CLINICAL RESEARCH

e-ISSN 1643-3750
© Med Sci Monit, 2025; 31: e947877
DOI: 10.12659/MSM.947877

Received: 2024.12.30
Accepted: 2025.09.06
Available online: 2025.07.02
Published: 2025.07.30

Comparative Study of the Rehabilitation Exercise 5R System and Aerobic Exercise on Postpartum Recovery: Impacts on Muscle Function and Metabolic Health

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Financial support: This study was supported by the national research foundation of Korea (NRF) under grant NRF-2022R1A2C1092131
Conflict of interest: None declared

Background: This study evaluated the effectiveness of a postpartum rehabilitation exercise using rehabilitative ultrasound imaging (RUSI) compared to an aerobic exercise and routine daily activities over a 12-week period.

Material/Methods: We randomly assigned 56 postpartum women to 3 groups: Group 1 (5R system), Group 2 (aerobic exercise), and Group 3 (control). Groups 1 and 2 engaged in supervised exercise sessions twice per week over a 12-week intervention period. Outcomes included inter-rectus distance (IRD), muscle thickness, muscle strength, body composition, fasting blood glucose (FBG), and postpartum depression.

Results: No significant group-by-time interaction effects were observed for IRD ($p>0.05$). For rectus abdominis thickness (RAT), quadriceps thickness (QT), and gluteus maximus thickness (GMT), significant group-by-time interaction effects were observed during contraction and relaxation ($p<0.05$). Significant group-by-time interaction effects were observed for muscle strength, including knee extension (KE), hip flexion (HF), trunk flexion (TF), and trunk extension (TE) ($p<0.05$). Body weight and body mass index (BMI) decreased significantly in all groups ($p<0.001$). Abdominal fat percentage (AFP) and FBG levels decreased only in Group 1, with a statistically significant interaction effect observed ($p<0.05$). No significant differences were found in the Korean version of the Edinburgh Postnatal Depression Scale (K-EPDS) scores ($p>0.05$).

Conclusions: Systematic rehabilitation exercise is important for facilitating rapid postpartum recovery. Integrating core-strengthening exercises with resistance training has been shown to be more effective than aerobic exercise alone in improving muscle thickness, muscle strength, AFP and FBG.

Keywords: Diastasis, Muscle • Exercise Therapy • Muscle Strength • Postpartum Period • Rehabilitation • Women's Health

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Introduction

Postpartum women frequently experience musculoskeletal changes, such as diastasis recti, pelvic pain, and low back pain, which can lead to physical instability, reduced muscular function, and decreased quality of life [1-3]. While some musculoskeletal changes resolve naturally, recovery is often slow and highly individual. Without appropriate interventions, conditions such as diastasis recti and pelvic pain can result in long-term complications [4,5], impacting women's ability to return to pre-pregnancy activity levels and potentially affecting their quality of life for years. Given the high prevalence and potential long-term consequences of these conditions, disease prevention has become a critical public health concern. In response, the 2020 World Health Organization (WHO) guidelines emphasize the importance of maintaining adequate physical activity levels during pregnancy and the postpartum period as a necessary intervention [6]. Accordingly, engaging in structured physical activity is regarded as a crucial strategy for preventing a range of postpartum complications.

While previous studies have shown the importance of postpartum exercise, the criteria for adequate exercise and rehabilitation protocols after childbirth remain unclear, with limited emphasis on whole-body musculoskeletal recovery. Previous studies have primarily focused on individuals with specific conditions, such as diastasis recti or pelvic floor dysfunction, with limited emphasis on whole-body musculoskeletal recovery [7,8]. In addition, most prior studies have highlighted the psychological benefits of postpartum exercise, particularly in alleviating postpartum depression symptoms [9]. Moreover, as existing research has generally focused on short-term, early postpartum recovery, a gap remains in understanding long-term functional restoration [10]. Few studies have evaluated a graded, integrated rehabilitation model designed to promote the whole-body recovery most needed by postpartum women. Therefore, this study aimed to fill this gap by evaluating the effectiveness of the 5R system, which is a structured, graded intervention.

According to the American College of Obstetricians and Gynecologists (ACOG), light activities such as walking or pelvic floor exercises are permissible immediately after birth if medically safe, and it is considered safe to gradually resume physical activity from 4 to 5 weeks postpartum for mothers who delivered vaginally rather than by cesarean section [11]. In addition, most women have a low risk of infection at 5 weeks postpartum, as the uterus typically returns to its pre-pregnancy size within 4–6 weeks, and the discharge of lochia is generally complete [12]. A previous study implemented an exercise training program consisting of aerobic exercise, muscle strengthening, and stretching for women at 4-6 weeks postpartum and demonstrated that moderate exercise had no adverse effects on weight loss, psychological stability, or breastfeeding [13].

In the early postpartum period, relaxin hormone levels increase, contributing to joint laxity and physical instability [14]. Therefore, the risk of injury due to inappropriate or excessive exercise aimed at weight reduction may be elevated. To mitigate these risks, previous studies have suggested that structured postpartum rehabilitation is necessary and that effective rehabilitation should follow a stepwise progression, beginning with stabilization exercises, incorporating functional exercises, and gradually increasing resistance and aerobic training to enhance muscle strength, cardiovascular fitness, and weight management [15-17]. Therefore, postpartum exercise programs should use a stepwise approach, ensuring gradual recovery of both local and global musculoskeletal function and ultimately allowing for a safe return to pre-pregnancy activity levels. In response to this need, our research team developed a systematic postpartum recovery program called the 5R system. The system consists of 4 phases: (1) recovery deformity (RD) with RUSI, which focuses on activating the rectus abdominis and transversus abdominis to restore initial physical stability; (2) recovery posture (RP), which aims to achieve proper posture and stabilization through core coordination; (3) recovery movement (RM), which emphasizes precise and efficient movements through resistance training; and (4) recovery conditioning (RC), which integrates aerobic and strength training to burn calories and improve overall fitness. Therefore, the program was designated as the "5R System," derived from the 5 key components, each beginning with letter "R"

RUSI is an established tool for evaluating muscle structure and providing visual biofeedback during exercise, and is particularly effective in activating deep muscles such as the transverse abdominis. This muscle plays a pivotal role in addressing diastasis recti and pelvic instability in postpartum women, where selective contraction enhances training effectiveness and minimizes compensatory actions. RUSI-based training offers a targeted approach to prevention and rehabilitation by focusing on core muscle activation [18,19]. As ultrasound technology advances, dual-probe ultrasound systems have been developed, allowing simultaneous imaging of bilateral muscles. This enables the assessment of muscle activation symmetry and interactions between agonist and antagonist muscles, significantly improving the quality of rehabilitative training [20]. However, conventional ultrasound visual feedback training is limited by the need for the clinician to manually hold the probe, restricting its application in clinical settings. To address this, our research team developed the Dual-Probe Fixing Frame (DPF), which allows hands-free operation and consistent imaging of target muscles. This innovation improves posture correction, intervention precision, and the overall efficiency of visual feedback training [21]. In this study, the DPF was utilized with dual-probe ultrasound to implement the RD phase of the 5R System, focusing on transverse abdominis and rectus abdominis activation. This approach seeks to overcome postpartum

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musculoskeletal recovery challenges and scientifically validate the benefits of RUSI-based training. This study evaluated the effectiveness of the 5R system, using RUSI, compared to aerobic exercise and routine daily activities in improving IRD, muscle thickness, muscle strength, body composition, FBG, and postpartum depression.

Material and Methods

Study Design

This study was designed as a randomized controlled trial (RCT). This study employed a single-blind design, where participants were unaware of their group assignments, while the researchers were aware of the intervention groups. Group 1 participated in a postpartum rehabilitation exercise (5R system), Group 2 engaged in aerobic exercises, and Group 3 maintained their normal daily activities without any specific intervention. Measurements were conducted for all groups at 3 time points: pre- (0 weeks), mid- (6 weeks), and post- (12 weeks) intervention, for a total of 3 assessments.

Participants

The required sample size was calculated using G*Power version 3.1.9.2. A priori power analysis was conducted for a repeated-measures ANOVA within factors. The input parameters included an effect size of f=0.25, a significance level (α) of 0.05, a desired statistical power (1-β) of 0.95, 3 groups, and 3 measurements per participant. A non-sphericity correction (ε) of 0.75 and a correlation among repeated measures of 0.5 were assumed. Based on this analysis, the minimum required sample size was 54 participants. To account for an anticipated dropout rate of 10%, the total sample size was increased to 60 participants.

Participants were recruited using a convenience sampling method based on voluntary response to advertisements. Recruitment advertisements were posted from January 2, 2024, to July 14, 2024, through Instagram and educational bulletin boards at the Momsbodycare center in South Korea. Recruitment materials provided a brief overview of the study, including inclusion criteria and study objectives. A total of 62 individuals expressed interest in participating in the study. Eligibility was assessed through structured telephone interviews conducted by the research team based on predefined inclusion and exclusion criteria. Among the 62 individuals, 2 were excluded: 1 for being more than 5 weeks postpartum and 1 for having delivered via cesarean section, resulting in 60 eligible participants. Eligible participants attended an in-person meeting, where the research team provided a detailed explanation of the study procedures. After obtaining written informed consent, demographic data (eg, age, height, weight, and BMI) were collected. Participants were randomly allocated to 3 groups using a computer-generated randomization table: Group 1 (n=20), Group 2 (n=20), and Group 3 (n=20). During the intervention, 1 participant in Group 1 and 1 in Group 3 voluntarily withdrew from the study. Additionally, 2 participants in Group 3 discontinued due to unrelated health issues. Therefore, the final analysis included Group 1 (n=19), Group 2 (n=20), and Group 3 (n=17). The participant recruitment and allocation process is illustrated in the CONSORT flow diagram (**Figure 1**).

The inclusion criteria were: women aged 20-40 years, who had delivered a singleton infant via natural vaginal delivery within 5 weeks postpartum. This age range was selected to ensure a relatively homogeneous population in terms of musculoskeletal recovery potential and hormonal status, as previous studies have shown that musculoskeletal healing capacity, estrogen levels, and physical adaptability decline with increasing maternal age, particularly beyond age 40 years [22,23]. Participants were required to have delivered a singleton infant via natural vaginal delivery. The 5-week postpartum point was chosen based on clinical guidelines and prior evidence suggesting that it is a safe period to initiate physical activity following uncomplicated vaginal delivery [11-13]. Exclusion criteria were: women with third- or fourth-degree perineal tears following vaginal delivery; a history of pelvic or abdominal surgery or specific gynecological conditions, including pubic symphysis separation; severe illnesses affecting either the mother or the infant; cesarean delivery; neurological disorders; cardiovascular or respiratory diseases; severe visual field defects; a BMI exceeding 30 kg/m^2 (moderate obesity); and cognitive limitations preventing comprehension of the study protocol or participation in the exercise program. This study was approved by the Institutional Review Board (IRB) of Sahmyook University (Approval No. SYU 2023-12-015-001). In accordance with international research guidelines, the study was also prospectively registered with the Clinical Research Information Service (CRIS), Republic of Korea, under the registration number KCT00010145.

Outcome Measures

IRD and muscle thickness were assessed using B-mode ultrasound imaging with TELEMED equipment, including convex and linear probes (TELEMED, Vilnius, Lithuania), analyzed via Echo Wave II software. B-mode ultrasound is a validated and reliable tool for musculoskeletal imaging, with intraclass correlation coefficients (ICCs) typically > 0.90 for thickness measurements of abdominal and lower-extremity muscles in both static and dynamic conditions [24,25]. All measurements were performed twice per condition (relaxed and contracted states), and the averages were used for analysis. To ensure accuracy, participants relaxed their body and measurements were taken during the

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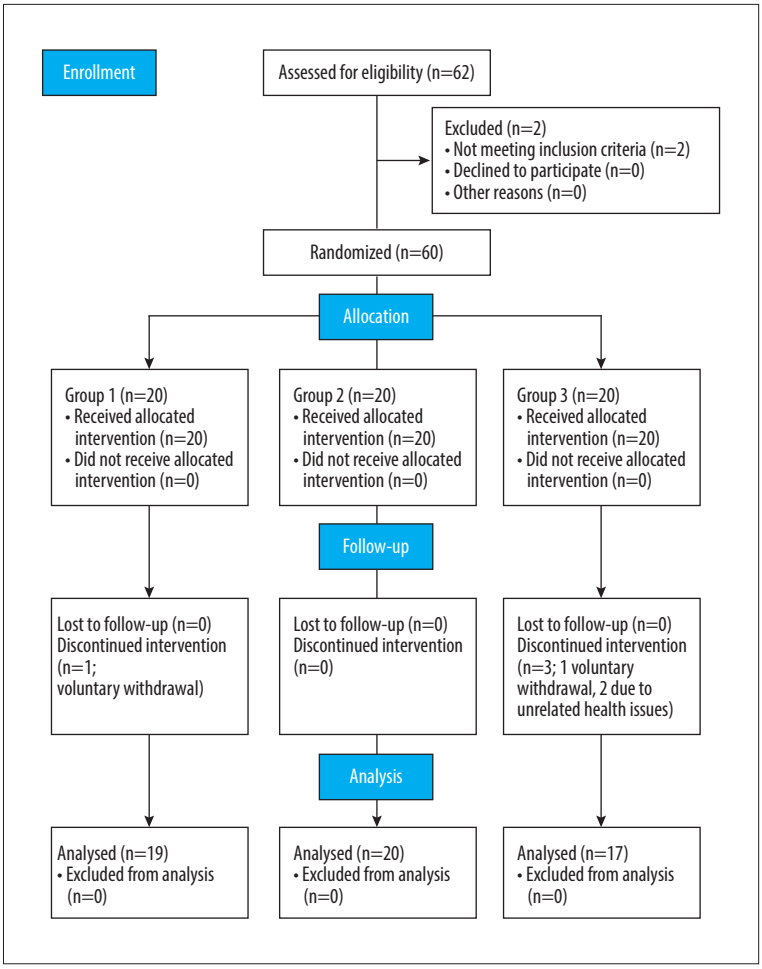


Figure 1. CONSORT flow diagram of participant recruitment, allocation, follow-up, and analysis. A total of 62 individuals were assessed for eligibility. Two were excluded for not meeting inclusion criteria, and 60 participants were randomized into 3 groups (n=20 per group). During the intervention, 1 participant in Group 1 and 3 in Group 3 discontinued participation. The final analysis included 19 participants in Group 1, 20 in Group 2, and 17 in Group 3. *The figure was created using Microsoft PowerPoint 2019 (Microsoft Corporation, Redmond, WA, USA).*

expiratory phase. All measurements were conducted by a single physical therapist with extensive experience in anatomical and ultrasound imaging. IRD was measured using a convex probe (3.5 MHz, 70 dB) with participants positioned supine and knees flexed comfortably. The probe was placed along the abdominal midline at 4 locations relative to the umbilicus (upper margin, 2.5 cm above, lower margin, and 2.5 cm below) [26]. The built-in caliper function was used to measure the linear distance between the medial borders of the rectus abdominis. RAT was measured using a convex probe (3.5 MHz, 70 dB) placed 2.5 cm above the umbilicus and oriented perpendicularly to the muscle's long axis [27]. Participants were supine with knees flexed. For the relaxed state, participants were instructed to exhale naturally and remain still without any voluntary muscle contraction. For the contracted state, participants were instructed to perform a partial curl-up (crunch) to activate the rectus abdominis, maintaining controlled movement to avoid compensation from other muscle groups. Measurements of the upper and lower fascial borders were taken using the built-in caliper function. Transverse abdominis thickness (TAT) was measured using a linear probe (12 MHz, 65 dB) placed along the lateral abdominal wall at the mid-axillary line between the iliac crest and lower rib border [28]. Participants were supine with knees flexed. For the relaxed condition, participants were instructed to breathe out gently and remain completely still without engaging the abdominal muscles. For the contracted condition, participants were asked to perform an abdominal drawing-in maneuver (ADIM), which selectively activates the transverse abdominis without engaging global muscles. The probe orientation provided a transverse view, allowing clear visualization of the transverse abdominis. Fascial border distances were measured using the caliper function. QT was measured using a linear probe (10 MHz, 65dB) placed perpendicularly at the midpoint between the anterior superior iliac spine and the patella [29]. Participants were seated with knees at 90° flexion. For the relaxed condition, participants were instructed to remain still with the quadriceps relaxed. For the contracted condition, the examiner applied manual resistance against knee extension, and participants were instructed to perform an isometric contraction by attempting to extend the knee without producing joint movement. GMT was measured using a convex probe (3.5 MHz, 65dB) placed transversely at the intersection of the posterior superior iliac spine and the ischial tuberosity (IT) [30]. Participants were prone with legs abducted to

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30° to reduce gluteal tension. For the relaxed condition, participants were instructed to remain still without activating the gluteal muscles. For the contracted condition, participants were instructed to perform a maximal isometric hip extension by pushing their leg upward toward the ceiling without actual limb movement, while maintaining the same prone posture. Measurements were taken from the skin boundary to the IT using the caliper function.

Muscle strength was assessed using a Commander Echo Muscle Tester (JTECH Medical, Salt Lake City, United States) in conjunction with a wireless manual evaluation console, Commander Echo Console (JTECH Medical, Salt Lake City, United States). Participants performed maximum voluntary contractions for 3 seconds, with 1-2 minutes rest between trials. The placement of the dynamometer was performed according to the manufacturer's guidelines provided by Commander (JTECH Medical). Muscle strength values, recorded in Newtons (N), were averaged over 3 trials. The reliability and validity of handheld dynamometry for muscle strength assessment have been well established in previous studies, demonstrating excellent intra- and inter-rater reliability (ICC >0.90) and strong criterion validity across various populations [31,32]. Knee flexion (KF): Participants were seated on a fixed chair with a backrest, ensuring that the hip and knee joints were at 90° flexion, while both feet were kept off the ground. Participants were instructed to exert their maximum effort to straighten their knee [33]. Hip flexion (HF): Participants sat on a fixed chair with a backrest, maintaining 90° flexion at both the hip and knee joints. The upper body and pelvis were stabilized to restrict unnecessary movement. Participants were instructed to exert their maximum effort to lift their knee towards their chest, flexing the hip [34]. Hip extension (HE): Participants lay prone on a mat with the right knee flexed to 90° and the sole of the foot facing upward. Participants were instructed to exert their maximum effort to extend their hip by pushing the leg backward [35]. Trunk flexion (TF): Participants lay supine on a mat with their knees bent and feet flat on the ground. Both hands were crossed over the chest, resting on the sternum [36]. Trunk extension (TE): Participants lay prone on a mat with their hands clasped behind their head. The pelvis and legs were stabilized using straps to restrict movement [37].

Body composition was measured using a bioelectrical impedance analysis (BIA) device (InBody 770, InBody company, Seoul, Republic of Korea), which assessed variables, including body weight, BMI, skeletal muscle mass (SMM), fat mass (FM), body fat percentage (BFP), and AFP. To ensure accurate and consistent measurements, participants were instructed to refrain from eating or drinking for at least 2 hours prior to the assessment and to use the restroom before the measurement. All measurements were conducted in a single session, and the recorded values were used for analysis.

FBF levels were assessed using the Accu-Chek Instant Kit (Roche diabetes care GmbH, Mannheim, Germany) [38]. Participants were instructed to fast for at least 8 hours prior to the measurement. The measurement procedure followed the manufacturer's instructions. FBG levels (mg/dL) were assessed and analyzed from a single measurement.

Postpartum depression was evaluated using the K-EPDS [39]. The K-EPDS comprises 10 items rated on a 4-point Likert scale, with a score of 10 or higher indicating a potential risk of postpartum depression. All participants completed the questionnaires independently, with the examiner providing clarification when necessary. The questionnaires used in this study were validated Korean versions, ensuring cultural and linguistic appropriateness.

Intervention

Group 1 performed the 5R system twice a week for 12 weeks. Each session lasted 40–50 minutes, consisting of a 5-minute warm-up, 30-40 minutes of targeted exercises, and a 5-minute cool-down. To ensure safety and clinical appropriateness, all exercises were developed by a sports medicine expert specializing in postpartum rehabilitation and were pre-screened by licensed physical therapists. No contraindicated or high-risk activities were included in the protocol, supporting the suitability of the 5R program for early postpartum women.

Phase 1: RD with RUSI was implemented during the initial 3 weeks and focused on abdominal exercises using visual feedback from RUSI (3.5 MHz, 70 dB). Previous studies have demonstrated that RUSI effectively enhances deep core muscle activation, particularly targeting the transverse abdominis, which is crucial for postpartum trunk stabilization and diastasis recti recovery [40]. To improve the precision and efficiency of visual feedback training, our team developed the DPF [21], enabling hands-free ultrasound probe operation and consistent imaging of target muscles. Real-time feedback has been shown to improve motor learning and neuromuscular control, reinforcing correct muscle activation patterns and minimizing compensatory movements [41]. Based on evidence that 2-3 weeks of repetitive training is required to facilitate neuromuscular adaptation [42], the RD phase duration was set accordingly. Exercise intensity was maintained at an RPE of 5-6, reflecting a moderate level of effort.

Phase 2: RP was conducted over the following 3 weeks to enhance postural control and core coordination. Exercises included resistance-based abdominal drawing-in maneuvers (ADIM) and coordinated movements targeting the iliopsoas muscle. This phase was also conducted at a moderate intensity (RPE 5-6), with a focus on trunk alignment and stability. The 3-week duration aligns with prior research indicating improvements in

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Table 1. Phase-specific exercise composition of the 5R system.

Phase	Phase	Weeks	Exercise
1	RD with RUSI	1-3	Warm-up, ADIM(with RUSI), Crunch(with RUSI), Pelvic tilt, Pelvic hiking, Bridging
2	RP	4-6	Warm-Up, Band pull and abdominal bracing, Pelvic tilt, Leg lift on a chair + Single-leg lowering (Weeks 4-5), Leg lift from the floor + Wall plank (Weeks 5-6)
3	RM	7-10	Warm-up, Hip hinge, Squat, Lunge, Pull, Loaded carry (All exercises are performed while holding a dumbbell that is 1 kilogram heavier than the baby's weight)
4	RC	11-12	Warm-up, Single-leg balance, Single-leg squat, Single-leg running man pose, Step-up run, Forward bounding, Single-leg jump, Single-leg calf raise, Single-leg bridge, Single-leg sit-to-stand, Side kick, aerobic exercise

RD – recovery deformity; RUSI – rehabilitative ultrasound imaging; RP – recovery posture; RM – recovery movement; RC – recovery conditioning.

neuromuscular efficiency following short-term postural training interventions [43].

Phase 3: RM lasted for 4 weeks and focused on strengthening muscles essential for daily childcare activities and injury prevention. Progressive resistance training was implemented using dumbbells approximately 1 kg heavier than the weight of the participant's infant. Exercise intensity was increased each week by adjusting repetitions while maintaining moderate intensity (RPE 6-7). This phase was guided by recommendations for gradual muscle adaptation and strength development over a minimum of 4 weeks [44].

Phase 4: RC was implemented during the final 2 weeks and combined aerobic and resistance training to promote metabolic adaptation, cardiorespiratory endurance, and fat reduction. Functional resistance exercises such as single-leg balance and single-leg squats were performed alongside aerobic activities including single-leg jumping and sit-to-stand with single-leg support. Exercise intensity was maintained at a moderate-to-vigorous level (RPE 6-7). The short duration of this phase reflects its role in transitioning participants toward higher functional capacity and increased physical activity tolerance.

The detailed protocol of the 5R system is summarized in **Table 1**. The RD phase of the 5R system involved a physical therapist visiting the participant's home to ensure proper performance of the prescribed exercises. The RP, RM, and RC phases were conducted at a designated fitness center (Momsbodycare), where participants performed the prescribed exercises under one-on-one supervision by a licensed physical therapist. Exercise intensity was monitored and adjusted according to each participant's physical condition using the Borg Rating of Perceived Exertion (RPE) scale, and was maintained within a moderate range of RPE 5-7 to ensure safety and optimize participation. While each phase includes distinct exercises, they are integrated components of a structured rehabilitation process rather than isolated interventions. This stepwise approach aligns with evidence supporting gradual neuromuscular adaptation and injury prevention in postpartum rehabilitation [15]. Thus, the 5R system was implemented as a unified intervention, ensuring that each phase builds upon the previous one to promote comprehensive recovery.

Group 2 followed a 12-week aerobic exercise program. Each session consisted of a 5-minute dynamic stretching warm-up, 20-35 minutes of aerobic exercise, and a 5-minute dynamic stretching cool-down. Participants were primarily encouraged to use a treadmill; alternatively, outdoor walking, cycling, or stair climbing exercises were suggested. The researcher recommended that participants set the treadmill speed to 5.0-6.5 km/h and incline to 3-5%, encouraging them to reach their target heart rate. To accurately monitor exercise intensity, participants wore a wearable watch, the Galaxy Fit 2 (Samsung, Seoul, Republic of Korea) to track their exercise duration and verify whether they reached their target heart rate. Participants then reported this information to a researcher licensed as a physical therapist for confirmation. The exercise intensity was set at 50-65% of the participants' maximum heart rate (HR_{max}), representing moderate intensity. To personalize exercise intensity, the Karvonen Formula was used to calculate each participant's target heart rate (THR). THR: = (HR_{max} - HR_{est} × Intensity [%]) + HR_{est} [45]. Here, HR_{max} is the maximum heart rate (220 - age), HR_{est} is the resting heart rate, and Intensity is the exercise intensity expressed as a percentage [46]. Based on this formula, each participant's target heart rate was calculated to adjust exercise intensity. The exercise duration was increased by 5 minutes every 3 weeks, and the intensity was raised by 5% to ensure gradual progression.

Group 3 was instructed to maintain their usual daily activities, including household chores, childcare, and walking for routine purposes. They were explicitly advised not to engage in any structured or intentional exercise during the 12-week study period. Compliance with these instructions was monitored through regular check-ins and verbal self-reports. At the

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Table 2. Participant demographics.

Variable	Group 1 (n=19) Mean±SD	Group 2 (n=20) Mean±SD	Group 3 (n=17) Mean±SD	Total (n=56)
Age (years)	34.68±1.83	35.50±3.20	33.24±2.91	34.54±2.80
Height (cm)	164.43±5.50	162.30±5.83	162.91±5.41	163.21±5.52
Weight (kg)	59.84±8.21	58.93±10.19	60.86±5.72	59.83±8.18
BMI (kg/m^2)	22.23±2.67	22.25±2.47	22.88±1.60	22.44±2.27

SD – standard deviation.

conclusion of the study, Group 3 participants were invited to attend a workshop introducing the experimental exercise programs to ensure equitable access to the potential health benefits of the intervention.

All participants were instructed to maintain their habitual dietary patterns without intentional restriction or overconsumption to minimize potential dietary influences on the study outcomes. In addition, they were advised not to engage in any physical activity beyond the prescribed intervention and their routine daily activities. Compliance with these guidelines and adherence to the study protocol were regularly monitored throughout the intervention period. Attendance for each session was individually recorded in an Excel file, and attendance rates were calculated as the percentage of completed sessions out of the total 24 planned sessions. Participants with an attendance rate below 80% were to be excluded from the analysis; however, all participants exceeded the 80% attendance threshold.

Statistical Analysis

Statistical analyses were performed using IBM SPSS version 27.0. This study employed a two-way repeated-measures ANOVA to analyze the effects of 2 independent variables on repeated measurements of the dependent variables. This analysis was conducted to examine the main effects between groups and within time points, as well as their interaction effects. Prior to the analysis, the Shapiro-Wilk test was used to assess the normality of the data distribution ($p>0.05$). For variables that did not meet the normality assumption, the Friedman test was used for comparing repeated measures, and the Kruskal-Wallis test was used to compare differences among the 3 groups, performing non-parametric analyses. The assumption of sphericity was evaluated using Mauchly's test of sphericity. If the p value was greater than 0.05, the assumption of sphericity was considered satisfied. However, when the p value was less than 0.05, indicating a violation of the sphericity assumption, Greenhouse-Geisser correction was applied to adjust the degrees of freedom, and results were interpreted accordingly. Post hoc analyses were performed when significant main effects or interaction effects were observed to identify specific differences between groups. Bonferroni correction was applied during post hoc tests to control for Type I error due to multiple comparisons. To determine the effect size, partial eta squared values were reported, which were used to interpret the magnitude of each factor's effect on the dependent variables. Effect sizes were interpreted based on conventional cut points, where $\eta^2_p=0.01$ indicated a small effect, $\eta^2_p=0.06$ a medium effect, and $\eta^2_p=0.14$ a large effect [47]. All statistical analyses were conducted at a significance level of 0.05, with p values less than 0.05 considered statistically significant.

Results

The demographic information of participants by group is presented in **Table 2**. The mean age of all participants was 34.54±2.80 years, with an average height of 163.21±5.52 cm, weight of 59.83±8.18 kg, and BMI of 22.44±2.27kg/m^2.

The results for IRD and muscle thickness are presented in **Table 3**. No significant group-by-time interaction effects was observed in IRD measurements ($p>0.05$). TAT in the relaxed state showed no significant changes across all groups ($p>0.05$). The contracted TAT of group 1 increased compared to groups 2 and 3, but the group-by-time interaction effect was not significant ($p>0.05$). QFT showed significant interaction effects at relaxation ($F=5.561$, $p<0.001$, $\eta^2=0.173$) and during contraction ($F=4.204$, $p=0.005$, $\eta^2=0.137$), with Group 1 demonstrating greater increases compared to the other 2 groups. In the relaxed and contracted state, GMT was maintained in Group 1 but decreased in Groups 2 and 3, with a significant interaction effect observed ($F=2.642$, $p=0.046$, $\eta^2=0.091$), ($F=3.860$, $p=0.008$, $\eta^2=0.127$).

For RAT, significant group-by-time interaction effects were observed during both rest ($F=4.973$, $p=0.001$, $\eta^2=0.158$) and contraction ($F=5.859$, $p<0.001$, $\eta^2=0.181$). **Figure 2** presents a graph illustrating the average RAT in the relaxed state, while **Figure 3** depicts the average RAT in the contracted state.

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Table 3. IRD and muscle thickness results.

Measurement	Variable	Time	Group 1 Mean±SD	Group 2 Mean±SD	Group 3 Mean±SD	Statistics (Group*Time)	P value	Partial (η^2)
IRD (mm)	Superior umbilicus	Pre	1.45±0.23	1.56±0.37	1.64±0.38	F=0.450	p=0.718	0.017
		Mid	1.27±0.20	1.39±0.26	1.43±0.21			
		Post	1.10±0.15	1.15±0.26	1.29±0.27			
	Umbilicus +2.5 cm	Pre	1.28±0.26	1.32±0.30	1.35±0.27	F=1.368	p=0.255	0.049
		Mid	0.98±0.22	1.13±0.22	1.18±0.28			
		Post	0.89±0.20	1.01±0.22	1.14±0.28			
	Inferior umbilicus	Pre	1.41±0.38	1.46±0.38	1.51±0.37	F=0.856	p=0.493	0.031
		Mid	1.18±0.31	1.33±0.37	1.34±0.32			
		Post	1.06±0.30	1.19±0.23	1.31±0.35			
	Umbilicus -2.5 cm	Pre	1.17±0.34	1.24±0.34	1.28±0.29	F=0.439	p=0.780	0.016
		Mid	0.96±0.31	1.08±0.21	1.15±0.25			
		Post	0.88±0.25	0.99±0.16	1.09±0.26			
Muscle thickness (mm)	TAT_rest	Pre	0.21±0.06	0.19±0.04	0.17±0.03	F=0.494	p=0.703	0.018
		Mid	0.22±0.04	0.18±0.04	0.17±0.03			
		Post	0.20±0.03	0.18±0.02	0.17±0.03			
	TAT_con	Pre	0.48±0.12	0.45±0.11	0.42±0.10	F=0.825	p=0.512	0.030
		Mid	0.50±0.11	0.43±0.10	0.45±0.12			
		Post	0.54±0.14	0.45±0.11	0.45±0.13			
	QFT_rest	Pre	2.80±0.58	3.01±0.52	3.11±0.38	F=5.561	p=0.000*	0.173
		Mid	2.89±0.51	3.05±0.52	2.83±0.35			
		Post	3.08±0.46	2.97±0.51	2.74±0.35			
	QFT_con	Pre	3.53±0.43	3.60±0.47	3.75±0.35	F=4.204	p=0.005*	0.137
		Mid	3.76±0.41	3.81±0.55	3.77±0.35			
		Post	3.97±0.30	3.78±0.46	3.87±0.28			
	GMT_rest	Pre	1.59±0.44	1.52±0.40	1.42±0.30	F=2.642	p=0.046*	0.091
		Mid	1.52±0.29	1.47±0.28	1.33±0.33			
		Post	1.58±0.36	1.25±0.26	1.29±0.23			
	GMT_con	Pre	4.20±0.72	4.04±0.56	4.15±0.43	F=3.860	p=0.008*	0.127
		Mid	4.57±0.62	4.18±0.55	4.25±0.46			
		Post	4.82±0.64	4.16±0.65	4.16±0.58			

SD – standard deviation; pre – 0 week; mid – 6 weeks; post – 12 weeks; IRD – inter-recti distance; RAT – rectus abdominis thickness; TAT – transverse abdominis thickness; QFT – quadriceps femoris thickness; GMT – gluteus maximus thickness; relx – relaxed state; con – contracted state. * p<0.05.

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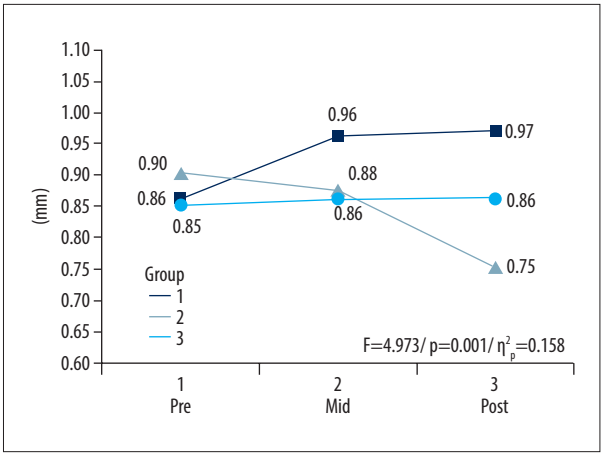


Figure 2. The Estimated marginal mean of RAT in a relaxed state. RAT – rectus abdominis thickness. Group 1 (dark blue line with squares): 5R system group; Group 2 (grey line with triangles): Aerobic exercise group; Group 3 (light blue line with circles): Control group. A significant group × time interaction was observed (F=4.973, p=0.001, η^2_p=0.158). *The figure was created using Microsoft PowerPoint 2019 (Microsoft Corporation, Redmond, WA, USA).*

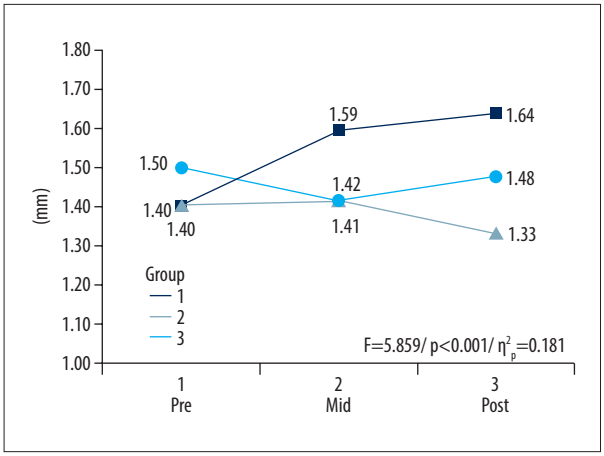


Figure 3. Estimated marginal mean of RAT in a contracted state. RAT – rectus abdominis thickness. Group 1 (dark blue line with squares): 5R system group; Group 2 (grey line with triangles): Aerobic exercise group; Group 3 (light blue line with circles): Control group. A significant group × time interaction was observed (F=5.859, p<0.001, η^2_p=0.181). *The figure was created using Microsoft PowerPoint 2019 (Microsoft Corporation, Redmond, WA, USA).*

The results for muscle strength in **Table 4**. Significant interaction effects were observed for muscle strength in KE (F=3.012, p=0.021, η^2=0.102), HF (F=3.879, p=0.006, η^2=0.128), TF strength (F=5.198, p=0.001, η^2=0.164), and TE strength (F=5.609, p<0.001, η^{22}=0.175).

The results for body composition, FBG and postpartum depression in **Table 5**. Weight and BMI significantly decreased over time across all groups (χ^2=18.107, p<0.001; χ^2=24.361, p<0.001, respectively). No significant group-by-time interaction effects were observed for other body composition variables, including FM, SMM, and BFP (p>0.05), but AFP demonstrated a significant group-by-time interaction effect (F=3.148, p=0.022, η^2=0.106), indicating that the reduction in AFP over time differed among the groups. Significant interaction effects were observed for FBG (F=4.587, p=0.002, η^2=0.148). For the K-EPDS, no significant differences were observed across groups or time points (p>0.05).

The results of the post hoc analysis are presented in **Table 6**, including only the significant findings. Post hoc analysis revealed that IRD at 2.5 cm above the umbilicus significantly decreased in Group 1 compared to Group 3 (p=0.042). For muscle thickness, relaxed-state transverse abdominis (TAT_relx) showed significantly greater increases in Group 1 compared to Groups 2 and 3 (p=0.016, p=0.000, respectively). Trunk flexor strength (TF) significantly increased in Group 1 compared to Group 3 (p=0.041).

Discussion

This study evaluated the effectiveness of the 5R system using RUSI compared to aerobic exercise and maintaining routine daily activities. The findings highlight the superiority of the 5R system in improving key physical and functional outcomes, including IRD, muscle thickness, muscle strength, body composition, FBG, and postpartum depression.

Diastasis recti is a condition where the connective tissue (linea alba) between the 2 rectus abdominis muscles becomes stretched and weakened, leading to separation of the muscles. This condition destabilizes the core and affects posture maintenance, placing excessive strain on lumbar muscles and the spine, which can result in chronic low back pain associated with lumbar instability [48]. Postpartum hormonal shifts, including reductions in relaxin and changes in estrogen and progesterone levels, influence the natural repair of the linea alba through fibroblast activation and new connective tissue formation [49,50]. Reduced intra-abdominal pressure and repeated stretching and contraction postpartum facilitate the recovery of linea alba elasticity [51]. Although diastasis recti may naturally improve within 6–8 weeks postpartum, unresolved cases can persist for over a year without intervention [26]. In the present study, no significant group-by-time interaction effects were observed for IRD across all groups. However, significant reductions were seen over time in all groups, with Group 1 demonstrating greater reductions compared to Groups 2 and 3. Post hoc analysis revealed a significant difference between Group 1 and Group 3 at the location

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Table 4. Muscle strength results.

Measurement	Variable	Time	Group 1 Mean±SD	Group 2 Mean±SD	Group 3 Mean±SD	Statistics (Group*Time)	P value	Partial (η^2)
Muscle strength (N)	KE	Pre	176.72±47.33	172.65±45.45	187.43±32.78	F=3.012	p=0.021*	0.102
		Mid	184.60±45.93	190.52±37.88	184.75±30.05			
		Post	216.08±42.67	204.40±38.57	190.76±32.51			
	HF	Pre	160.97±32.15	164.72±38.90	165.02±20.36	F=3.879	p=0.006*	0.128
		Mid	171.83±26.85	184.81±31.20	158.34±17.33			
		Post	191.23±28.42	180.00±29.99	171.19±26.05			
	HE	Pre	157.87±52.03	151.67±36.99	146.07±38.33	F=1.003	p=0.404	0.036
		Mid	170.73±43.71	172.39±32.92	161.40±26.11			
		Post	197.28±40.54	183.10±40.69	169.03±33.22			
	TF	Pre	100.04±33.03	107.19±26.70	100.86±18.88	F=5.198	p=0.001*	0.164
		Mid	127.34±26.53	114.09±24.10	107.81±23.24			
		Post	142.10±18.15	118.24±23.45	109.64±25.14			
	TE	Pre	155.82±34.51	162.86±26.57	162.65±34.40	F=5.609	p=0.000*	0.175
		Mid	182.44±32.50	180.68±31.77	191.27±34.85			
		Post	216.49±43.02	198.61±24.95	187.15±39.36			

SD – standard deviation; pre – 0 week; mid – 6 weeks; post – 12 weeks; KF – knee flexion; HF – hip flexion; HE – hip extension; TF – trunk flexion; TE – trunk extension. * p<0.05.

2.5 cm above the umbilicus (p=0.042). These findings validate the effectiveness of the core stabilization exercises in the RC phase of the 5R system, which utilizes RUSI for visual feedback to activate the transverse abdominis and rectus abdominis. The recovery of diastasis recti relies on the activation of the transverse abdominis, which stabilizes the abdominal center and reduces IRD. Furthermore, diaphragmatic breathing exercises aimed at optimizing the distribution of intra-abdominal pressure, combined with upper-abdominal strengthening exercises incorporated into the program, likely contributed to these outcomes by enhancing the elasticity of the linea alba and promoting biomechanical stability during the postpartum recovery period. The 5R system's emphasis on progressive core activation using RUSI may have contributed to the observed improvements in muscle function by enhancing neuromuscular control and promoting selective activation of key stabilizing muscles. The visual feedback provided by RUSI may have allowed participants to engage the correct muscles more effectively, leading to greater gains in thickness.

Muscle thickness is a critical indicator of muscle strength and metabolic activity. Resistance training induces mechanical stress, causing microdamage to myofibrils and activating satellite cells, which repair tissues and enhance protein synthesis, leading to hypertrophy [52]. Relaxed muscle thickness reflects structural size and cross-sectional area, while contracted muscle thickness demonstrates functional activation and neural adaptations. Concurrent increases in both states suggest combined structural and functional improvements, such as enhanced motor unit recruitment and efficient force generation [53-55]. In this study, Group 1 showed significant increases in RAT, QFT, and GMT compared to Groups 2 and 3. Both relaxed and contracted RAT and QFT increased, suggesting simultaneous hypertrophy and contractile strength improvements. TAT and GMT increased only in the contracted state, indicating improved neural adaptations and contractile efficiency without hypertrophy. This suggests that a longer exercise duration or greater intensity than provided by the 5R system may be necessary to achieve hypertrophy in the TAT and GMT. Our finding of significant improvements in muscle thickness with the 5R system aligns with previous research demonstrating the efficacy of resistance training in increasing muscle hypertrophy in postpartum women. However, our study extends this finding by showing that these improvements are greater than those achieved with aerobic exercise alone. Groups 2 and 3 showed minimal or no changes, highlighting that aerobic exercise or

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Table 5. Results for the body composition, FBG, and postpartum depression.

Measurement	Variable	Time	Group 1 Mean±SD	Group 2 Mean±SD	Group 3 Mean±SD	Statistics (Group*Time)	P value	Partial (η^2)
Body composition	Weight (kg)	Pre	59.84±8.21	58.93±10.19	60.86±5.72	χ^2=18.107 H=2.563	p<0.001* p=0.278	–
		Mid	58.95±8.33	58.07±10.72	59.36±5.79			
		Post	58.30±8.29	57.39±10.97	58.84±5.96			
	FM (kg)	Pre	18.91±5.36	18.38±5.20	20.91±4.04	F=0.406	p=0.734	0.015
		Mid	18.43±5.83	18.10±6.13	20.12±4.44			
		Post	18.04±5.70	17.64±6.86	19.67±4.69			
	SMM (kg)	Pre	21.97±2.39	21.89±3.31	21.45±1.90	χ^2=1.775 H=1.249	p=0.412 p=0.536	–
		Mid	21.79±2.21	21.53±3.03	21.08±1.80			
		Post	21.76±2.10	21.43±2.91	21.05±1.83			
	BFP (%)	Pre	31.11±4.87	30.69±4.37	34.13±4.45	F=0.122	p=0.950	0.005
		Mid	30.69±5.67	30.52±5.04	33.58±5.00			
		Post	30.13±5.52	29.90±6.26	33.07±5.41			
	AFP (%)	Pre	0.870±0.05	0.868±0.05	0.891±0.05	F=3.148	p=0.022*	0.106
		Mid	0.865±0.05	0.854±0.04	0.886±0.05			
		Post	0.849±0.05	0.852±0.05	0.884±0.05			
	BMI (kg/m^2)	Pre	22.16±2.62	22.25±2.47	22.88±1.60	χ^2=24.361 H=3.459	p<0.001* p=0.117	–
		Mid	21.78±2.70	21.92±2.67	22.29±1.61			
		Post	21.51±2.72	21.68±2.81	22.10±1.63			
Fasting blood glucose	FBG (mg/dL)	Pre	98.00±9.93	92.20±6.05	92.94±4.31	F=4.587	p=0.002*	0.148
		Mid	93.42±5.54	96.00±9.78	96.65±6.81			
		Post	92.58±6.18	96.50±9.61	95.06±8.95			
Postpartum depression	K-EPDS (score)	Pre	4.68±4.41	5.00±5.20	6.76±3.98	χ^2=5.258 H=2.341	p=0.072 p=0.310	–
		Mid	3.74±3.18	4.50±3.69	5.35±4.66			
		Post	2.47±2.87	3.95±4.26	4.76±4.02			

SD – standard deviation; pre – 0 week; mid – 6 weeks; post – 12 weeks; FM – fat mass; SMM – skeletal muscle mass; BFP – body fat percentage; AFP – abdominal fat percentage; BMI – body mass index; FBG – fasting blood glucose; K-EPDS – Korean version of the Edinburgh postnatal depression scale. * p<0.05.

Table 6. Post hoc (Bonferroni)_ between-subjects effects.

Measurements	Variable	Group	Group	SD	SE	P value
IRD	Umbilicus +2.5 cm	1	3	-0.176	0.069	0.042*
Muscle thickness	TAT_relx	1	2	0.027	0.009	0.016*
		1	3	0.044	0.010	0.000*
Muscle strength	TF	1	3	17.058	6.691	0.041*

SD – standard deviation; SE – standard error; IRD – inter-recti distance; TAT – transverse abdominis thickness; relax – relaxed state; TF – trunk flexion. * p<0.05.

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daily activities alone are insufficient for effectively targeting and increasing these muscle groups' thickness. Furthermore, QFT and GMT improvements in Group 1 emphasize the role of resistance training in enhancing lower-extremity and gluteal strength, which are crucial for functional tasks like lifting and carrying infants. Larger muscle fibers generate greater force and play a pivotal role in glucose regulation and lipid metabolism. A reduction in muscle thickness can lead to decreased insulin sensitivity, contributing to the development of diabetes and increased cardiovascular risk. Therefore, the 5R system contributes to promoting muscle hypertrophy and activation through progressive strengthening, further enhancing muscle strength and metabolic activity.

Increases in muscle strength, as measured by a dynamometer, reflect improvements in maximum contraction capacity and force production. These changes are driven by both neuromuscular adaptations and structural enhancements. Improved muscle strength contributes to better performance in daily activities, enhances independence, and positively impacts joint stability, potentially reducing pain and risk of injury [56]. Early strength gains, typically observed within the first 4-8 weeks of training, are primarily attributed to neural adaptations, such as improved motor unit recruitment, synchronization, and enhanced cooperation among motor units [44,57]. Repetitive training also reduces spinal inhibitory mechanisms, such as Golgi tendon organ activation, and accelerates neural signal transmission, resulting in more efficient muscle function and faster contraction responses [58]. Beyond the initial phase, strength gains are further supported by structural changes, including hypertrophy and increased glycogen and creatine phosphate storage within muscle fibers [59]. The enlargement of Type II muscle fibers plays a pivotal role in high-intensity strength development, while metabolic adaptations enhance energy delivery efficiency [60]. In this study, Group 1 demonstrated significant improvements in muscle strength across all measured parameters, including KE, HF, TF, and TE. Notably, TF and TE in Group 1 showed the greatest improvements during the RD and RP phases of the 5R system. This suggests that the reduced IRD facilitated biomechanically favorable conditions for abdominal muscle engagement, while concurrent increases in muscle thickness contributed to strength gains. Additionally, substantial increases in KE, HF, and HE were observed after 6 weeks of training, particularly during the RM and RC phases, highlighting the impact of resistance training. Conversely, Groups 2 and 3 showed limited improvements due to the absence of resistance training. While Group 2, which participated in aerobic exercise, exhibited slight increases in KE and HE strength, these changes likely resulted from enhanced muscle endurance and fiber activation through repetitive movements. However, it did not provoke the neuromuscular engagement required for significant strength gains.

This study utilized BIA to assess body composition, revealing reductions in body weight and BMI across all groups, which align with the natural postpartum recovery process. Decreased BMI is associated with benefits such as reduced cardiovascular strain, improved glucose regulation, and decreased musculoskeletal loading. However, BMI alone does not differentiate between FM and SMM, emphasizing the need for additional indices. Group 1, which used the 5R system, likely experienced complex metabolic and mechanical effects, balancing fat reduction and muscle stimulation. Group 2's aerobic exercise effectively reduced FM through enhanced fat metabolism but may have failed to sufficiently recruit Type II muscle fibers for muscle preservation. Group 3's daily activities likely contributed to calorie expenditure and metabolic adjustments, leading to concurrent reductions in FM and SMM. The simultaneous reduction in muscle and fat mass in Group 1 may be attributed to a negative energy balance and insufficient protein intake, resulting in muscle breakdown despite exercise-stimulated protein synthesis. Notably, the 5R system effectively reduced AFP, highlighting its impact on regional fat distribution. This reduction in AFP may be related to the combined effects of resistance training and aerobic exercise on fat mobilization and oxidation. Resistance training increases muscle mass, which in turn enhances metabolic rate, while aerobic exercise directly contributes to calorie expenditure. While ultrasound analyses captured localized muscle changes, BIA provided insights into systemic changes. The reduction in intramuscular adipose tissue (IMAT), included as part of muscle mass in BIA estimates, may explain the apparent decrease in total muscle mass. These findings suggest the need for dietary interventions and prolonged exercise protocols to optimize muscle preservation and systemic hypertrophy alongside weight loss.

FBG serves as a critical marker for metabolic and hormonal regulation, with normal levels ranging from 70 to 99 mg/dL, indicating healthy glucose control. Elevated levels of 100-125 mg/dL suggest prediabetes, necessitating lifestyle modifications, while levels above 126 mg/dL meet the diagnostic criteria for diabetes. During pregnancy, hormonal changes, including increased placental lactogen, estrogen, and progesterone, elevate insulin resistance to supply glucose for fetal energy demands, often resulting in heightened glucose levels [61]. Postpartum, glucose regulation gradually normalizes, but recovery may be delayed due to the physiological impact of pregnancy and delivery. Exercise plays a pivotal role in enhancing glucose regulation by improving insulin sensitivity and promoting glucose uptake into muscle cells through GLUT-4 protein translocation. Resistance training increases muscle mass, while aerobic exercise enhances fat metabolism, together creating a synergistic effect on glucose control [62]. In this study, only Group 1 demonstrated significant reductions in FBG. The decrease in FBG, particularly in the high-normal range (90-99 mg/dL), is noteworthy as it indicates a reduced risk of diabetes and potential

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cardiovascular benefits. By contrast, the slight increases in FBG observed in Groups 2 and 3 may reflect the residual effects of postpartum insulin resistance. While aerobic exercise in Group 2 likely enhanced fat metabolism and cardiovascular health, its exclusion of resistance training may have limited improvements in skeletal muscle glucose uptake and insulin sensitivity. In Group 3, the lack of structured physical activity likely contributed to the observed increase in FBG, as sedentary behavior is associated with reduced insulin action and glucose regulation [63]. These findings underscore the importance of combined resistance and aerobic exercise, as employed in the 5R system, to accelerate metabolic recovery and reduce long-term health risks.

K-EPDS was used to screen for postpartum depression. Postpartum depression is commonly observed following childbirth due to abrupt hormonal changes, such as decreases in estrogen, progesterone, and cortisol levels, which can impair emotional regulation and stress responses. Physical and physiological changes during this period, including sleep deprivation, fatigue, and inadequate nutrition, further challenge emotional balance. In this study, no significant differences in K-EPDS scores were observed between groups or time points, indicating a low prevalence of postpartum depression among the participants. This outcome may reflect the inclusion of mothers with good overall health, proactive attitudes toward health management, and adequate social support. Additionally, cultural norms in South Korea, which emphasize strong maternal responsibility and dedication, may have influenced participants' reluctance to express negative emotions, potentially leading to underreporting. Limitations of self-reported questionnaires like the K-EPDS, such as social stigma and self-protective biases, may also contribute to this possible underestimation. Future studies should incorporate objective measures, such as structured clinical interviews, to more accurately assess postpartum depression prevalence.

These findings suggest that the 5R system, with its structured progression and use of RUSI, shows promise as a targeted intervention for postpartum women seeking to improve muscle function and body composition. Clinicians can consider incorporating RUSI-guided core strengthening into postpartum rehabilitation programs, particularly for women with diastasis recti or core muscle weakness. The 5R system can be delivered in a clinical setting or adapted for home-based exercise programs with appropriate supervision. The use of the DPF facilitates the application of RUSI, making it more feasible for clinicians to provide real-time feedback to patients. Postpartum women with abdominal muscle weakness, pelvic instability, or elevated FBG levels may particularly benefit from the 5R system. Further research is needed to determine the optimal parameters of the intervention and to identify individual predictors of response.

Study Limitations

This study has several strengths, including a randomized allocation design, the use of RUSI for objective muscle assessment, and a comprehensive evaluation of multiple physical and metabolic parameters. However, several limitations should be noted. First, pre-pregnancy and early postpartum physical activity levels were not formally assessed using standardized instruments, although informal interviews indicated that most participants engaged in light to moderate activity before pregnancy. These data were not systematically collected and thus may have confounded the results. Second, dietary intake was not monitored, which could have contributed to variations in body composition and fasting blood glucose (FBG) outcomes across participants. Third, although the study was designed with progressive intensity and individualized supervision, exercise intensity was regulated using the subjective Borg Rating of Perceived Exertion (RPE) scale, and unintended variations in actual training load may have occurred due to inter-individual differences in perceived effort. Fourth, the RUSI measurements, though performed by a trained operator, are inherently operator-dependent. As such, potential variability in image acquisition and interpretation may have introduced measurement error. Fifth, the study employed a single-center design and used 1 assessor for outcome measurements, which may limit the generalizability and increase the risk of assessor bias. Additionally, exercise providers were not blinded, introducing a possible performance bias. Moreover, the relatively small sample size may have limited the statistical power to detect subtle differences between groups or interactions over time. The study duration was also limited to 12 weeks, preventing evaluation of the long-term effects and sustainability of the intervention.

Future research should include multicenter randomized controlled trials (RCTs) with larger sample sizes, extended follow-up periods, and the use of blinded assessors to improve internal and external validity. Objective monitoring of both dietary intake and daily physical activity using validated tools is also recommended to better control for potential confounding variables. Furthermore, comparative studies examining the effects of the 5R system on different delivery types (eg, vaginal vs cesarean) or patient subgroups (eg, with or without pelvic floor dysfunction) may help identify populations that benefit most. Economic analyses evaluating cost-effectiveness and studies on quality of life or pelvic floor function outcomes will further enhance the clinical relevance of the intervention.

Conclusions

Systematic postpartum rehabilitation exercise is essential and should be approached progressively based on the stages of

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recovery. A comprehensive postpartum exercise must incorporate deep core strengthening and resistance training. The 5R system, a structured rehabilitation exercise, can effectively enhance muscle thickness and strength and AFP, and lower FBG levels.

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