

Effect of combined training on body composition of adult who undergoing bariatric surgery: a systematic review

Efeito do treino combinado na composição corporal de adultos submetidos a cirurgia bariátrica: uma revisão sistemática

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ABSTRACT

Introduction: Bariatric surgery, when indicated, helps to reduce total body mass. However, for medium-to long-term efficacy, regular physical exercise is recommended as an adjuvant treatment to surgery. **Objective:** To verify, through a systematic review, the effect of combined training on the body composition of adults undergoing Roux-en-Y gastric bypass surgery (RYGB). **Methods:** The electronic search was carried out in the Pubmed, Scielo, and Lilacs databases, in English, Portuguese, and Spanish languages. Only randomized controlled studies with a combined training protocol after RYGB were included. **Results:** 2071 articles were identified, of which only six were eligible for this review. With a total of 272 participants, five of the articles analyzed had patients of both sexes in their sample and one had only women. Physical exercise attenuated the loss of bone mineral density in different regions (-1.87%-2.91%; $p = 0.007-0.038$), as well as preventing body mass gain. On the other hand, only the study by Herring et al. (2017) showed a greater reduction in body mass in subjects who performed physical exercise (- 2.4kg; $p = 0.003$). Finally, the assessment of muscle strength showed inconclusive data. **Conclusion:** The lack of studies with high methodological quality and low risk of bias, as well as the inadequate choice of assessment instruments to obtain measures of body integrity, has led to a significant reduction in body mass.

Keywords: gastroplasty; morbid obesity; physical exercise; jejunioleal bypass; exercise therapy

RESUMO

Introdução: A cirurgia bariátrica, quando indicada, contribui para a redução da massa corporal total. No entanto, para eficácia a médio e longo prazo, a prática de exercícios físicos regulares é indicada como tratamento adjuvante à cirurgia. **Objetivo:** Verificar, através de uma revisão sistemática, o efeito do treinamento combinado na composição corporal de adultos submetidos à cirurgia bariátrica de bypass gástrico em Y de Roux (BGYR). **Métodos:** A busca eletrônica foi realizada nas bases de dados Pubmed, Scielo e Lilacs, nos idiomas inglês, português e espanhol. Foram incluídos apenas estudos controlados e randomizados com protocolo de treinamento combinado após RYGB. **Resultados:** Foram identificados 2071 artigos, sendo apenas seis elegíveis para a presente revisão. Com um total de 272 participantes, cinco dos artigos analisados contêm pacientes de ambos os sexos em sua amostra e um tinha apenas mulheres. O exercício físico atenuou a perda de densidade mineral óssea em diferentes regiões (-1,87%-2,91%; $p = 0,007-0,038$), além de prevenir o reganho de massa corporal. Por outro lado, apenas o estudo de Herring et al. (2017) apresentou maior redução de massa corporal nos sujeitos que realizaram exercício físico (- 2,4kg; $p = 0,003$). Por fim, a avaliação da força muscular apresentou dados inconclusivos. **Conclusão:** A falta de estudos com alta qualidade metodológica e com baixo risco de viés, bem como a escolha inadequada dos instrumentos de avaliação para obtenção das medidas de interesse e o baixo número de artigos aptos para as medidas de interesse demonstram a necessidade de novos trabalhos a serem produzidos.

Palavras-chave: gastroplastia; obesidade mórbida; exercício físico; derivação jejunoileal; terapia por exercício

Introdução

The fight against obesity has become a significant public health challenge in Brazil, having been classified as a disease and/or chronic non-communicable condition in 2013.

According to 2021 data from the Surveillance of Risk and Protective Factors for Chronic Diseases by Telephone Survey [1], the percentage of adults with obesity was 22.35% [2]. The containment measures imposed by COVID-19 exacerbated this situation, as Brazil appears to have experienced a predominance of weight gain over weight loss during the pandemic [3].

Bariatric surgery is an invasive strategy used in situations in which the subject has a high risk of death due to obesity ($\geq 40 \text{ kg/m}^2$ or $\geq 35 \text{ kg/m}^2$ with comorbidity). Despite the data from the last two years showing a decrease in the number of bariatric surgeries, this reduction may be attributed to the pandemic [4]. Currently, the most widely used bariatric surgery technique in Brazil by the SUS is gastric bypass, also known as Roux-en-Y intestinal bypass gastroplasty (RYGB) [5].

This procedure is performed with a stapling of part of the stomach and a deviation of the initial part of the small intestine, reducing the area available to hold food and favoring the increase in the production of hormones associated with satiety [6]. These effects favor the loss of body mass and attenuation of comorbidities associated with obesity [6].

However, many patients experience a regain of body mass months after surgery [7–9]. The drop in basal metabolic rate [10], reduction in muscle mass [11], and nutritional deficiencies [12] may explain this phenomenon. Another chronic adverse effect associated with RYGB is the accelerated reduction in bone mineral density, increasing the risk of fractures [13]. Additionally, public spending on gastric bypass surgery, also known as gastroplasty, has increased significantly over the last decade [14]. However, the adoption of a physical training program as a non-pharmacological therapeutic activity may represent an important strategy to combat the adverse effects observed after RYGB, as it helps to promote the reduction of body mass [15], blood pressure [16], in addition to stimulating the increase of strength and muscle mass [17].

Among the established models of physical exercise prescription, combined training

is particularly noteworthy.

This training protocol designed to promote better metabolic control and body mass, being defined as programs that combine strength training and aerobic capacity in the same exercise session, as well as the possible antagonistic adaptations produced by both [18].

Although physical exercise alone is not the primary driver of body mass reduction, its positive effects on health justify the pursuit of further studies to develop strategies and training proposals that promote greater adherence, reduce sedentary

lifestyles, minimize public costs, and mitigate related comorbidities [18].

Therefore, the objective of this systematic review was to verify the effect of combined training on body mass, muscle mass, muscle strength, bone mineral density, and body mass regain in adult individuals who underwent RYGB.

Methods

Protocol and registration

The present study followed the recommendations of the PRISMA Declaration and was registered in the International Prospective Register of Systematic Reviews (PROSPERO) with the identifier CRD42021286299 [19].

Eligibility criteria

Following the strategy PICOS (participants, intervention, comparator, result and design of the studies) were considered as inclusion criteria for the selection of studies for this review: (1) the participants were individuals of both sexes from 18 to 60 years of age submitted to RYGB, (2) internationally accepted standards for undergoing bariatric surgery ($\text{BMI} \geq 35 \text{ kg/m}^2$ associated with comorbidities or $\text{BMI} \geq 40 \text{ kg/m}^2$), (3) the performance of only combined exercises as an intervention strategy after 3 months of RYGB, (4) the studies would have to have at least one of the outcomes of interest (body mass, muscle mass, muscle strength, bone mineral density and body mass regain) of this review in their results, (5) only randomized controlled studies were accepted. Studies in which the intervention was performed before the RYGB and studies considered gray literature were excluded.

Search strategy

Between January 26 and February 2, 2022, the authors (TSA, BAR, and ISS) searched the PubMed, Scielo and Lilacs databases. No filter was used for the period of publication and the native language of the original text. The following search terms were used: combined training, combined exercise, concurrent training, concurrent exercise, aerobic resistance, training, physical activity, exercise, therapy, aerobic-resistance program, gastric bypass, bariatric surgery, gastroplasty, body composition, weight loss, cap density, bone mineral density, muscle strength, body mass, strength, Roux-en-Y, gastroplasty, entrenamiento concurrente, concurrent training, concurrent training protocol, combined exercise training, physical activity, physical exercise, gastroplasty, concurrent training, combined training, bariatric surgery, obesity, morbid obesity, physiology, surgery, therapy, gastric bypass, bone density, weight loss, muscle strength, body composition, body weight changes. For each database, a specific search equation was used, taking into account the characteristics of each one.

Selection process

We located 2071 records. Then, using EndNote Web, the duplicates were found and deleted. This process was repeated with a visual inspection to delete the duplicate records not identified by the platform. Subsequently, the screening and eligibility processes were carried out, in which two authors (TSA and BAR) performed the selection independently. In the screening, the selection was performed by reading the titles and abstracts. During the eligibility process, the evaluation was conducted by reading the full text of the selected articles. After individual evaluation, both in the screening processes and in eligibility, the evaluators met to resolve the divergences. When the disagreements remained, a third evaluator (RFC) made the decision. Ultimately, six articles were included in this study. The entire process is presented in the flowchart of systematic review steps (Figure 1).

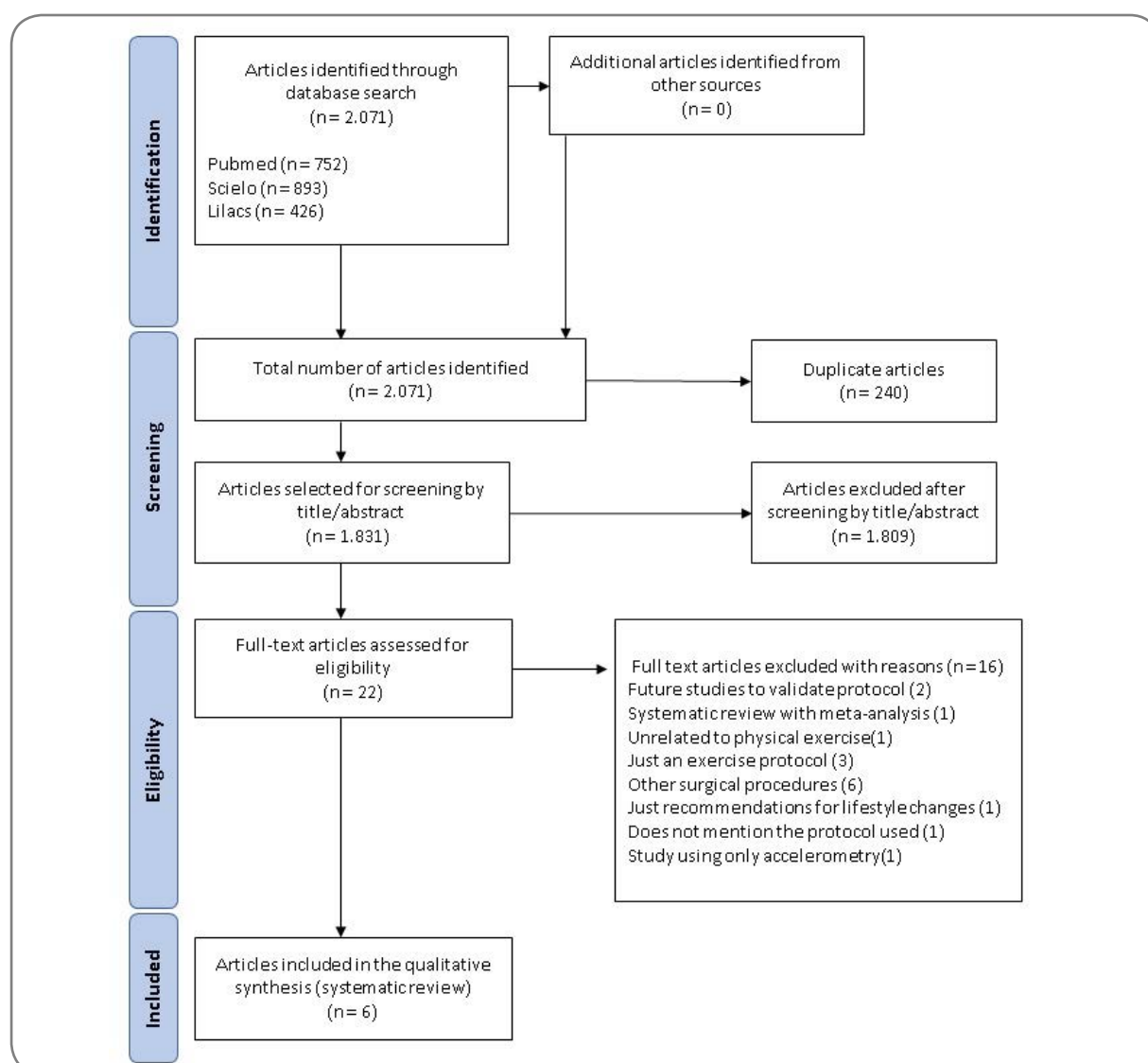


Figure 1 - PRISMA 2020 flow diagram for searches of databases, registrar and other sources

In October 2024, a new search was conducted, with a selection period of publications from 2022 to 2024, to update the database for this review. This new search used the same process as the previous one. In this update, 35 new articles were found, but none of them met the search criteria determined for this systematic review. Of the 35 articles found, seven were removed because they had a different outcome, seven were removed because they had a different study time, and 21 were removed due to incompatibility.

Methodological quality assessment and risk of bias

Methodological quality was assessed through the Tool for the Assessment of Study quality and reporting in Exercise (TESTEX), which was developed specifically for studies that use physical training as an intervention [20]. The identification of the risk of bias of randomized clinical trials was performed through Cochrane's Risk of Bias tool version 2 (RoB 2) [21]. Both the methodological quality and the risk of bias followed the same procedure. Two researchers (TSA and BAR) performed both evaluations independently. Then a meeting was held to resolve the disagreements, and when necessary, a third researcher (RFC) made the final decision [21].

Results

Characteristics of the studies

Information on population, treatment, and results of the measures of interest is presented in Table I. In general, the sample size among these studies ranged from 15 to 60 subjects, aged between 30 and 50 years. Only one study (16.7%) was composed of an exclusively female sample and the remaining five studies (83.3%) included participants of both sexes. In three articles (50%) analyzed, physical exercise was initiated between 12 and 24 months after RYGB [22-24]. In two other studies (33.3%), the intervention with physical exercise started 1 month after RYGB [25-26] and in only one study (16.67%), the training began 3 months after the RYGB [27]. In general, the intervention with physical exercise lasted between 3 and 6 months. Physical exercise interventions occurred 2 to 3 times a week. Each training session lasted approximately 60 to 75 minutes. In all the articles evaluated, the combined training was supervised. It consisted of a warm-up period, aerobic exercises, strength exercises, and was concluded by a cooling period (return to calm).

Body mass and body mass regain

No significant differences were observed in the loss of body mass between the intervention and control groups in the studies selected for this systematic review [22-26]. However, three studies have shown that combined training was able to prevent weight regain after 6 to 12 months of training [22-24]. Mundbjerg et al. [23-24] demonstrated that after the intervention period with combined exercises performed in a supervised manner, participants were able to maintain body mass for the sub-

sequent 12 months. This result is a strong indication of the positive influence of combined exercise and the necessity of maintaining adherence to avoid weight regain.

Table I - Studies included in the systematic review

Author (year)	Sample	Duration and weekly frequency of the physical exercise protocol	Physical exercise protocol	Variables of interest	Instruments	Results
Hering et al. (2017) [22]	24 (W + M) IG = 12 CG = 12 (48.4 ± 8.9 years) 12 a 24 month after BC	3 months 3x weeks	TA 2 weeks 35min ↑ 45min 64 a 77% HRmax PSE (12-14) TF 3 de 12 rep c/ 30 a 60s RECOV LL, LP; ABD; EX	FF FPM MS BC	ISWT DINAM TSLC BIOIMPED	IG X CG FF: ↑ 143,3 ± 86,6 m x CG ↓ 32,50 ± 75,93 FPM: IG ↑ DINAM right side 2,5kg x CG ↓ 0,9kg MC 12 weeks: IG ↓ 2,4kg x CG ↑ 1,0kg MC 24 weeks: IG ↓ 2,9kg x CG ↑ 2,9kg
Mundbjerg et al. (2018) [23]	60 (m =18; w= 42) IG = 32 CG = 28 (42.3 ± 9.1 years) 12 a 24 month after BC	6 months 2x weeks	TA 15min CYCLE 6-20 PSE + 10min OPC 50% VO2máx ↑ 50 a 70% ↑ 70% TF 10min UL, EL; PD; BENCH 20 rep 60% 1RM ↑ 15 rep 65% 1RM ↑ 10 rep 75% 1 RM	BC MS UL MS LL	ANTHROP DINAM TSLC TSE	IG X CG MC 12 months: IG = CG MC 24 months: IG ↓ 0,1 kg x CG ↑ 2,1 kg MS LL: IG ↑ 8,3N MS UL: IG = CG
Mundbjerg et al. (2018) [24]	60 (M= 18; W= 4) IG = 32 CG = 28 (42.3 ± 9.1 years) 12 a 24 month after BC	6 months 2x weeks	TA 15min CYCLE + 15min OPC TF 10min UL FSI: 50% VO2máx to FSF: 70%	BC VGA	ANTHROP SCANNER	IG X CG MC 12 months: IG = CG MC 24 months: IG ↓ 0,1 kg x CG ↑ 2,1 kg VGV: IG = CG RCQ: IG = CG

Table I - Continuation

Author (year)	Sample	Duration and weekly frequency of the physical exercise protocol	Physical exercise protocol	Variables of interest	Instruments	Results
Stegen et al. (2011) [25]	15 (M= 4; W= 11) IG: 8 CG: 7 (40.5 ± 8.1 anos) 1 month after BC	3 months 3x weeks	TA 30min (10min CYCLE + 10min CAM + 10min STEP) 60% ↑ 75% FCR TF 25min FLE e EX ELB e KNEE c/ 15 initial session 2x 15rep a 60% 1RM; 18 final session 3x de 10rep a 75% 1RM c/ 60s RECUP	BC FM STA-TIC MS DYNAMIC	ANTHROP BIOIMPED MC= MLG + MG 1RM METOD HOLTEN DINAM TSL	IG X CG FPM: IG = CG CC: IG = CG MS UL: IG ↑ BÍC 18,8%; ↑ TRÍC 26,3% x CG ↓ BIC 23,8%; ↓ TRIC 26,9% MS LL IG ↑ 63,3% QUADR x CG ↓ 19,9% QUADR CF MS: CG ↓ 16% QUADR; 36% BÍC; 39% TRÍC
Murai et al. (2019) [27]	W = 70 IG = 35 (40.0 ± 7.8) CG = 35 (42.1 ± 8.2) 3 months after BC	6 months 3x weeks	TA 30 a 60min (↑ 10 min every 4 weeks) CAM EST (50%) TF 3x 8 a 12 rep LLLL + UL LG; EX leg; ½ SQUAT; BENCH; PD; ROW e CALF c/ 60 RE-CUP ↑ 5% load	DMO VOL. DMO BC MRO	DEXA HR-pQCT EXBIO	TF ↓ the loss of DMO no FEM, QUADR e RD e ↓ collagen type I C-telopeptide, procollagen and sclerostin
Noack-Segovia et al. (2019) [28]	43 (W= 32; M= 11) IG = 21 CG = 22 (33 ± 6.9 years) 1 month after BC	6 months 3x weeks	TA 30min TREAD WALK 54% ↑ 59% HRdRes TF 15min UL BIC; TRIC; DELT; PEIT ↑ INT e REP 1RM CYCLE 15min ST LL+ UL c/ BREATH.	BC MS	BIOIMPED DINAM	IG X CG (after 6 months) MC: IG = CG MS: IG = CG MM: IG = CG MG: IG = CG

*IG = Intervention Group; CG = Control Group; WHR = Waist-Hip Ratio; BS = Bariatric Surgery; MS = Muscle Strength; AEROB = Aerobic training; ST = Strenght training; HRR = Reserve Heart Rate; MMSS = Upper Limbs; LLLL = Lower Limbs; PSE = Perception of Effort; Rep = Repetitions; INT = Intensity; 1RM = one maximum repetition; BM = Body Mass; BC = Body Composition; FM = Fat Mass; FFM = Fat-Free Mass; BMD = Bone Mineral Density; IWT = Incremental Walking Test; HR = Heart Rate; LP = Leg Press; SIT = Sit-ups; PUSH = Push-ups; EX = Extensions; ELB = Elbow; KNEE = Knee; FF = Physical Function; OPC = Optional; IP = Initial Phase; FP = Final Phase; VFV = visceral fat volume; WALK = Walking; STEP = “stepping”; “=” = no significant difference; HGS = Handgrip Strength; FC = Functional Capacity; TREAD = Treadmill; DINAM = Dynamometer; MF = Muscle Function; SSL = Sit and Stand Up Test; STRETCH = Stretching; ANTHROP = Anthropometry; LCT = Ladder Climbing Test; AFV = Abdominal Fat Volume; BIA = Bioimpedance; DEXA = Bone Densitometry; VOL= Volume; HR-pQCT = high-resolution peripheral quantitative computed tomography; BRM = Bone Remodeling Markers; EXBIO = Biochemical Tests; HRdRes = Capacity and Frequency of Resistance; QUADR = Quadriceps; HAMS = Hamstrings; BIC = Biceps; TRÍC = Triceps; DELT = Deltoid; PEIT = Pectoral; CYCLE = Cycle ergometer; BREATH. = Breathing Exercises; LM = lean mass; HRmax = maximum heart rate; RECOV = Recovery; LE = Lateral elevation; PULL = Pull or Pull Down; BENCH = Bench press; SQUAT = Squat; CALF = Calf; FEM = Femur; DR = Distal Radio

Table II - Studies with a 3-month treatment protocol included in the systematic review

Author (year)	Hering et al. (2017) [22]	Stegen et al. (2011) [25]
Sample	24 (M + W) IG = 12 CG = 12 (48.4 ± 8.9 years) 12 to 24 months after BS	15 (M= 4; W= 11) IG:8 CG:7 (40.5 ± 8.1 years) 1 month after BS
Duration/Weekly Frequency of the physical exercise protocol	3 months 3xweek	3 months 3xweek
Physical exercise protocol	AEROB 2weeks 35min ↑ 45min 64 to 77% HRmax PSE (12-14) ST 3 of 12 rep w/ 30 to 60s RECOV MMII LP; ABD; EX	ST 30min (10min CYCLE + 10min WALK + 10min STEP) 60% ↑ 75% HRR ST 25min PUSH and EX ELB and KNEE w/ 15 initial sessions 2x 15rep at 60% 1RM 18 final 3x sessions of 10rep at 75% 1RM w/ 60s RECOV
Variables of interest	FF HGS MS BC	BC STATIC MS NAMIC MS DY-
Instruments	IWT DINAM SSL BIA	ANTHROP BIA BM= FFM + FM 1RM HOLTEN METHOD SSL DINAM
Findings	IG X CG FF: ↑ 143.3 ± 86.6 m x CG ↓ 32.50 ± 75.93 HGS: IG ↑DINAM right side 2.5kg x CG ↓ 0.9kg BM 12 weeks: IG ↓ BM 24 weeks: IG ↓ 2.9kg x GC ↑ 2.9kg2.4kg x CG ↑ 1.0kg	IG X CG FPM: IG = CG CC: IG = CG MS MMSS: IG ↑ BÍC 18,8%; ↑ TRÍC 26,3% x CG ↓ BÍC 23,8%; ↓ TRIC 26.9% MS MMII: IG ↑ 63,3% QUADR x CG ↓ 19,9% QUADR FC MS: CG ↓ 16% QUADR; 36% BÍC; 39% TRIC

*IG = Intervention Group; CG = Control Group; WHR = Waist-Hip Ratio; BS = Bariatric Surgery; MS = Muscle Strength; AEROB = Aerobic training; ST = Strength training; HRR = Reserve Heart Rate; MMSS = Upper Limbs; LLLL = Lower Limbs; PSE = Perception of Effort; Rep = Repetitions; INT = Intensity; 1RM = one maximum repetition; BM = Body Mass; BC = Body Composition; FM = Fat Mass; FFM = Fat-Free Mass; BMD = Bone Mineral Density; IWT = Incremental Walking Test; HR = Heart Rate; LP = Leg Press; SIT = Sit-ups; PUSH = Push-ups; EX = Extensions; ELB = Elbow; KNEE = Knee; FF = Physical Function; OPC = Optional; IP = Initial Phase; FP = Final Phase; VFV = visceral fat volume; WALK = Walking; STEP = "stepping"; "=" = no significant difference; HGS = Handgrip Strength; FC = Functional Capacity; TREAD = Treadmill; DINAM = Dynamometer; MF = Muscle Function; SSL = Sit and Stand Up Test; STRETCH = Stretching; ANTHROP = Anthropometry; LCT = Ladder Climbing Test; AFV = Abdominal Fat Volume; BIA = Bioimpedance; DEXA = Bone Densitometry; VOL= Volume; HR-pQCT = high-resolution peripheral quantitative computed tomography; BRM = Bone Remodeling Markers; EXBIO = Biochemical Tests; HRdRes = Capacity and Frequency of Resistance; QUADR = Quadriceps; HAMS = Hamstrings; BIC = Biceps; TRÍC = Triceps; DELT = Deltoid; PEIT = Pectoral; CYCLE = Cycle ergometer; BREATH. = Breathing Exercises; LM = lean mass; HRmax = maximum heart rate; RECOV = Recovery; LE = Lateral elevation; PULL = Pull or Pull Down; BENCH = Bench press; SQUAT = Squat; CALF = Calf; FEM = Femur; DR = Distal Radio

Muscle mass and muscle strength

Unfortunately, none of the studies selected for this systematic review measured muscle mass. On the other hand, muscle strength was the focus of interest in four selected studies [22,23,25,26]. Only Stegen et al. [25] showed significant differences in strength gain in the quadriceps, biceps brachii, and triceps brachii. The other three articles [22,23,26] presented inconclusive results regarding this one. Although Mundingberg et al. [23] observed significant differences in strength in hip abduction, the same did not happen in the other axes of hip and deltoid movement, while Noack-Segovia et al. [26] and Herring et al. [22] did not identify significant differences in handgrip strength.

Bone mineral density

Only Murai et al. investigated the effects on bone mineral density through DEXA, high-resolution peripheral quantitative computed tomography (HR-pQCT), and biochemical tests. The study observed that supervised training reduced the damage caused by RYGB in the BMD of the femur, quadriceps, and distal radius regions. In addition, they demonstrated that the training was able to minimize the levels of collagen type I C-telopeptide (a marker of bone resorption), procollagen, and sclerostin (a protein inhibitor of osteoblast activity) [27].

Testex Scale and Risk of Bias

In the Testex scale, studies considered to be of high methodological quality have a score of 10 points or higher. Just the work of Stegen et al. [25] received a rating below this cut-off point. None of the studies blinded the evaluators to at least one result of interest, and only one article collected information about possible participation in physical activity outside the study among the participants in the control group [26].

Through the Cochrane tool, it was possible to observe that of the six studies selected for the present systematic review, five obtained an uncertain risk classification of bias, and the one article was classified with high risk of bias.

The individual results of each study, for regarding methodological quality and risk of bias are presented in Tables IV and V, respectively.

Table III - Studies with a 6-month treatment protocol included in the systematic review

Author (year)	Mundbjerg et al. (2018) [23]	Mundbjerg et al. (2018)[24]	Murai et al. (2019) [27]	Noack-Segovia et al. (2019) [28]
Sample	60 (M =18; W= 42) IG = 32 CG = 28 (42.3 ± 9.1 years) 12 to 24 months after BS	60 (M= 18; W= 4) IG = 32 CG = 28 (42.3 ± 9.1 years) 12 to 24 months after BS	W = 70 IG = 35 (40.0 ± 7.8) CG = 35 (42.1 ± 8.2) 3 months after BS	43 (M= 32; W= 11) IG = 21 CG = 22 (33 ± 6.9 years) 1 month after BS
Duration/Weekly/Frequency of the physical exercise protocol	6 months 2x week	6 months 2x week	6 months 3x week	6 months 3x week
Physical exercise protocol	ST 15min CYCLE 6-20 PSE + 10min OPC 50% VO ₂ max ↑ 50 to 70% ↑ 70% ST 10min MMSS LE; PD; SUP 20 REP 60% 1RM ↑ 15 rep 65% 1RM ↑ 10 rep 75% 1 RM	ST 15min CYCLE + 15min OPC ST 10min MMSS IP: 50% VO ₂ max to FP: 70%	AEROB 30 to 60min (↑ 10 min every 4 weeks) WALK TREAD (50%) ST 3x 8 to 12 rep MMII + MMSS LG; EX leg; 1/2 SQUAT; SUP; PD ROWING and CALF w/ 60 RECOV ↑ 5% load	AEROB 30min WALK TREAD 54% ↑ 59% HRdRes ST 15min MMSS BIC; TRIC; DELT; PEIT ↑ INT and REP 1RM CYCLE 15min STRETCH MMII + MMSS w/ BREATH
Variables of interest	BC MS MMSS MS LLLL	BC VFV	BMD VOL. DMO BC MRO	BC MS
Instruments	ANTHROP DINAM SSL LCT	ANTHROP SCANNER	DEXA HR-Pqct EXBIO	BIA DINAM
Findings	IG X CG BM 12 months: IG = CG BM 24 months: IG ↓ 0.1 kg x CG ↑ 2.1 kg MS MMII: IG ↑ 8.3N MS MMSS: IG = CG	IG X GC BM 12 months: GI = CG BM 24 months: IG ↓ 0.1 kg x CG ↑ 2.1 kg PSV: IG = CG WHR: IG = CG	ST ↓ the loss of BMD in the FEM, QUADR and DR and ↓ collagen type I C-telopeptide, procollagen and sclerostin	IG X CG (after 6 months) BM: IG = CG MS: IG = CG MM: IG = CG FM: IG = CG

*IG = Intervention Group; CG = Control Group; WHR = Waist-Hip Ratio; BS = Bariatric Surgery; MS = Muscle Strength; AEROB = Aerobic training; ST = Strength training; HRR = Reserve Heart Rate; MMSS = Upper Limbs; LLLL = Lower Limbs; PSE = Perception of Effort; Rep = Repetitions; INT = Intensity; 1RM = one maximum repetition; BM = Body Mass; BC = Body Composition; FM = Fat Mass; FFM = Fat-Free Mass; BMD = Bone Mineral Density; IWT = Incremental Walking Test; HR = Heart Rate; LP = Leg Press; SIT = Sit-ups; PUSH = Push-ups; EX = Extensions; ELB = Elbow; KNEE = Knee; FF = Physical Function; OPC = Optional; IP = Initial Phase; FP = Final Phase; VFV = visceral fat volume; WALK = Walking; STEP = “stepping”; “=” = no significant difference; HGS = Handgrip Strength; FC = Functional Capacity; TREAD = Treadmill; DINAM = Dynamometer; MF = Muscle Function; SSL = Sit and Stand Up Test; STRETCH = Stretching; ANTHROP = Anthropometry; LCT = Ladder Climbing Test; AFV = Abdominal Fat Volume; BIA = Bioimpedance; DEXA = Bone Densitometry; VOL= Volume; HR-pQCT = high-resolution peripheral quantitative computed tomography; BRM = Bone Remodeling Markers; EXBIO = Biochemical Tests; HRdRes = Capacity and Frequency of Resistance; QUADR = Quadriceps; HAMS = Hamstrings; BIC = Biceps; TRIC = Triceps; DELT = Deltoid; PEIT = Pectoral; CYCLE = Cycle ergometer; BREATH. = Breathing Exercises; LM = Lean Mass; HRmax = maximum heart rate; RECOV = Recovery; LE = Lateral elevation; PULL = Pull or Pull Down; BENCH = Bench press; SQUAT = Squat; CALF = Calf; FEM = Femur; DR = Distal Radio

Table IV - Methodological quality result through the TESTEX Scale

Studies	Domains												Total
	1	2	3	4	5	6	7	8	9	10	11	12	
Stegen <i>et al.</i> (2011) [25]	1	0	0	0	0	1	0	2	1	0	1	1	7
Hering <i>et al.</i> (2017) [22]	1	1	1	1	0	2	1	2	1	0	1	1	12
Mundbjerg <i>et al.</i> (2018) [23]	1	1	1	1	0	1	1	2	1	0	1	1	11
Mundbjerg <i>et al.</i> (2018) [24]	1	1	0	1	0	1	1	2	1	0	1	1	10
Murai <i>et al.</i> (2019) [27]	1	1	1	1	0	1	1	2	1	0	1	1	11
Noack-Segovia <i>et al.</i> (2019) [28]	1	1	0	1	0	2	0	1	1	1	1	1	10

Domain 1: specified eligibility; 2: specified randomization; 3: allocation concealment; 4: baseline-like groups; 5: evaluator blinding; 6: outcome measures; 7: intention-to-treat analysis; 8: statistical comparisons; 9: point and variability measures; 10: control group monitoring; 11: relative exercise intensity; 12: exercise volume and energy cost

Table V - Risk of bias of selected articles

Author (year)	Domains					Results
	1	2	3	4	5	
Herring <i>et al.</i> (2017) [22]	↓	↔	↓	↓	↔	Some concerns
Mundbjerg <i>et al.</i> (2018) [23]	↓	↔	↓	↓	↔	Some concerns
Mundbjerg <i>et al.</i> (2018) [24]	↓	↔	↓	↓	↔	Some concerns
Murai <i>et al.</i> (2019) [27]	↓	↔	↓	↓	↓	Some concerns
Noack-Segovia <i>et al.</i> (2019) [28]	↓	↔	↓	↓	↓	Some concerns
Stegen <i>et al.</i> (2011) [25]	↑	↔	↓	↓	↔	High risk of bias

Criteria 1: Bias arising from the randomization process; 2: Bias due to deviations from intended interventions; 3: Bias due to missing outcome data; 4: Bias in measurement of the outcome; 5: Bias in selection of the reported result; ↓: low risk of bias; ↔: some concerns; ↑: high risk of bias

Discussion

The present systematic review identified that combined training was able to prevent the regain of body mass and minimize the loss of bone mineral density observed in the control groups. However, the reduction in body mass, fat-free mass, and muscle strength after surgery was similar between the groups regardless of exercise. Further studies are needed to better understand changes in muscle mass, because this variable is usually observed indirectly through fat-free mass. In general, great care should still be taken in interpreting these results, especially regarding bone mineral density, due to the limited number of studies available.

The initial hypothesis shared among some authors [22,25], that the inclusion of combined training could maximize the loss of body mass after RYBG due to the combination of reduced caloric intake with increased energy expenditure caused by exercise has not been confirmed [22,24,25]. Despite the limitation of not having

calculated the caloric expenditure of the exercise, likely, that the energy expenditure was not high due to the inherent characteristics of the population studied and the combination of volume and intensity proposed. In addition to the low energy expenditure of the proposed exercises, the gross energy expenditure of the exercise needs to be subtracted from the basal metabolic rate at rest, since, for the individual to engage in an exercise program, must stop performing other activities at rest [28]. Therefore, the effective energy expenditure of the exercise program is reduced, and insufficient to induce the reduction of body mass. However, the training was able to avoid the regain of body mass in up to 12 months [22–24]. In addition to the exercises, the subjects of the training group received recommendations on diets and the adoption of an active lifestyle soon after the intervention period. Such recommendations may have contributed to the result, considering that the regain of body mass is often attributed to the lack of adherence to adequate eating habits and physical exercise routine [22,24]. The importance of this finding lies in the observation that body weight regain occurs in several subjects who undergo RYGB and has significant negative impact on health [29].

Regarding muscle strength, the results are inconclusive [22,23,25,26]. Four studies evaluated the impact on strength, and three of these studies did not observe a significant difference [22,25,26]. All studies that did not observe any difference in the ability to produce strength in subjects trained with combined versus untrained exercises (control group) after RYGB, with strength measured with the handgrip test. However, caution is needed in interpreting these results because this measure of strength is dependent on a particular task. None of the three studies included handgrip exercises in their training program. Therefore, the non-specificity of the exercise program with the strength measurement performed in the tests may mask the possible strength gains in the muscle groups trained [22,26]. This hypothesis could be reinforced by Stegen et al. [25] who observed a significant increase in strength levels in the quadriceps, biceps brachii, and triceps brachii after 12 weeks in the subjects undergoing the training compared to their untrained peers. However, Stegen et al. [25] presented a serious threat to the risk of bias for random sequence generation (randomization) and allocation concealment. Thus, further studies are needed to determine the real actual effect of a combined exercise program on muscle strength gains in obese individuals undergoing RYGB.

Although few studies have sought to observe the effect of combined exercises on bone mineral density, their training appears to reduce the negative impact caused by RYGB [27]. Murai et al. [27] observed that supervised combined training attenuated bone loss in the quadriceps, femur, and distal radius regions, also obtained benefits in reducing bone resorption components [27]. RYGB promotes the increase of sclerostine and DKK-1, which are responsible for the inhibition the WNT signaling pathway that primarily acts on bone remodeling through osteoblast stimulation [30]. Combined exercise can be a direct agent in preserving bone mineral density by decreasing the concentrations of sclerostine and DKK-1 in the bloodstream [27].

It is estimated that 31% of the reduction in post-surgical body mass is a reflection of the decrease in fat-free mass [31,32]. Due to reduced food and caloric consumption, nutrient absorption is hampered, which markedly decreases lean mass, exerting metabolic, anti-inflammatory effects, maintaining insulin sensitivity, and reducing oxidative stress [33]. However, muscle mass is just another component of fat-free mass [34]. Therefore, the specific measurement of muscle mass is fundamental to understanding the extent to which physical exercise can contribute to reducing the adverse effects of RYGB on this variable. In the studies suitable for this review, none measured the muscle mass directly, instead observing only the changes in fat-free mass [22,25,26]. Therefore, measuring of fat-free mass must not be sufficient to understand this important variable for the health of the target population. Consequently, further studies are needed to understand better the effects of combined exercise training on muscle mass.

An important limitation of the studies selected for this systematic review is the low adherence to training reported by some [23,24]. In the studies by Mundjberg et al. [23,24], 32 subjects were examined. Only 59.4% had training frequency equal to or greater than 50% of the sessions, while 25% attended less than 10% of the scheduled training sessions. In addition to the low adherence to the practice of physical exercise characteristic of the sample, the authors reported that the subjects were trained in a public training center. This condition may have contributed to the low attendance rate, as the subjects could experience low self-esteem and dissatisfaction with their body mass. In addition, the long distance between the residences of some participants, and the training site, as well as the workload, may have impacted the rate of attendance at exercise sessions [23,24]. The absence of control over caloric intake or the observation of dietary habits of study participants through food recall was observed in several studies [25-27]. The control of eating behavior not only facilitates the correct observation of changes in body composition and strength level, but can also interfere with bone mineral density results, as RYGB causes changes in the percentages of absorption of dietary macro- and micronutrients [27,35].

An important difference of this systematic review was the evaluation of both the risk of bias by the Cochrane Scale and the methodological quality by TESTEX, allowing for a comprehensive of the confidence and extrapolation of the results of the selected articles. Given this, it was possible to observe that half of the studies selected in this systematic review presented, in at least one domain of the Cochrane scale, a high risk of bias, despite having high scores on the TESTEX scale. Therefore, the certainty of the results observed (internal validity) in the selected studies is diminished, reinforcing the need for further studies with greater methodological rigor.

The present review also demonstrated that there are still gaps to be investigated in regarding combined exercise training and the target population, especially in terms of measuring muscle mass and bone mineral density, as well as efforts to minimize the risks of bias commonly observed in these studies. Although it was not the primary focus of this review, and the selected studies present some important

limitations, it was observed that a combined exercise program can improve functionality [23], reduce cardiovascular risks [24] and the lipid profile [24] of subjects who underwent RYGB. These results taken together can contribute to an improved overall quality of life of the individual.

Conclusion

Although physical exercise is commonly recommended to individuals who have undergone bariatric surgery, the knowledge gap regarding the effect of combined exercise training in this population remains substantial. The lack of high-quality studies with low risk of bias, the inadequate choice of evaluation tools to obtain measures of interest, and the limited number of articles selected for the measures of interest underscore the need for new studies to be conducted to increase confidence in the reported results.

Of the measures of interest, the non-observation of the most significant body weight reduction between the individuals who trained and the control, as well as the lower magnitude of weight regain in the trained individuals, has the best reliability in the observations compared to the other measures of interest (bone mineral density, strength and muscle mass).

Conflict of interest

All authors declare no conflict of interest

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Authors' contributions

Conception and design of the research: Carvalho R, Pires L; Data collection: Almeida T, Arruda B Tenius V; Data analysis and interpretation: Carvalho R, Pires L; Statistical analysis: Carvalho R, Pires L; Writing of the manuscript: Almeida T, Arruda B; Critical revision of the manuscript for important intellectual content: Carvalho R, Pires L

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