cardiovascular prevention while highlighting the potential added value of The present study demonstrated that a 20-week individualized periodized combined training program, regulated through objective (Training Impulse [TRIMP]) and subjective (session Rating of Perceived Exertion [sRPE]) internal training load monitoring, produced clinically meaningful improvements in cardiometabolic health in previously sedentary middle-aged Colombian women. Significant reductions were observed in total cholesterol, LDL cholesterol, waist circumference, and both Castelli Risk Indices, together with an increase in HDL cholesterol, high program adherence (88.3%), and the absence of exercise-related adverse events. Collectively, these findings indicate that individualized regulation of internal training load may facilitate safe exercise progression while promoting favorable adaptations in lipid metabolism and atherogenic cardiovascular risk, supporting current concepts of individualized exercise prescription and precision exercise medicine [25, 26, 29, 30, 35, 39-41, 43, 44].

Heart rate-derived Training Impulse (TRIMP) and session Rating of Perceived Exertion (sRPE) were combined to enable continuous regulation of internal training load to each participant's physiological and perceptual responses. Whereas TRIMP objectively quantified cardiovascular stress, sRPE captured the integrated psychophysiological perception of effort by reflecting cardiovascular, neuromuscular, respiratory, and perceptual responses to exercise. Their complementary use provides a more comprehensive characterization of exercise-induced stress than either method alone and has been increasingly recommended to optimize individualized exercise prescription and monitor training adaptations, particularly in heterogeneous community-based populations in which physiological responses may differ despite similar external workloads [33-35, 39, 40, 43, 44, 48, 50]. The individualized regulation of exercise intensity throughout the intervention may also explain the high adherence observed (88.3%) by maintaining an appropriate balance between training stimulus and recovery while minimizing excessive physiological stress [35, 38-41].

The favorable changes observed in lipid profile and atherogenic cardiovascular risk are biologically plausible and can be explained by several complementary physiological mechanisms induced by periodized combined training. Regular aerobic and resistance exercise increases skeletal muscle lipoprotein lipase (LPL) activity facilitating hydrolysis and clearance of triglyceride-rich lipoproteins and promoting HDL maturation and reverse cholesterol transport. Also, repeated exercise activates AMP activated protein kinase (AMPK), a key regulator of cellular energy homeostasis, which promotes fatty acid oxidation and inhibits hepatic lipid synthesis. Exercise-induced activation of peroxisome proliferator-activated receptor gamma coactivator-1 alpha (PGC-1α) promotes mitochondrial biogenesis and improves oxidative capacity, thereby increasing β-oxidation and decreasing lipid accumulation. These adaptations result in reduced LDL cholesterol, increased HDL cholesterol, and decreased Castelli Risk Indices, which provide biological plausibility for the cardiometabolic benefits observed in the present study [26, 29, 32, 36, 43, 48, 53, 54].

In the current study, the marked reduction in waist circumference, along with moderate-to-strong correlations observed between decreases in waist circumference, LDL cholesterol, and Castelli Risk Index II, suggest that reductions in central adiposity may have been an important mediator of the favorable cardiometabolic adaptations. However, mechanistic biomarkers such as insulin sensitivity, inflammatory mediators, lipoprotein kinetics, or inflammatory cytokines were not directly assessed; therefore, these physiological mechanisms remain biologically plausible rather than experimentally confirmed and warrant further investigation in future mechanistic trials [15, 27, 28, 30, 53, 54].

The present findings are consistent with the highest level of available evidence supporting combined aerobic and resistance exercise as an effective non-pharmacological strategy for improving lipid profile and reducing cardiometabolic risk among middle-aged and postmenopausal women. Recent systematic reviews, meta-analyses, and randomized controlled trials consistently demonstrate significant reductions in total cholesterol and LDL cholesterol together with increases in HDL cholesterol following structured combined exercise programs, although the magnitude of these responses varies according to exercise dose, intervention duration, progression strategy, and participant characteristics [26-28, 30, 32, 37, 42].

The reductions observed in total cholesterol (−8.2%), LDL cholesterol (−11.6%), and the increase in HDL cholesterol (+4.1%) are therefore consistent with previous evidence, although the reduction in LDL cholesterol appears slightly greater than that reported in several pooled analyses [26, 28, 30, 32]. One plausible explanation is that, unlike many previous interventions employing standardized exercise prescriptions, the present study incorporated individualized periodization together with continuous regulation of internal training load using complementary objective (TRIMP) and subjective (sRPE) monitoring. This individualized approach may have optimized the balance between exercise stimulus and recovery, thereby maximizing physiological adaptation while maintaining the high adherence observed throughout the intervention [35, 39-41, 43, 44]. Furthermore, whereas most previous studies evaluated only conventional lipid biomarkers, the present investigation simultaneously incorporated Castelli Risk Indices, providing a more comprehensive assessment of exercise-induced changes in atherogenic cardiovascular risk [20-24].

Importantly, these improvements were accompanied by moderate-to-large effect sizes, suggesting that the observed changes occurred not only at the level of statistical significance, but also at the level of clinical meaningfulness. The consistency between statistical significance, effect size estimates, and clinically relevant changes strengthens the robustness of the present findings and supports the potential value of individualized periodized exercise as an effective strategy for cardiovascular risk reduction in sedentary middle-aged women [25, 26, 30, 35-41].

A distinctive strength of the present study lies in the integration of structured periodization with complementary objective (Training Impulse [TRIMP]) and subjective (session Rating of Perceived Exertion [sRPE]) monitoring of internal training load, an approach that remains relatively uncommon in community-based exercise interventions involving sedentary middle-aged women. Whereas previous studies have generally prescribed exercise intensity using fixed percentages of maximal heart rate or one-repetition maximum, the present intervention continuously individualized exercise intensity according to participants' physiological and perceptual responses, consistent with current recommendations advocating individualized exercise prescription and internal load monitoring [35-41, 43, 44]. This strategy likely contributed to the high adherence (88.3%), the absence of exercise-related adverse events, and the large effect sizes observed for waist circumference, LDL cholesterol, and both Castelli Risk Indices. These findings are consistent with contemporary exercise physiology principles, which recognize that internal rather than external training load provides a more accurate representation of the biological stress imposed by exercise and therefore constitutes a more appropriate basis for exercise prescription and progression [39-41, 43, 44, 46, 47].

Although internal training load was continuously regulated using TRIMP and sRPE, these variables cannot fully account for the magnitude of individual cardiometabolic adaptations. The exercise responses are inherently multifactorial and depend on baseline fitness, genetic predisposition, autonomic regulation, hormonal status, habitual physical activity, sleep quality, nutritional factors and exercise adherence. Therefore, subjects exposed to a similar internal training load may respond differently in terms of metabolism, even when receiving a similar exercise stimulus. The interindividual variability further emphasizes the importance of an individualized exercise prescription and that the internal training load should be considered as one component of a larger physiological adaptation process rather than the only determinant of cardiometabolic outcomes [35-41, 46].

The reduction in triglyceride concentrations was relatively modest and is consistent with previous systematic reviews and meta-analyses which have shown that the response of triglycerides to exercise interventions is generally more heterogeneous than that of LDL-C or HDL-C and are strongly influenced by baseline metabolic status, dietary intake, intervention duration and exercise dose [28, 43]. The intervention was associated with statistically significant improvements in total cholesterol, LDL cholesterol, HDL cholesterol and atherogenic cardiovascular risk. Several randomized controlled trials have reported that clinically meaningful reductions in triglycerides are more likely to occur in individuals presenting hypertriglyceridemia or metabolic syndrome at baseline, whereas participants with normal or only mildly elevated triglyceride concentrations tend to show smaller responses despite significant improvements in other cardiometabolic outcomes [30, 32].

Therefore, the relatively modest triglyceride reduction observed in the present study should not be interpreted as evidence of limited intervention efficacy but rather as reflecting the multifactorial regulation of triglyceride metabolism. In addition, dietary intake was not objectively monitored throughout the intervention, and nutritional factors are recognized as major determinants of fasting triglyceride concentrations and overall cardiometabolic health. Therefore, despite the beneficial adaptations evoked by the exercise program, the degree of triglyceride lowering may have been attenuated by residual dietary variability [55-59]. Importantly, the concomitant improvements seen in LDL cholesterol, HDL cholesterol, waist circumference and both Castelli Risk Indices suggest that the intervention was associated with a clinically relevant reduction in global atherogenic cardiovascular risk, even in the absence of a significant triglyceride response. This interpretation is supported by current cardiovascular prevention guidelines, which emphasize that comprehensive improvement in multiple cardiometabolic risk factors provides a more robust indicator of cardiovascular risk reduction than isolated changes in a single lipid parameter [3, 10, 19, 60].

In addition to the cardiometabolic beneficial adaptations observed, the present findings have important implications for clinical practice and public health. Cardiovascular disease remains the leading cause of mortality among women worldwide and the menopausal transition is associated with profound metabolic and hormonal changes that greatly increase cardiovascular risk [1, 2, 14, 16]. Consequently, identifying safe, feasible, and cost-effective non-pharmacological strategies capable of improving multiple cardiovascular risk factors simultaneously has become a major public health priority [5-7]. The present intervention suggests that an individualized periodized combined exercise program can be successfully implemented in a community setting with high adherence and without exercise-related adverse events, supporting its potential applicability within primary healthcare services and community-based cardiovascular prevention programs. The use of low-cost equipment and the use of self-monitoring tools further enhance the sustainability of this approach in resource-limited settings. Unlike highly supervised laboratory interventions requiring sophisticated equipment, the present protocol was based on practical exercise modalities that can be reproduced in recreational, community, and primary care settings, thereby increasing its translational potential. Moreover, the integration of objective (TRIMP) and subjective (session-RPE) monitoring provides a practical framework for individualizing exercise prescription according to each participant's physiological response, which is consistent with current recommendations advocating personalized exercise as a cornerstone of precision prevention [36, 37, 39]. Nevertheless, the present approach, which relies on low-cost, scalable tools such as heart rate monitors and perceived exertion scales, is likely to be particularly relevant for low- and middle-income countries, where affordable and sustainable lifestyle interventions are urgently needed to reduce the growing burden of cardiometabolic diseases among aging women [8, 9].

Although accumulated TRIMP was not significantly correlated with changes in lipid profile, this finding should not be interpreted as evidence that internal training load monitoring lacks clinical relevance. Rather, cardiometabolic adaptations to exercise are known to depend on multiple interacting determinants, including baseline metabolic status, exercise adherence, recovery capacity, genetic variability, hormonal status, and individual responsiveness to training. Therefore, TRIMP may serve an indirect role in optimizing exercise prescription, progressive overload and limiting excessive physiological stress rather than as a stand-alone predictor of lipid adaptations [35, 39-41].

The variability between individuals in several cardiometabolic endpoints further supports the concept that exercise responses are highly individual. Despite all participants completing the same periodized program, the magnitude of lipid improvements varied between individuals, which highlights the need for individualized exercise prescription based on continuous internal training load monitoring, rather than standardized external workloads. This finding is consistent with current evidence showing considerable heterogeneity in physiological responses to exercise interventions, even when individuals are subjected to similar training stimuli [35-41].Overall, the present findings support the concept that individualized periodized combined training regulated through complementary objective (Training Impulse [TRIMP]) and subjective (session Rating of Perceived Exertion [sRPE]) internal training load monitoring represents a feasible and potentially effective strategy to improve lipid profile and reduce atherogenic cardiovascular risk in sedentary middle-aged women. These findings support the emerging paradigm of precision exercise medicine in which exercise prescription is tailored to an individual's physiological response rather than to standardised external workloads [25, 35-41, 43, 44, 46, 47]. Future well-powered randomised controlled trials with larger sample sizes, objective assessment of aerobic fitness, mechanistic biomarkers, dietary monitoring and long-term follow-up are needed to confirm these observations and to further elucidate the biological mechanisms of exercise individualised adaptations [28, 35, 39-41, 46, 47]. Such studies will help establish whether the cardiometabolic benefits of individualised internal training load monitoring surpass those of conventional exercise prescription strategies.

4.1. Strengths and Limitations

4.1.1. Strengths

The present study has several strengths that should be considered when interpreting its findings. To our knowledge, it is one of the first investigations conducted in Latin American middle-aged women to evaluate the effects of a periodized combined training program integrated with individualized internal load monitoring using both Training Impulse (TRIMP) and session Rating of Perceived Exertion (sRPE). In addition, the assessment of cardiovascular risk was not only based on the classical lipid parameters but also on the use of Castelli atherogenic indices, enabling a more complete evaluation of the cardiometabolic adaptations induced by exercise. The high adherence rate (88.3%) and the absence of adverse events further strengthen the feasibility and safety of implementing this intervention in community-based health promotion programs.

4.1.2. Limitations

Despite these strengths, some limitations should be acknowledged. First, the quasi-experimental single-group design without a non-exercising control group limits causal inference and introduces the possibility of selection bias and prevents complete exclusion of the influence of external factors, confounding variables, or regression to the mean. Although the high adherence rate, the consistency of the observed physiological adaptations, and the progressive regulation of internal training load strengthen the plausibility that the intervention contributed to the observed improvements, the findings should be interpreted with appropriate caution.

Second, the relatively small sample size (n = 15) limits the external validity and generalizability of the findings, although the large effect sizes observed across the primary outcomes lend support to the clinical relevance of the intervention. Third, there was no objective monitoring of dietary intake using standardized nutritional assessments or repeated dietary records during the intervention period. Consequently, the independent effect of exercise should be interpreted with caution [55-59].

Fourth, statistical comparisons across the primary outcomes did not incorporate a correction for multiple comparisons (e.g., Bonferroni adjustment). This decision was made to reduce the risk of Type II error in this exploratory study; therefore, the results should be interpreted considering the accompanying effect sizes, confidence intervals, and their clinical relevance rather than p-values alone.

Fifth, although menopausal status was documented, objective hormonal characterization (e.g., circulating estrogen concentrations) was not performed, and the relatively small sample size precluded subgroup analyses according to menopausal stage. Because endocrine changes substantially influence lipid metabolism and cardiovascular risk, future studies should incorporate hormonal assessment to better understand whether physiological responses differ between peri- and postmenopausal women.

Sixth, cardiorespiratory fitness was not directly assessed with maximal oxygen uptake (VO2max), and it was not possible to verify whether the improvement in aerobic capacity mediated the favorable changes found in lipid profile and atherogenic cardiovascular risk. Since VO2max is a strong predictor of cardiovascular morbidity and mortality, future studies should include direct assessment of aerobic fitness to clarify the physiological mechanisms underlying exercise-induced cardiometabolic adaptations.

Finally, the absence of post-intervention follow-up did not allow the assessment of the long-term maintenance of the observed cardiometabolic improvements. It is unknown whether these positive adaptations are maintained after the completion of the supervised program and should be further investigated in longitudinal studies with a longer follow-up period.

5. Conclusions

This study demonstrated that a 20-week periodized combined training program integrated with individualized internal load monitoring elicited clinically meaningful improvements in lipid profile, central adiposity, and atherogenic cardiovascular risk among previously sedentary middle-aged Colombian women. Beyond confirming the established benefits of combined exercise, the present findings suggest that individualized regulation of internal training load through TRIMP and session rating of perceived exertion may enhance exercise prescription by facilitating progressive adaptation, optimizing adherence, and minimizing excessive physiological stress in community-based settings. Importantly, the reductions observed in LDL cholesterol, waist circumference, and the Castelli atherogenic risk indices suggest that this type of exercise program may offer a practical and relatively low-cost approach to reducing cardiovascular risk during the menopausal transition. These findings indicate that an individualized periodized combined training program, adjusted according to each participant’s internal training load, can contribute to meaningful improvements in cardiometabolic health among previously sedentary middle-aged women. Nevertheless, the present results should be interpreted with caution because of the quasi-experimental design and limited sample size. Future research should include randomized controlled trials with larger and more diverse populations, longer follow-up periods, and more rigorous dietary control to confirm the long-term sustainability of the benefits and their generalizability to wider populations.

These findings support individualized periodized combined training regulated through complementary objective (TRIMP) and subjective (session Rating of Perceived Exertion) internal training load monitoring as a feasible community-based precision exercise strategy to improve cardiometabolic health in previously sedentary middle-aged women. Future randomized controlled trials with larger samples are warranted to confirm these findings and establish the long-term effectiveness of individualized exercise prescription for cardiovascular disease prevention.

Abbreviations

STRAW+10	Stages of Reproductive Aging Workshop
ACWR	Acute-Chronic Workload Ratio
CTL	Chronic training load
ATL	Acute training load

AU	Arbitrary Units
BMI	Body Mass Index
CVD	Cardiovascular diseases
HDL	High-Density Lipoprotein Cholesterol
HRmax	Maximum Heart Rate
HRR	Heart Rate Reserve
IPAQ	International Physical Activity Questionnaire
LDL	Low-Density Lipoprotein Cholesterol
RPE	Rating of Perceived Exertion
SD	Standard Deviation
sRPE	Session Rating of Perceived Exertion
TC	Total Cholesterol
TG	Triglycerides
TRIMP	Training Impulse
WC	Waist Circumference
WHO	World Health Organization
CI	Confidence interval
TREND	Transparent Reporting of Evaluations with Nonrandomized Designs
ACSM	American College of Sports Medicine
FITT	Frequency, Intensity, Time, Type
1RM	One-Repetition Maximum

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Author Contributions

Arays Hernandez Garay: Conceptualization, Formal Analysis, Investigation, Methodology, Visualization, Writing – original draft

Alejandro Valero Inerarity: Conceptualization, Methodology, Resources, Validation, Writing – review & editing

Ricardo Leonardo Perea Rodriguez: Conceptualization, Methodology, Project administration, Supervision, Writing – review & editing

Monica Paola Murcia Doncel: Data Curation, Investigation, Validation, Writing – review & editing

Luis Fernando Cruz Quiroga: Data Curation, Investigation, Validation, Writing – review & editing

Eder Jair Sepulveda Molina: Investigation, Resources, Validation, Writing – review & editing

Marjorie Gissella Galofre Vasquez: Investigation, Resources, Validation, Writing – review & editing

Juan Pablo Garzon Sanchez: Investigation, Software, Validation, Writing – review & editing

Jhoan David Romana Martinez: Investigation, Software, Validation, Writing – review & editing

Data Availability Statement

The data supporting the outcome of this research work has been reported in this manuscript.

Conflicts of Interest

The authors declare no conflicts of interest.

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