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Obesity Prevention

Impact of physical activity and fitness in class II and III obese individuals: a systematic review

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Summary

The objective of this systematic review was to appraise current knowledge on the impact of physical activity (PA) and physical fitness (PF) on the health of class II and III obese subjects and bariatric surgery (BS) patients. All original studies were searched using four databases (Medline®, Scopus®, CINAHL and Sportdiscus). Two independent investigators selected studies assessing the impact of PA or PF on specific health outcomes (anthropometric parameters, body composition, cardiometabolic risk factors, PF, wellness) in adults with a body mass index ≥35 kg m^{-2} or in BS patients. Conclusions were drawn based on a rating system of evidence. From 3,170 papers identified, 40 papers met the inclusion criteria. The vast majority of studies were recently carried out with a predominance of women. Less than one-third of these studies were experimental and only three of them were of high quality. Each study reported at least one beneficial effect of PA or PF. However, a lack of high-quality studies and heterogeneity in designs prevented us from finding high levels of evidence. In conclusion, although results support the importance of PA and PF to improve the health of this population, higher-quality trials are required to strengthen evidence-based recommendations.

Keywords: Bariatric surgery, exercise, health, severe obesity.

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Introduction

Physical activity (PA) intervention is strongly recommended by experts in the medical and surgical management of obesity (1–5). However, no recommendation on PA prescription (type, frequency, duration, intensity) is currently available for people with severe obesity, and PA recommendations for bariatric surgery (BS) patients come from those used in the general population of obese subjects (3,6). Considering the increasing prevalence of severe obesity during the last decade in North America (7,8), the development of an optimal PA intervention is necessary.

Several studies have concluded that regular PA improves weight loss when combined with diet or BS, as well as

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weight loss maintenance in the context of obesity in general (9–14). Moreover, regular practice of PA, with or without weight loss, may induce other health benefits, such as improving cardiometabolic risk factors and quality of life (QOL) in obese individuals (4,14–16). For most individuals, an increase in PA is associated with an increase in physical fitness (PF) (17). Even though PA and PF are closely related, PF depends not only on the PA level, but also on genetic components (17). PF is defined by the ability to carry out daily tasks with vigour and alertness, without undue fatigue and with ample energy to enjoy leisure–time pursuits and to meet unforeseen emergencies (18), whereas PA is any bodily movement produced by skeletal muscles that results in energy expenditure (19). Thus, it is important to consider these two parameters in parallel. The improvement of PF by itself is an interesting target as it is shown to be more easily achievable than weight loss and is associated with a reduction in cardiovascular risks and premature mortality in obese individuals (20–22). In addition, improving PF of candidates for BS could potentially reduce perioperative complications, as higher PF has been associated with lower risks of complications during and after BS (23–25).

The health benefits of PA and PF presented earlier have not been thoroughly examined in people with class II (body mass index [BMI] 35–39.9 kg m^{-2}) and III ($\text{BMI} \geq 40\ \text{kg m}^{-2}$) obesity (26) and no systematic review is currently available on this subject. Yet, this population requires to be considered specifically because of higher premature mortality rates and prevalence of comorbidities, such as hypertension, type 2 diabetes, dyslipidaemia, cardiovascular disease, sleep apnoea and cancer; poorer QOL and PF; and more musculoskeletal pain compared with people with less severe obesity (27–30). Moreover, a distinction is needed within the population with class II and III obesity, between surgery-seekers and lifestyle intervention-seekers as several studies showed that BS-seekers are more likely to have higher BMI and comorbidities, and lower QOL (30–33).

Therefore, the first objective of this systematic review was to appraise current knowledge available in all peer-reviewed original studies on the impact of PA or different PA modalities on (i) anthropometric parameters and body composition; (ii) cardiometabolic risk factors; (iii) PF and (iv) QOL and psychological parameters in adult subjects with class II and III obesity and in subjects awaiting or having undergone BS.

Secondly, we aimed to evaluate the current knowledge available in all peer-reviewed original studies on the association between PF level and the outcomes identified earlier in adult subjects with class II and III of obesity and in BS subjects. Finally, we aimed to identify key knowledge gaps and research priorities on the impact of regular PA among these populations.

Methods

Information sources and search

This systematic review follows the guidelines of the Preferred Reporting Items for Systematic Reviews and Meta-analysis (34). A systematic search of relevant literature was conducted in four databases (Medline®, Scopus®, CINAHL and Sportdiscus) and the reference lists of selected studies were hand-searched to find other potentially eligible studies (cross-referencing). In addition, PA and obesity experts were consulted to add relevant missing references. No publication date restrictions were used in any database and the search was completed on November 16, 2012.

Study selection

The search for publications was performed using the following keywords and medical subject headings: (Severe obesity OR Morbid obesity OR BS) AND (Exercise OR Exercise therapy OR Physical fitness OR Physical endurance OR Walking OR Physical exertion OR Exercise Movement Techniques OR Physical activity OR Functional capacity OR Functional status OR Physical status). The search strategy was adapted to each database (see Supporting Information Table S1 for the complete search syntax used).

Duplicate records were removed. Two independent reviewers screened all records according to titles and abstracts (AB and MMRF) and assessed selected full-text papers for inclusion and exclusion criteria (AB and MA). Disagreements were resolved by a third party (MFL). Excluded papers were listed with the reason for exclusion (Fig. 1). Reviewers' agreement was calculated on a dichotomous scale (included vs. excluded) using Cohen's kappa coefficient (35).

Eligibility criteria

The following inclusion criteria were applied: (i) peer-reviewed original studies; (ii) adult population (>18 years); (iii) subjects with class II and III obesity (more than 75% of the sample with $\text{BMI} \geq 35\ \text{kg m}^{-2}$ and no normal weight subject) or subjects awaiting or having undergone BS (except intra-gastric balloon); (iv) study including an intervention or recommendations on PA or with an evaluation of PF or PA level; (v) studies involving multiple interventions needed to present their data in a way that allowed data extraction on the isolated effect of PA and (vi) study assessing at least one of these outcomes: anthropometric parameters, body composition, cardiometabolic risk factors, PF, QOL or psychological parameters. Studies

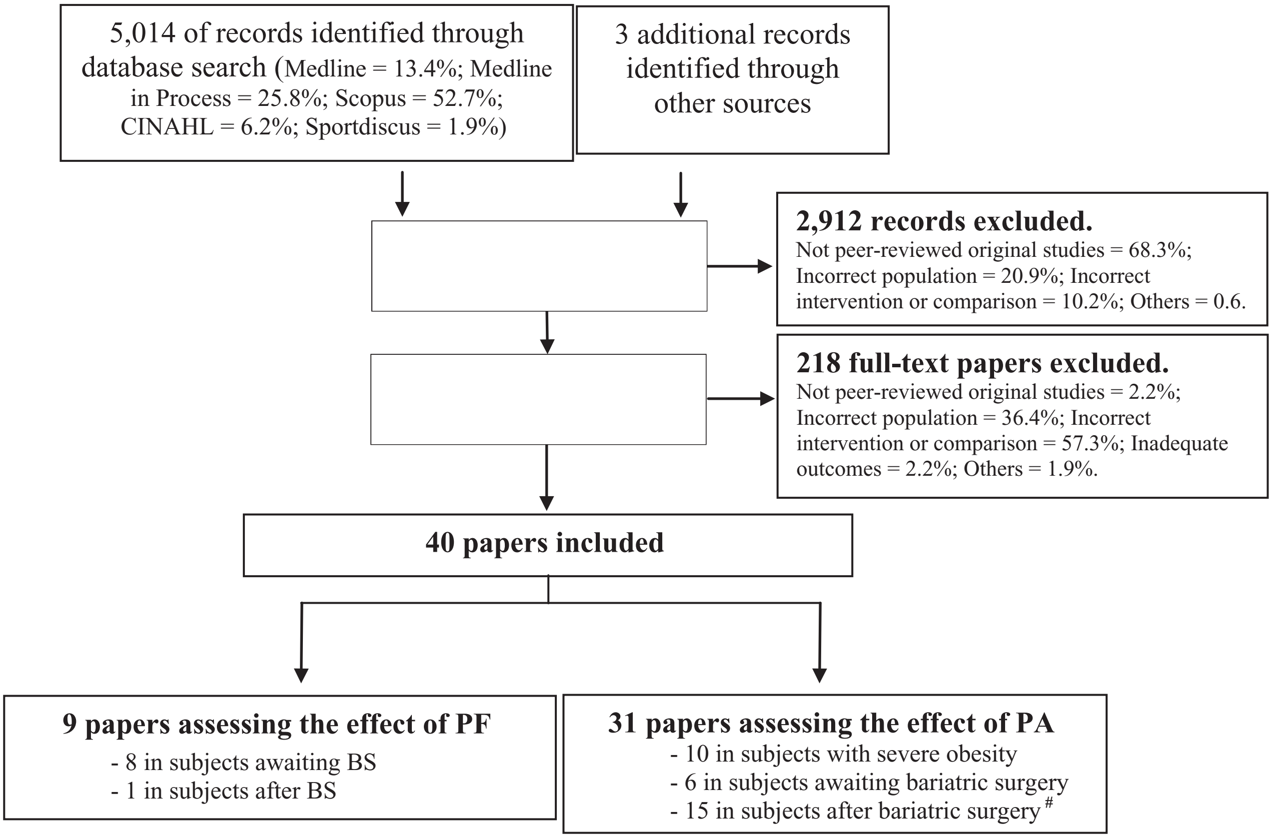

Figure 1 Flow chart of studies selection throughout the review process. BS = bariatric surgery; PA = physical activity; PF = physical activity. # = one study was classified in subjects after bariatric surgery but it performed also one association before surgery.

evaluating only weight loss after BS were excluded since this was previously reviewed (10–12).

In this review, we focused on the health-related components of PF: cardiorespiratory endurance, muscular endurance, muscular strength, body composition and flexibility (36). The concept of PF was also extended to the physical component of functional capacity. We considered that appropriate assessment of functional capacity would be for example, grip strength, balance, chair rises, speed and distance walking (37,38).

All languages papers were considered for inclusion and translated when necessary. Authors were contacted twice in case of missing or incomplete data for the study selection step. When more than one publication used the same cohort, we included only the results from the publication with the largest sample size, unless specific findings (e.g. on selected outcomes) were present only in the other papers.

Data collection process

One reviewer (AB) extracted data from each study: country, design, sample size, baseline subject characteristics, tools used and intervention characteristics (length, PA modalities [type, supervision, intensity, duration, frequency], exercise compliance and the presence of diet and behavioural therapy). Data on baseline and post-intervention outcomes of interest were reported as means with standard deviations and *P*-values. For observational studies baseline means with standard deviations and/or other results (i.e. correlations, associations) were extracted with *P*-values. All extracted data were double checked by another reviewer (MA).

Quality assessment of individual studies

The quality assessment of included papers was performed by an investigator (AB) using the Quality Assessment Tool for Quantitative Studies developed by the Effective Public Health Practice Project (39,40). A second independent investigator (MA) conducted quality control on 25% of randomly selected papers ($n = 10$).

Final results lead to an overall methodological rating of high, moderate or weak in six sections: selection bias, study design, confounders, blinding, data collection methods and withdrawals or dropouts. These six scores were combined to produce a global quality rating for each study (39,40). We reassigned the study design according to the data used in our analysis. For example, if a study had a prospective cohort design, but the outcome and exposure of interest were assessed only at one time point, we considered the design as cross-sectional. Depending on the study design, some items were scored as not applicable (confounders, withdrawals and dropouts); thus, only global ratings within the same study design are comparable. In cases of disagreements, consensus was reached by discussion with a third investigator (MFL) and kappa coefficient was calculated (35).

Strength of evidence across studies

No meta-analysis could be carried out because of the heterogeneity of studies (population, intervention, outcomes). Thus, a rating system of levels of evidence was used to draw conclusions, based on previously used best-evidence syntheses (41–43). Four levels of evidence were determined based on study design, methodological quality and the consistence of results. The following four levels were used (41) (i) *strong evidence*: at least two randomized controlled trials (RCTs) of high quality with consistent results; (ii) *moderate evidence*: at least one RCT of high quality and at least one RCT of moderate or low quality or one controlled trial of high quality (with consistent results); (iii) *low evidence:* only one RCT of high quality or multiple moderate to low-quality RCT, and clinical controlled trials (CCT) of high, moderate or low quality (for all situations, consistent results were required); (iv) *insufficient evidence*: only one low- or moderate-quality RCT or one clinical trial (high, moderate or low quality), or no relevant studies, or negative or contradictory outcomes of the studies limited evidence. If at least two-thirds of the relevant studies were reported to have significant results in the same direction, then we considered the overall results as consistent (43). Conclusions were drawn according to the strength of evidence and team consensus.

Results

Study selection

The electronic search provided a total of 5,014 records. After excluding duplicates (36.8%) and applying selection criteria on the basis of screening of titles/abstracts and full-text papers to the remaining 3,170 records, 40 papers were included: 31 assessing the effect of PA and 9 the effect of PF (Fig. 1). Investigators had a moderate agreement score concerning screening title/abstracts ($k = 0.7$) and strong agreement for eligible studies ($k = 0.86$) (35).

Study characteristics

Table 1 to 4 present studies' characteristics and results in each population studied (subjects with class II and III obesity, awaiting BS or after BS), according to the outcomes of interest. The same study may therefore appear several times in different tables. More than half of the studies were recently published (2010–2012) and only 12 (30%) had an experimental design. Except for four studies in subjects with class II and III obesity (44–47), all experimental studies were carried out in small samples (5–30 subjects). Most studies were carried out in the United States and included predominantly women (≥70%) with a mean age between 40 and 50 years. The majority of studies included at least 75% of subjects with class II and III obesity ($n = 22$; 53%), whereas 23% of studies included only class III ($n = 9$) or didn't give this information (only mean BMI; $n = 9$).

Anthropometric parameters and body composition were the most studied outcomes (60%; $n = 25$), followed by PF (30%; $n = 12$) and cardiometabolic risk factors (25%; $n = 10$). QOL was more frequently assessed in BS subjects compared with class II and III obese subjects (12.5%; $n = 15$ vs. 2.5%; $n = 1$). Psychological parameters (self-efficacy, depression) were the less-studied outcomes.

Table 1 to 3 present characteristics of interventions of the 12 experimental studies covering all subpopulations. The vast majority of studies proposed short-term interventions (≤16 weeks) with supervised exercise training (83.3%; $n = 10$). All studies included an endurance exercise component, and half added strength training and/or multidisciplinary intervention, including prescribed diet and behavioural therapy. Data on exercise compliance was provided in only half of these studies and the percentage of exercise sessions attended ranged from 67 to 100.

Quality assessment

Over three quarters of studies (78%; $n = 31$ studies) were rated as moderate quality (Supporting Information Table S2), while only three were of high quality (24,46,47) and six of weak quality (48–53). Inter-rater reliability for quality was strong with a Cohen's kappa coefficient of 0.82 (35). The vast majority of studies controlled for relevant confounders prior to the intervention when necessary (74%; $n = 14/19$). However, only seven studies verified the absence of significant medication use difference between groups (46,47,54,55) or excluded subjects taking medications known to influence weight or energy expenditure (56–58). Only three studies specified that the outcome assessors were blinded for the intervention or exposure status of participants (46,47,59). Awareness of the research question by the participants was almost never reported (93%; $n = 37$). The data collection tools were shown as valid and reliable in the vast majority of studies (83%; $n = 33$), even though the gold standard tool was not always used. In the majority of observational studies (74%; $n = 14$), PA level was self-reported.

Table 1 Effect of physical activity in subjects with class II and III obesity ($n = 10$)

Reference design	*N* by group (%W)	Age years ± SD or (range)	BMI kg m^{-2} ± SD or (range)	Intervention description	Outcomes (tools/methods used)	Results
Interventional studies						
Goodpaster (47) RCT	63 (92)	47.5 ± 6.2	43.5 ± 4.8 class II, III	– 24 weeks* – Exercise prescription: unsupervised moderate-intensity PA up to 5 × 60 min $week^{-1}$ – Diet prescription: 1,200–2,100 kcal d^{-1}. – Behavioural therapy	– BW, WC – FM, FFM (DEXA or ADP) – VAT, SAT (CT scan) – Hepatic fat content (CT scan) – Blood pressure – Insulin resistance (HOMA-IR index) – TC, HDL-C – Glucose, insulin	– ↘ BW in diet + PA > diet only at 6 months with NS difference at 12 months (–10.9 vs. –8.2 kg; $P = 0.02$). – ↘ WC, FM in Diet + PA > Diet only at 6 months with NS difference at 12 months (–8.6 vs. –5.2 cm; –8.7 vs. –5.9 kg; $P \leq 0.02$). – NS difference between groups in FFM, VAT, SAT changes. – ↘ hepatic fat in diet + PA > diet only at 6 months (+0.12 vs. +0.06 L/S HU, $P = 0.046$). – NS post-intervention difference between groups for cardiometabolic parameters.
	67 (85)	46.1 ± 6.5	43.7 ± 5.9 class II, III	– 24 weeks* – Diet prescription: 1,200–2,100 kcal d^{-1}. – Behavioural therapy		
Cooper (46)RCT	45 (96)	47.5 ± 6.2	44.0 ± 6.6 class II, III	– 24 weeks* – Exercise prescription: unsupervised moderate-intensity PA up to 5 × 60 min $week^{-1}$ – Diet prescription: 1,200–2,100 kcal d^{-1}. – Behavioural therapy	– Carotid artery thickness (ultrasonography) – Inter-adventitial diameter (MAPTM bead-based technology) – Adiponectin, CRP, leptin (ELISA)	– NS post-intervention difference between groups.
	45 (82)	46.8 ± 6.5	43.8 ± 4.8 class II, III	– 24 weeks* – Diet prescription: 1,200–2,100 kcal d^{-1}. – Behavioural therapy		
Sartorio (44) RCT	52 (69)	34.0 ± 8.0	41.3 ± 5.1 class II, III	– 3 weeks – Non-individualized supervised endurance training: 5 × 60 min $week^{-1}$ – Diet prescription: 1,200–1,800 kcal d^{-1}. – Behavioural therapy	– BW	– ↘ BW in E = ES > BE (–5.4, –5.1 vs. –4.0 kg, $P < 0.05$).
	22 (73)	29.0 ± 7.0	42.2 ± 5.7 class II, III	– 3 weeks – Supervised endurance training: 5 × 35 min $week^{-1}$ at 50–60% VO_2max – Diet prescription: 1,200–1,800 kcal d^{-1}. – Behavioural therapy		
	22 (77)	30.0 ± 8.0	41.5 ± 4.2 class II, III	– 3 weeks – Supervised endurance and resistance training: 5 × 30 min $week^{-1}$ at 50–60% VO_2max ; 5× (1 × 15 repetitions) per week at 40–60% 1-RM – Diet prescription: 1,200–1,800 kcal d^{-1}. – Behavioural therapy		

Table 1 *Continued*

Reference design	*N* by group (%W)	Age years ± SD or (range)	BMI kg m^{-2} ± SD or (range)	Intervention description	Outcomes (tools/methods used)	Results
Sukala (54) RCT	9 (67) T2D	48.0 ± 6.0	42.7 ± 12.1 class II, III	– 16 weeks – Supervised resistance training: 3× (2–3 ± 6–8 repetitions) per week	– BW (calibrated scale) – WC (standard method) – % FM (BIA) – Blood pressure (sphygmomanometer) – Insulin resistance (HOMA2-IR + McAuley index) – TC, HDL-C, LDL-C, Tg, FFA – HbA1c, glucose, insulin, C-peptide , log CRP, adiponectin	– C+ between attendance rate and WC ($r = -0.66$; $P = 0.003$). – ↘ SPB, DBP and ↗ Tg in endurance group only ($P = 0.006$; $P = 0.02$; $P = 0.004$). – Δ SBP endurance is different from ΔSBP resistance (–16.2 vs. +2.3 mmHg; $P = 0.02$). – Δ Tg resistance is difference from Δ Tg endurance (–0.2 vs. +0.3 mmol L^{-1}; $P = 0.03$). – NS post-intervention Δ and between groups for the other outcomes.
	9 (78) T2D	51.0 ± 4.0	45.0 ± 6.5 class II, III	– 16 weeks – Supervised endurance training: 3 × 40–60 min $week^{-1}$ at 65–85% HRR		
Lafortuna (60) RCT	9 (78)	34.3 ± 11.0	40.0 ± 4.7 class II, III	– 3 weeks – Non-individualized supervised endurance and resistance training: 5 × 60 min $week^{-1}$ + leisure walking 2 × 50–70 min $week^{-1}$ – Diet prescription: 1,200–1,800 kcal d^{-1}. – Behavioural therapy	– BW, BMI – VO_2max (submaximal CPX) – Strength (1-RM [indirect method]) – Locomotor capabilities (short running test)	– NS post-intervention difference in BW and BMI between groups and at 6 months of follow-up. – ↗ in relative VO2max in both groups ($P < 0.05$). – NS post-intervention difference between groups in relative and absolute VO2max. – ↗ absolute VO2 max in IET only ($P < 0.0001$). – ↗ in 1-RM for all muscles in both groups ($P < 0.05$). – ↗1-RM IET > NSET ($P < 0.05$). – ↗ locomotor pattern only in IET ($P < 0.001$).
	15 (60)	33.5 ± 7.8	40.4 ± 3.3 class II, III	– 3 weeks – Individualized supervised endurance and resistance training: 5 × 35 min $week^{-1}$ at 50–60% VO_2max; 5× (1 × 15 repetitions) per week at 40–60% 1-RM – Diet prescription: 1,200–1,800 kcal d^{-1}. – Behavioural therapy		
Sartorio (45) CCT	26 (73)	29.1 ± 6.6	41.7 ± 5.3 class II, III	– 3 weeks – Supervised endurance training: 5 × 35 min $week^{-1}$ at 50–60% VO_2max – Diet prescription: 1,200–1,800 kcal d^{-1}. – Behavioural therapy	– BMI – VO_2max (submaximal CPX) – Strength (1-RM (indirect method])	– NS post-intervention difference in BMI between groups. – ↗ in 1-RM in both groups for all variables ($0.001 < P < 0.01$); Δ 1-RM ES > E ; (leg +102.3 vs. +66.1 kg; chest +11.2 vs. +5.3 kg; upper body +18.7 vs. +8.3 kg) ($P < 0.05$). – ↗ VO2max in both groups (ES = $P < 0.001$; E = $P < 0.01$); NS difference between groups.
	26 (73)	29.8 ± 7.9	41.1 ± 4.1 class II, III	– 3 weeks – Supervised endurance and resistance training: 5 × 30 min $week^{-1}$ at 50–60% VO_2max; 5 × (1 × 15 repetitions) per week at 40–60% 1-RM – Diet prescription: 1,200–1,800 kcal d^{-1}. – Behavioural therapy		

Table 1 *Continued*

Reference design	N (%W)	Age years ± SD or (range)	BMI kg m^{-2} ± SD or (range)	PA assessment	Outcomes (tools/methods)	Results
Observational studies						
Otabe (50) CSS	358 (79)	44.0 ± 12.0	46.5 ± 7.5 not provided	Baecke questionnaire	– BMI	– C– between BMI and PA in the wild C/C genotype group ($P = 0.015$), but not in CT (heterozygotes) or TT (homozygotes) genotype groups.
Modesitt (48) CSS	38 (100)	58.3 (50–78)	41.2 (26–60) class II, III	Aerobics centre longitudinal study PA questionnaire	– BW, BMI (electronic scale) – WC (standard procedure) – FM, FFM (ADP) – Insulin, adiponectin, leptin (ELISA) – VO_2peak (CPX [modified Balke protocol]) – Quality of life (SF-36)	– Exercisers BW, BMI, WC, FM < non-exercisers. (99.3 vs. 114.3 kg; 38.6 vs. 43.7 kg m^{-2}; 122.9 vs. 135.8 cm; 48.4 vs. 61.4 kg; $P \leq 0.05$). – NS difference in hormones and VO2peak between current exercisers and non-exercisers. – Current exercisers vitality > non-exercisers ($P = 0.029$).
Vanhecke (59) CSS	10 (60)	45.9 ± 12.2	53.6 ± 11.7 class III	SenseWearPro2Armband	– VO_2max (CPX; modified Bruce protocol)	– C0 between VO2max and steps/day.
Bonsaksen (49) CSS	134 (70)	42.4 ± 10.5	≥ 35 class II, III	Two items on the Norwegian HUNT-2 survey	– Coping self-efficacy (general perceived self-efficacy scale)	– C+ between PA and self-efficacy ($r = 0.27$; $P < 0.01$). – Higher levels of PA = higher self-efficacy (5.3% of self-efficacy variance).

*At 6 months, the initial-activity group had significantly increased the number of steps per day and was engaged in approximately twice the amount of vigorous physical activity. The delayed-activity group did not significantly increase their physical activity in the first 6 months.

↗ = increase; ↘ = decrease;< = inferior; > = superior; Δ = change; 1-RM = one repetition maximal; ADP = air displacement plethysmography; BIA = body impedance analysis; BMI = body mass index; BW = body weight; C0 = no significant correlation; C + =significant positive correlation; C– = significant negative correlation; CCT = controlled clinical trial; CPX = cardiopulmonary exercise stress test; CRP = C-reactive protein; CSS = cross-sectional study; CT scan = computed tomography scan; d = day; DBP = diastolic blood pressure; DEXA = Dual-energy X-ray absorptiometry; ELISA = enzyme-linked immune assays; FFA = free fatty acids; FFM = fat-free mass; FM = fat mass; HbA1c = glycosylated haemoglobin; HDL-C = high-density lipoprotein-cholesterol; HRR = heart rate reserve; HOMA-IR = homeostasis model assessment insulin resistance; L/S HU = liver-to-spleen Hounsfield units; LDL-C = low-density lipoprotein-cholesterol; NS = non-significant; PA = physical activity; RCT = randomized controlled study; SAT = subcutaneous adipose tissue; SD = standard deviation; SF-36 = short form health survey; SPB = systolic blood pressure; T2D = type 2 diabetes; TC = total cholesterol; Tg = triglycerides; VAT = visceral adipose tissue; VO_2 = oxygen consumption; W = women; WC = waist circumference.

Table 2 Effect of physical activity in subjects awaiting bariatric surgery ($n = 7$)

Reference design	*N* by group (%W)	Age years ± SD or (range)	BMI kg m^{-2} ± SD or (range)	Intervention description	Outcomes (tools/methods used)	Results
Interventional studies						
Funderburk (61) RCT	3 (100) 4 (75)	49.3 (45–54) 37.3 (28–42)	Not provided	– 12 weeks – No supervised exercise training – 12 weeks – Supervised aquatic exercises including endurance, strength and Ai Chi exercises: 2 × 60 min $week^{-1}$	– BW (specialized scale) – BP (electronic sphygmomanometer) – Functional capacity (6MWT) – Quality of life (obesity adjustment scale; SF-36) – Depression (Beck depression inventory)	– All participants lost weight (–2.3 kg in control group vs. –5.0 kg (P = not provided)). – SBP: –57 in control group vs. + 34 mmHg; DBP: 0 mmHg in control group vs. –4 mmHg (P = not provided). – ↗ 6MWT distance in all subjects (+40.2 m in control group vs. +10.4 m (P = not provided)). – NS post-intervention difference in quality of life and depression scores between groups. – ↘ bodily pain and depression score only in exercise group ($P < 0.05$). – ↗ mental health only in control group ($P < 0.05$).
Hickey (62) UCT	5 (0)	29.6 ± 3.3	48.5 ± 4.5 class III	– 7 d – Supervised endurance training: 7 × 60 min $week^{-1}$ at 65% VO_2peak	– BW, % FM (hydrodensitometry) – Insulin action (OGTT, AUC glucose and insulin) – TC, HDL-C, LDL-C, Tg (spectrophotometrical method) – Glucose, insulin (ELISA) – VO_2peak (CPX [modified Balke protocol])	– ↘ fasting plasma insulin (–41.7pM) AUC insulin (–23%) ($P < 0.05$). – NS post–short-term intervention change in others outcomes.
Marcon (51) UCT	34 (79)	42.5 ± 12.5	48.7 ± 7.1 class III	– 24 weeks* – Supervised low-intensity endurance training: 1 × 20 min $week^{-1}$ with stretching: 1 × 10 min $week^{-1}$	– BW, BMI (digital balance scale) – BP (aneroid sphygmomanometer) – TC, HDL-C, LDL-C, Tg, glucose (ELISA) – Functional capacity (6MWT)	– ↘ BW (–5.3 kg, $P < 0.0001$) and BMI (–1.9 kg m^{-2}, $P < 0.001$) – ↘ SBP, DBP (–23.8 mmHg $P = 0.007$; –14.4 mmHg, $P = 0.001$). – Improvement = TC, HDL-C, LDL-C, Tg, glucose (–23.0 mg dL^{-1}; +1.7 mg dL^{-1}; –2.3 mg dL^{-1}; –24,3 mg dL^{-1}; –26.7 mg dL^{-1}; –17.2 mg dL^{-1}; $P \leq 0.007$) – ↗ 6MWT distance (+69.8 m; $P < 0.0001$).

Reference design	*N* (%W)	Age years ± SD or (range)	BMI kg m^{-2} ± SD or (range)	PA assessment	Outcomes (tools /methods)	Results
Observational studies						
King (64) CSS	757 (80)	44.6 ± 11.2	47.4 ± 7.6 class II, III	Biaxial accelerometer	– BMI (standard procedure)	– C- between BMI and mean steps/day ($P < 0.001$). – C- between BMI and peak PA intensity ($P < 0.001$).
Bond (63) PCS	89 (88)	40.8 ± 10.5	49.7 ± 7.1 class II, III	International PA Questionnaire-Short Sufficient PA group = ≥600 MET min $week^{-1}$	– BW, BMI – Quality of life (SF-36)	– NS difference in BW between sufficient and insufficient PA groups. – <BW gain in sufficient PA group (+0.01 kg vs. +1.7 kg, $P = 0.034$). – Physical component score, role-physical, physical functioning and vitality: sufficient PA > insufficient PA (P-values ≤ 0.033). – NS difference between groups for the mental component score.
Chuang (65) CSS	44 (70)	Not provided	≥35 class II, III	PA questionnaire: work index, sport activity index, leisure-time index	– TC, Tg (ELISA) – HDL-C, LDL-C (Friedewald's formula)	– C– between sport activity index and Tg ($r = –0.32$; $P < 0.05$) – C– between frequency of playing sports and Tg ($r = –0.37$; $P < 0.05$). – No others significant correlation.
Josbeno (66) PCS	18 (90)	41.6 ± 9.8	Not provided	7-d PA recall questionnaire	– Functional capacity (6MWT, SPPB) – Quality of life (SF-36) – PA self-efficacy (PA self-efficacy questionnaire)	– C+ between PA and the SPPB ($r = 0.84$; $P < 0.001$). – C0 between PA and 6MWT. – C0 between PA and SF-36 total score. – C0 between PA and PA self-efficacy.

*Analyses carried out in subjects with more than 70% of compliance.
↗ = increase; ↘ = decrease; < = inferior; 6MWT = 6-min walk test; AUC = area under the curve; BDI = Beck depression inventory; BMI = body mass index; BP = blood pressure; BW = body weight; C+ = significant positive correlation; C– = significant negative correlation; C0 = no significant correlation; CPX = cardiopulmonary exercise stress test; CSS = cross-sectional study; DBP = diastolic blood pressure; ELISA = enzyme-linked immunoassays; FM = fat mass; HDL-C = high-density lipoprotein-cholesterol; LDL-C = low-density lipoprotein-cholesterol; MET = metabolic equivalents of task; NS = not significant; PA = physical activity; PCS = prospective cohort study; RCT = randomized controlled study; SD = standard deviation; SF-36 = short form health survey; SPB = systolic blood pressure; SPPB = short physical performance battery; TC = total cholesterol; Tg = triglycerides; UCT = uncontrolled clinical trial; VO_2 = oxygen consumption; W = women.

Table 3 Effect of physical activity in subjects after bariatric surgery ($n = 15$)

Reference design	*N* by group (%W)	Age years ± SD or (range)	BMI kg m^{-2} ± SD or (range)	Intervention description	Outcomes (tools/methods used) time of assessment and type of surgery	Results
Interventional studies						
Castello (55) RCT	10 (100)	36.0 ± 4.0	44.5 ± 1.0 class III	– 12 weeks – No supervised exercise training	– Limbs circumferences (standard procedure) – FM, FFM (skinfold thickness) – BP (sphygmomanometer) – Functional capacity (6MWT) Before/4 months after GB	– ↘ limbs circumferences exercise group > control group (axillary –13.8 vs. –5.7; xiphoid –15.1 vs. –6.4; hip –14.7 vs. –6.3; waist –19.1 vs. –6.5; thigh –13.1 cm vs. –4.2; $P < 0.05$). – NS post-intervention difference between groups. – ↗ 6MWT distance only in exercise group (+49.7 months; $P < 0.05$).
	11 (100)	38.0 ± 4.0	45.6 ± 1.5 class III	– 12 weeks – Supervised endurance training: 3 × 40 min/week at 50–70%HRpeak; 3 × 25min/week warm-up +stretching		
Shah (56) RCT	8 (92)	53.9 ± 8.8	41.0 ± 3.7 class II, III	– 12 weeks – No supervised exercise training – Diet prescription: 1,200–1,500 kcal d^{-1}. – Behavioural therapy	– WC, hip circumference (standard procedure) – %FM, FFM, %trunk fat (DEXA) – BP – TC, HDL-C (ELISA) – LDL-C, Tg, insulin (calculation) – Glucose (RIA) – Insulin action (OGTT (n = 23) – VO2max (CPX [individualized protocol]) – Quality of life (SF-36 + IWQOL-Lite) Large range after GB or Gband*	– Improvement only in exercise group for postprandial response glucose IAUC ($P = 0.03$). – NS post-intervention difference between groups in other outcomes. – ↗ VO2max only in exercise group (+1.8 vs. –0.5 mL/kg/min; interaction $P = 0.009$). – ↗ in several QOL scores only in exercise group ($P < 0.05$).
	20 (90)	47.3 ± 10.0	42.4 ± 6.9 class II, III	– 12 weeks – Semi-supervised endurance training: ≥2,000 kcal $week^{-1}$ at least 5 d $week^{-1}$ at 60–70% VO2 max – Diet prescription: 1,200–1,500 kcal d^{-1}. – Behavioural therapy		
Stegen (67) CCT	7 (57)	43.1 ± 5.6	40.4 ± 8.1 Not provided	– 12 weeks – No supervised exercise training	– WC (standard procedure) – FM, FFM (BIA) – VO2 peak (CPX) – AT (Wasserman method) – Dynamic and static strength (1-RM [Holten diagram] handgrip dynamometer) – Functional capacity (sit-to-stand; 6MWT) Before/4 months after GB	– NS post-intervention difference between groups for WC, FM, FFM VO2 peak and static strength. – ↗ %VO2 at VAT/VO2peak[†] in exercise group> control (–4 vs. +6%; interaction $P = 0.049$). – Dynamic muscle strength ↗ or → in exercise and ↘ in control group (quadriceps –11.4 vs.+22.5; triceps –8.1 vs.+6.4; biceps –6.5 vs. +4.1k; interaction $P < 0.04$). – Tendency for an interaction effect for the sit-to-stand test ($P = 0.08$). – NS post-intervention difference between groups for 6MWT distance, +52 m only in exercise ($P = 0.002$).
	8 (88)	39.9 ± 9.9	45.3 ± 2.7 Not provided	– 12 weeks – Supervised endurance and resistance training: 3 × 30 min/week at 60–75%HRR; 3× (2–3 × 10–15 repetitions) per week at 60–75% 1-RM; 3 × 20min $week^{-1}$ warm-up + cool down		

Table 3 *Continued*

Reference design	*N* (%W)	Age years ± SD or (range)	BMI kg m^{-2} ± SD or (range)	PA assessment	Outcomes (tools/methods)	Results
Observational studies						
Vatier (68) PCS	86 (78)	42.3 ± 10.3	48.1 ± 5.9 class III	Modifiable Activity Questionnaire	– FM, FFM (DEXA) Before/12 months after GB	– C– between leisure-time PA and FM ($r = -0.20$; $P = 0.015$), trunk FM ($r = -0.11$; $P = 0.04$), trunk FFM ($r = -0.13$; $P = 0.006$) changes. – C+ between leisure-time PA and FFM ($r = 0.20$; $P = 0.02$), appendicular FM ($r = 0.11$; $P = 0.007$) changes. – C0 between leisure-time PA and appendicular FFM changes ($r = -0.04$; $P = 0.44$).
Liu (57) PCS	13 (85)	41.2 ± 2.0	44.6 ± 1.2 class II, III	Accelerometer uniaxial	– % fat loss (BIA) Before/6 months after GB	– C+ between % fat loss and the integrated PA level ($r = 0.74$; $P = 0.005$). – C+ between % fat loss and daily PA level ($r = 0.69$, $P = 0.01$). – C + between fat loss (kg) and the integrated NEAT ($r = 0.65$; $P = 0.016$).
Das (58) PCS	30 (80)	39.0 ± 9.6	50.1 ± 9.3 class III	Minnesota Leisure-Time; PA and Tecumseh Occupational Activity Questionnaires Doubly labelled water and indirect calorimetry	– FM loss (air displacement plethysmography) before and 14 ± 2 months after GB	– Reported PA, non-resting energy expenditure and PA level were not significant predictors of fat loss.
Westerterp (72) CSS	6 (17)	28.0 ± 3.0	42–62 class III	Doubly labelled water and respiration chamber	– FM, protein mass (hydrodensitometry and isotope dilution) Before/54 weeks after VBG	– C+ between FM loss and PA level after surgery ($r = 0.97$, $P < 0.01$). – C+ between protein mass gain and PA level after surgery ($r = 0.87$; $P < 0.05$).
Metcalf (53) PCS	100 (86)	27–63	Not provided class III	Exercisers = self-reported ≥ 30 min per session; 3 or + per week	– FM, FFM (BIA) Before/0.75, 1.5, 3, 6, 9, 12 and 18 months after DS	– NS ≠ between groups for the BW % changes each time. – Exercisers = higher FM loss and FFM gain than non-exercisers each time ($P < 0.05$). – Exercisers = > 28% more FM loss; 8% more FFM gain than non-exercisers18 months after DS.
Josbeno (66) PCS	18 (90)	41.6 ± 9.8	Not provided	7-d PA recall questionnaire	– Functional capacity (6MWT, SPPB) – Quality of life (SF-36) – Coping self-efficacy (PA self-efficacy questionnaire) 3 months after GB	– C+ between PA and both 6MWT ($r = 0.6$; $P = 0.01$) and SPPB after GB ($r = 0.55$; $P = 0.02$). – C+ between change PA and change 6MWT ($r = 0.53$; $P = 0.03$) and SPPB ($r = 0.48$; $P = 0.05$). – C0 between PA and SF-36 total score (after GB and change). – C0 between PA and PA self-efficacy (after surgery and change).

Table 3 *Continued*

Reference design	*N* (%W)	Age years ± SD or (range)	BMI kg m^{-2} ± SD or (range)	PA assessment	Outcomes (tools/methods)	Results
Bond (16) PCS	199 (83)	43.8 ± 11.0	49.8 ± 7.8 class III	International PA Questionnaire-Short	– Quality of life (SF–36) Before/12 months after GB	– PreGB physical CS, role-physical and vitality: A/A group > I/A or I/I groups (p ≤ 0.009). – PreGB physical functioning domain: A/A group > I/A ($P = 0.009$). – Mental CS, vitality, general and mental health after GB: Δ I/A and ΔA/A groups >I/I ($P = 0.009$). – C0 between Δ PA and improvements in physical and mental CS among all participants.
Colles (73) CSS	129 (75)	45.2 ± 11.5	35.0 ± 6.0[‡] class II, III	Baecke questionnaire	– Quality of life (SF–36) Before/12 months after Gband	– C+ between physical CS and Baecke Total Score ($r = 0.23$; $P = 0.008$) and Baecke leisure index score ($r = 0.20$; $P = 0.024$).
Josbeno (69) CSS	40 (90)	50.6 ± 9.8	32.6 ± 7.9[‡] Not provided	SenseWearPro2Armband	– Quality of life (Physical CS SF–36) Measures range from 2 to 5 years after GB	– C0 between MVPA and physical CS.
Rosenberger (70) CSS	131 (89)	42.9 ± 10.3	33.4 ± 6.4[‡] Not provided	Godin leisure-time questionnaire	– Quality of life (SF–36) – Depression (BDI) 12 months after GB	– PA frequency ($P < 0.05$) and intensity ($P < 0.01$) associated with physical and mental CS. – PA frequency ($P < 0.01$) and intensity ($P < 0.001$) associated with BDI scores.
Larsen (71) CSS	157 (92)	40.0 ± 7.9	35.3 ± 6.9[‡] class II, III	Baecke questionnaire	– Quality of life (SF–36) 34 months after Gband (8–68)	– Physical exercise related to mental CS (β = 0.17), but not to physical CS.
Forbush (52) CSS	265 (86)	48.2 (18–70)	30.0 ± 7.0[‡] Not provided	Arizona activity frequency questionnaire	– Quality of life (SF–36) Subjects range from 1 to 5 years after GB	– Higher EEAD and HOAD = better mental and physical CS ($P = 0.05$).

[*] Duration since surgery ranged from 3 months to 3.5 years in the control group and from 3 months to 8.5 years in the exercise group.

[†] Percentage of VO_2 at VAT relative to the VO_2at peak is also a measurement to define aerobic capacity.

[‡] Post-surgery BMI.

↗ = increase; ↘ = decrease; → = maintenance; < = inferior; > = superior; 1-RM = one repetition maximal; 6MWT = 6-min walk test; A/A = active before surgery/active after surgery group; AT = anaerobic threshold; AUC = area under the curve; BDI = Beck depression inventory; BIA = body impedance analysis; BMI = body mass index; B*P* = blood pressure; BW = body weight; C0 = no significant correlation; C+ = significant positive correlation; C– = significant negative correlation; CCT = controlled clinical trial; CPX = cardiopulmonary exercise stress test; CS = component summary; CSS = cross-sectional study; DEXA = dual-energy X-ray absorptiometry; DS = duodenal switch; EEAD = energy in activity/day; ELISA = enzyme-linked immunoassays; FFM = fat-free mass; FM = fat mass; Gband = gastric banding; GB = gastric bypass; HDL-C = high-density lipoprotein-cholesterol; HOAD = hours of activity/day; HOMA-IR = homeostasis model assessment insulin resistance; I/A = inactive active before surgery/active after surgery; I/I = inactive active before surgery/inactive after surgery; IUAC = incremental area under the curve; IWQOL-Lite = impact of weight on quality of life-lite; LDL-C = low-density lipoprotein-cholesterol; NEAT = non-exercise activity thermogenesis; NS = not significant; PA = physical activity; PCS = prospective cohort study; RCT = randomized controlled study; Ref = reference; RIA = radioimmunoassay; SD = standard deviation; SF-36 = short form health survey; SPPB = short physical performance battery; TC = total cholesterol; Tg = triglycerides; VBG = vertical banding gastroplasty;VO_2 = oxygen consumption; W = women; WC = waist circumference.

Table 4 Associations between physical fitness and the different outcomes studied ($n = 9$)

Reference design	*N* (%W)	Age years ± SD or range	BMI kg m^{-2} ± SD or (range)	PF assessment	Outcomes (tools/methods used)	Results
Observational studies						
Studies in subjects awaiting bariatric surgery						
McCullough (24) PCS	109 (75)	46.0 ± 10.4	48.7 ± 7.2 class II, III	– CPX (Bruce or modified Bruce protocols) Groups: first, second, third tertiles of VO_2 peak	– Operative complications (case report form) – BMI (Scale)	– Operative times = +24.8 min for the first vs. third tertile of VO_2 peak ($P = 0.04$). – Primary complication rate[‡] = 16.2% subjects with VO_2peak <15.8 vs. 2.8% with VO_2peak >15.8 mL kg min^{-1} ($P = 0.03$). – Firs tertile of VO_2 peak = OR of 12.9 for the prediction of post-operative complications ($P = 0.04$). – VO_2 peak and male gender = only significant predictors of complications ($P < 0.05$). – Hospital LOS and 30-d readmission rate: 3.8 d for the first tertile of VO_2 peak vs. 2.8 d for others ($P = 0.002$). – C– between BMI and peak VO_2 ($r = 0.50$; $P < 0.0001$).[§]
Hennis (25) PCS	106 (83)	43.0 (41–45)	Not provided	– CPX (cycle ergometer)	– Operative complications (medical follow-up)	– AT < in patients with post-operative complications (9.9 vs. 11.1 mL kg min^{-1}; $P = 0.049$). – AT = significant predictor of LOS > 3 d. (AUC 0.640; $P = 0.03$). – VO_2 peak not associated with post-operative outcomes. – AT, VO_2 peak: NS difference between CCU LOS > 1 d vs. ≤ 1 d and readmitted to hospital and those not.
King (78) CSS	1610 (78)	44.0 (36–52)	45.9 (42–51) class II, III	– LDCW	– BMI (standard procedure)	– C– : ↗ 10-points in BMI independently associated with a 10% slower time to complete LDCW.
Miller (74) CSS	64 (78)	47.4 ± 12.2	47.2 ± 9.2 class II, III	– CPX (modified Bruce protocol)	– BMI, BW (large-capacity scale)	– BMI and BW: highest quartile VO_2peak difference lowest quartile VO_2peak (117.4 vs. 141.7 kg; $P = 0.014$; 40.2 vs. 52.3 kg m^{-2}; $P < 0.001$).
Tessier (75) CSS	42 (60)	M 43 ± 8.9 W 38 ± 10.2	M 50 ± 9.8 W 51 ± 6.7 Not provided	– 6MWT	– QOL (SF–36 ; IWQOL-Lite) – WC (standard procedure) – Pa O_2 (radial artery cannulation)	– WC = predictor of PaO_2 at rest, PaO_2 at rest = predictor of walking capacity, which in turn predicted physical CS. – 6MWT = effect + on physical functioning ($P < 0.001$), which was related to better QOL ($\beta = 1.148$; $P < 0.001$).
Soares (76) CSS	13 (100)	44.0 ± 11.0	43.0 ± 5.0 class II, III	– 6MWT + shuttle walking test	– QOL (Stanford Health Assessment Questionnaire)	– C + only between 6MWT and dressing.
Kolotkin (77) CSS	326 (83)	40.9 ± 10.1	46.5 ± 7.0 class II, III	– CPX (modified Bruce)	– QOL (SF–36; IWQOL-Lite)	– C + between treadmill exercise duration and IWQOL-Lite score ($r = 0.21$; $P < 0.001$), and SF–36 physical CS ($r = 0.39$ $P < 0.001$). – C– between treadmill exercise duration and mental CS ($r = –0.19$; $P < 0.001$). – Adjustments for age, gender and BMI:↘ significance of C + between treadmill exercise and SF–36, and eliminated significance with IWQOL.
Flum (23) PCS	4610 (79)[†]	44.5 ± 11.5	46.5* [42–52] class II, III	– Inability to walk 61 months	– Operative complications (chart review)	– An inability to walk 200 ft is significantly associated with the operative complications[¶].
Tompkins (79) PCS	25 (92)	44 ± 6.3	45.5 ± 6.9 class II, III	– 6MWT	– QOL (SF–36) – BW (Scale)	– C+ between percentage change in 6MWT distance and scores for the physical CS ($r = 0.41$, $P < 0.05$). – C0 between percentage change in 6MWT distance and scores for the mental CS component. – C0 between percentage changes in 6MWT distance and WL.

*Median (25th–75th percentile).

[†] Percentage of women on the baseline sample ($n = 477$).

[‡] Death, unstable angina, myocardial infarction, venous thromboembolism, renal failure, or stroke.

[§] Authors confirmed us that correlation was negative and not positive as written in the paper.

[¶] Composite end point of any of the following occurring within 30 d after surgery: death; deep-vein thrombosis or venous thromboembolism; reintervention with the use of percutaneous, endoscopic, or operative techniques; or failure to be discharged from the hospital within 30 d after surgery.

6MWT = 6-min walk test; AT = anaerobic threshold; AUC = area under the curve; BMI = body mass index; BW = body weight; C0 = no significant correlation; C+ = significant positive correlation; C– = significant negative correlation; CCU = critical care unit; CPX = cardiopulmonary exercise stress test; CS = component summary; CSS = cross-sectional study; IWQOL-Lite = impact of weight on quality of life-lite; M = men; LDCW = long-distance corridor walk; LOS = hospital length of stay; PCS = prospective cohort study; QOL = quality of life; ROC = receiver operating characteristic; SD = standard deviation; SF–36 = short form health survey; VE/VCO2 = ventilatory equivalent for CO2; VO_2 = oxygen consumption; W = women; WC = waist circumference.

Findings and strength of evidence regarding the effect of PA in subjects with class II and III obesity

Six controlled experimental studies (44–47,54,60) and four cross-sectional studies (CSS) (48–50,59) evaluating the effect of PA or different PA modalities in subjects with class II and III obesity were found in this literature review (Table 1).

First, two high-quality RCTs related to the same study, comparing diet with PA intervention to diet alone (46,47) provided limited evidence. They found that recommending moderate-intensity PA, such as brisk walking, in addition to diet had a beneficial effect on body weight (–10.9 vs. –8.2 kg; $P = 0.02$), waist circumference (–8.6 vs. –5.2 cm; $P = 0.01$), body fat (–8.7 vs. –5.9 kg; $P = 0.008$) and hepatic fat content (+0.12 vs. +0.06 liver-to-spleen Hounsfield units [L/S HU]; $P = 0.046$), without significant additional effect on other body composition parameters (fat-free mass, subcutaneous adipose tissue and visceral adipose tissue) and cardiometabolic risk factors (46,47). This study is the only one of this review that compared class II and III obesity. Results were not affected when obesity class was included in the analysis.

Secondly, three moderate-quality studies performed by the same research team compared different exercise modalities combined with interventions including systematic diet and behavioural therapy (44,45,60). They reported that in multidisciplinary intervention, individualized vs. non-individualized training was better to improve strength (leg +48 vs. +22%; chest +44 vs. +20%; upper body +30 vs. +11%; $P < 0.05$ [data extracted from figure]) (60), and the addition of strength exercises to endurance training led to a larger improvement in strength (leg +10.3 vs. +66.1 kg; chest +11.2 vs. +5.3 kg; upper body +18.7 vs. +8.3 kg; $P < 0.05$) (45). In addition, cardiovascular and strength program in a multidisciplinary intervention led to greater weight loss (–5.4 vs. –4.0 kg; $P < 0.05$) (44). One moderate-quality study compared resistance with endurance exercise training without diet or behavioural therapy (54). Endurance training alone significantly reduced systolic blood pressure (–16.2 vs. +2.3 mmHg; $P = 0.02$), but slightly increased triglycerides (+0.3 vs. –0.2 mmol L^{-1}; $P = 0.03$) compared with strength training in morbidly obese Polynesian adults with type 2 diabetes (54). The study of Lafortuna *et al.* (60) is the only one of this review that compared results between gender. Results showed no significant difference between men and women in weight loss and the one repetition maximal improvement after the different interventions. The heterogeneity and the moderate quality of these studies led us to consider that insufficient evidence is currently available to determine the best modalities of exercise with or without multidisciplinary intervention in subjects with class II and III obesity.

Finally, few moderate to weak quality studies provided data on the effects of PA alone in subjects with class II and III obesity (48–50,54,59). In morbidly obese Polynesian adults with type 2 diabetes, 16 weeks of endurance training reduced systolic (–16.2 mmHg; $P = 0.006$) and diastolic blood pressure (–4.7 mmHg; $P = 0.002$) and slightly increased triglycerides (+0.3mmol L^{-1}; $P = 0.004$) without other significant changes in cardiometabolic, glycaemic and anthropometrics markers (54). Resistance training in this same population lead to no significant improvement in cardiometabolic, glycaemic and anthropometric markers (54). Four CSS also studied associations between PA and weight, PF, QOL and self-esteem (48–50,59). However their design prevented us to know any direction of causation. Thus, there is insufficient evidence to conclude on the effect of PA alone on all the outcomes studied in subjects with class II and III obesity because of the moderate to weak quality of the existing studies and the absence of experimental controlled studies.

Findings and strength of evidence regarding the effect of PA in subjects awaiting BS

Three experimental (51,61,62) and three observational studies (63–65) assessed the effect of PA in subjects awaiting BS (Table 2). Data from analysis conducted prior to BS from one prospective cohort study (PCS) classified in the category PA in subjects after BS were also considered (66). Two moderate (61,62) and one weak (51) quality experimental studies found positive impacts of PA on bodily pain (–20%; $P < 0.05$) (61), depression scores (–12.3%; $P < 0.05$) (61), weight (–5.3 kg, $P < 0.0001$) (51), functional capacity (+69.8 m; $P < 0.0001$) (51), resting systolic and diastolic blood pressure (–23.8 mmHg; $P = 0.007$, –14.4 mmHg; $P = 0.001$) (51), cardiovascular risk (Framingham score risk: –4.4; $P < 0.0001$) (51), and insulin action (fasting plasma insulin [–41.7pM] area under the curve insulin [–23%]; [$P < 0.05$]) (62) (Table 2). However, these experimental studies had small sample sizes, heterogeneous interventions in terms of training load and length of intervention, and only one had a control group (Table 2), preventing us to consolidate and generalize the results in one conclusion. Interesting results from a PCS showed that sufficiently physically active subjects (≥600 metabolic equivalents of task min $week^{-1}$) had less weight gain before surgery (+0.01 kg vs. +1.7 kg; $P = 0.034$) and reported higher physical QOL than insufficiently active subjects ($P \leq 0.03$) (63). Nevertheless, all other studies had cross-sectional designs, making the direction of association between PA and other outcomes unclear.

In conclusion, the evidence on the effect of PA in subjects awaiting BS is insufficient for all outcomes studied, because of the absence of large RCT or CCT and the moderate to weak quality of these studies.

Findings and strength of evidence regarding the effect of PA in subjects after BS

Three controlled experimental studies (55,56,67) and 12 observational studies (16,52,53,57,58,66,68–73), that assessed the effect of PA in subjects after BS were included in our literature review (Table 3). In the vast majority of studies, gastric bypass surgery was performed ($n = 10$; 66.7%), whereas gastric banding ($n = 2$; 13.3%), vertical banding ($n = 1$; 6.7%) and duodenal switch ($n = 1$; 6.7%) were performed less often (Table 3). Only the study of Castello *et al.* (55) included subjects having undergone two types of surgeries: gastric banding or gastric bypass and had an intervention with diet (1,200–1,500 kcal day^{-1}) in the control and exercise groups.

Based on these three experimental studies of moderate quality, we judged that some low evidence are actually available to show that 12 weeks of endurance training does not seem to add significant benefits on body composition changes in operated patients with short-term interventions (55,56,67). For example, Stegen *et al.* (67) found that fat mass and fat-free mass decreased significantly 4 months after gastric bypass, without significant difference between the exercise and non-exercise groups (respectively, fat mass = −17.3 vs. −19.0 kg; $P = 0.689$, fat-free mass = −5.4 vs. −7.6 kg; $P = 0.299$).

Only moderate to weak quality observational studies considered long-term effects of PA after BS on body composition. PCS found significant positive associations between body composition change and PA level after gastric bypass or duodenal switch (53,57,68). On the other hand, in a study examining preoperative predictors of weight loss, initial PA was not a significant predictor of fat loss after gastric bypass (58) and surprisingly a CSS found that lower PA level after vertical banding gastroplasty was associated with a greater fat mass and lower protein mass loss (72). In the absence of experimental studies, there is insufficient evidence for the long-term effects of PA after BS on body composition.

Regarding functional capacity, two moderate-quality experimental studies showed that the 6-min walk test distance (6MWTD) improved significantly only in the exercise training group after gastric bypass (+49.7 and +52 m; $P < 0.05$), but there was no significant difference between groups at the last evaluation (group-by-week interaction) (55,67). A PCS also showed positive correlations between PA and changes in the short physical performance battery ($r = 0.55$; $P = 0.02$) and 6MWTD ($r = 0.6$; $P = 0.01$) after gastric bypass (66). The strength of evidence for the positive effect of PA on functional capacity after gastric bypass was rated limited based on these three studies. No consistent results are found concerning the effect of PA after BS on maximal aerobic capacity (VO_2max. [mL kg min^{-1}]) (56,67). While Shah *et al.* (56) found a 10% significant increase of VO_2max. (mL kg min^{-1}) in the intervention group after 12 weeks of endurance training, Stegen *et al.* (67) showed no significant effect of endurance and strength intervention. In addition, only one moderate-quality RCT assessed muscle strength (67). Thus, insufficient evidence on the effect of PA on maximal aerobic capacity and muscle strength was available.

Finally, QOL, which was the most studied outcome in subjects after BS, was assessed by one moderate-quality RCT (56) and seven observational studies (16,52,66,69–71,73). Nevertheless, given the low number of controlled study and inconsistent results (Table 3), we judged that insufficient evidence is present to conclude of an additional effect of PA on QOL after BS.

Findings and strength of evidence in studies regarding the effect of PF

Eight observational studies evaluating PF were conducted in subjects awaiting BS (23–25,74–78) and one in subjects after BS (79) (Table 4). Beneficial and significant associations were found between PF and weight, QOL and operative complications in the majority of studies (Table 4). Nevertheless, the strength of evidence remains insufficient because of the absence of experimental studies.

Discussion

To our knowledge, this is the first review that aimed to systematically examine the impact of PA and PF on the general health of subjects with class II and III obesity and BS patients. From the 40 publications included in this review, the majority was performed recently in the United States with a clear predominance of women participants (≥70%), and only 12 used an experimental design.

Findings and strength of evidence regarding the effect of PA in subjects with class II and III obesity

Interventions in studies with class II and III obese individuals are too heterogeneous to produce any recommendations based on strong evidence, and no experimental study evaluated the impact of PA or PF on QOL and mental health. Nevertheless, available data support some interesting evidence. Six months of interventions based on recommendation for moderate-intensity PA and diet compared with diet alone have additional positive effects on body weight (−10.9 vs. −8.2 kg; $P = 0.02$), waist circumference (−8.6 vs. −5.2 cm; $P = 0.01$), body fat (−8.7 vs. −5.9 kg; $P = 0.008$) and hepatic fat content (+0.12 vs. +0.06 L/S HU, $P = 0.046$) without additional significant effect on cardiometabolic risk factors (46,47). In accordance with these results, two previous meta-analyses showed that interventions combining diet plus exercise may produce a greater weight loss among overweight and obese adults compared with diet alone (+1.14 to 3.1 kg; $P = 0.06$) (80,81). On the other hand, in subjects with class II and III obesity, no study among those included could provide evidence on the effect of PA alone, because of co-interventions or inappropriate control groups.

Findings and strength of evidence regarding the effect of PA in subjects awaiting BS

We chose to separately consider subjects with class II and III obesity and subjects awaiting BS because the latter is a subgroup of the class II and III obese population, selected for and seeking a specific treatment. They are certainly more homogenous than the general class II and III obese population and are more likely to have higher BMI, comorbidities, and lower QOL than class II and III obese lifestyle-seekers (30–33). We found only six studies in subjects awaiting BS. The absence of large RCT or CCT limits the ability to find strong or moderate evidence for any of the outcomes studied, and supports the recent interest of research on PA for this specific population. However, the results of the three experimental studies, showing positive impact of PA on bodily pain, depression scores, weight, functional capacity, and cardiovascular risk are encouraging (51,61,62), and results of a pilot study from our team strengthens the importance to investigate exercise training before BS (82).

Findings and strength of evidence regarding the effect of PA in subjects after BS

We found three experimental studies in subjects after gastric bypass or gastric banding. Those were of higher quality, had better intervention homogeneity and larger sample sizes ($n = 15$, 21 and 28 subjects) than studies in subjects awaiting BS ($n = 5$, 8 and 34). Systematic reviews based on observational studies have previously showed that PA can improve weight loss of approximately 4 kg, 1 year after BS (10–12). In our review, low evidence demonstrated that 12 weeks of endurance exercise training after gastric bypass or gastric banding does not add significant benefits on body composition changes in the short term (55,56,67). However, insufficient evidence is available to conclude with regards to long-term effects of PA on this outcome. Data on the long-term effects of PA on fat-free mass loss and skeletal muscle quality after surgery are thus needed. Indeed, fat-free mass plays an important role in resting energy metabolism, which is involved in weight loss maintenance (56,83). Moreover, it seems that metabolic alterations of skeletal muscle observed in subjects with class III obesity are not all resolved with weight loss alone but only with PA (84,85), hence the importance to study the quality of fat-free mass after BS.

Low-rated evidence also shows that the 6MWTD significantly improves only in the exercise training groups after gastric bypass (55,67). However, the absence of group-by-week interaction, probably explained by the small sample sizes, prevents us from concluding clearly about this outcome. It is now well established that class III obesity greatly alters functional capacity (28,29). Thus, it is important to understand the specific long-term impact of both weight loss and PA on indicators of functional capacity.

The absence of concordance concerning the effect of exercise training on maximal aerobic capacity after BS may be due to the different endurance exercise training volumes, AS Stegen *et al.* (67) still found a significant improvement in submaximal aerobic capacity only in the endurance and strength intervention group. The varying times of assessment after BS and the types of surgery performed leading to different weight loss magnitude between these two studies (−22.7 kg [67] vs. −4 kg [56]) can also explain these different results. Additional evidence is therefore necessary to know the impact of exercise training after BS on maximal and submaximal aerobic capacity.

One RCT found that after 12 weeks of endurance exercise training in addition to BS or gastric banding, the exercise group tended to report greater improvement in QOL than the control group; however, there was no group-by-week interaction possibly because of the limited sample size (56). It is unfortunate that only one RCT assessed QOL (56), especially as the results of observational studies are not consistent (positive associations $n = 5$ [16,52,70, 71,73] negative associations $n = 4$ [16,66,69,71]), probably explained by tools used, the different times of assessment after BS and the different type of surgery performed, that can add confusion in the interpretation of results. Indeed, the type of surgery led to different effects that can influence the QOL change, with for example more weight loss and complication rates for gastric bypass compared with gastric banding (86,87). Furthermore, even if severely obese populations have a high prevalence of mental disorders (88–90), data on the effect of PA on mental health in this population are lacking. King *et al.* recently found that adults undergoing BS who met relatively low thresholds of PA (1 h week^{-1} of moderate to vigorous intensity PA) are less likely to have recently received treatments for depression or anxiety compared with less active counterparts (91). Therefore, PA could play a role in mental health, but we still need to determine the potential impact of adding PA to other lifestyle interventions in this population.

To conclude, because of small sample sizes, and lack of high-quality and long-term studies, no current strong evidence was found on the effect of PA in subjects after BS. There is no study available to compare modalities of training in BS patients.

Findings and strength of evidence in studies regarding the effect of PF

Finally, only observational studies evaluating the effect of PF were found in BS subjects. Even if the majority of studies found beneficial associations between PF and weight or QOL, no causal association could be identified. Nevertheless, interesting data showed the positive effect of a good PF on perioperative complications. For example, the composite complication rate, defined as death, unstable angina, myocardial infarction, venous thromboembolism, renal failure or stroke, occurred in 6 of 37 patients (16.6%) and 2 of 72 patients (2.8%) with peak VO_2 levels <15.8 mL kg min^{-1} or >15.8 mL kg min^{-1} (lowest tertile), respectively ($P = 0.02$). Hospital lengths of stay and 30-d readmission rates were highest in the lowest tertile of peak VO_2 ($P = 0.005$) (24). Now, it would be interesting to examine whether improving PF before surgery would have positive impacts on this last outcome.

Strengths and limitations

Our review is an extensive systematic search across multiple databases, including studies of all types of design with no date or language restriction and high agreement levels. Subject's medication that could be a confounding variable was considered in each study that allows us to rate evidence as low or limited. However, some limitations should be considered. First, we used only original studies referenced in electronic databases, excluding the grey literature and conference abstracts. In addition, some papers with relevant data may have been excluded because of missing BMI data, lack of response from authors to our queries or secondary analyses on PA that were not clearly identified in the abstract. Second, this review reported the major health outcomes studied in the literature; however, other infrequent outcomes such as mortality rates (92), gallstones (65), endometrial cancer (48), lower urinary tract symptoms (93), dietary intake (56), resting metabolic rate (56) and heart rate variability (55) have been found in a few studies, but were considered out of scope for this review. Finally, it cannot be excluded that publication bias could affect our findings

Implications for practice

The evidence supporting the beneficial effect of PA and PF in all subpopulations studied is currently limited in both quantity and quality of studies. Nevertheless, the studies included in this review show promising results and support the feasibility of various types of exercise training in subjects with class II and III obesity and BS patients. Regular PA and good PF seem positively associated with several health outcomes. Despite the growing number of studies ($n = 40$), the novelty of this research field (>50% of the studies were recently published [2010–2012]) probably explains why there are no specific and accurate recommendations available for individuals with class II and III obesity and BS subjects (6). Awaiting more evidence-based findings, recommendations given by expert committees for the general obese population should be followed: 150 min week^{-1} to obtain health benefits and at least 60 min d^{-1} to maintain weight loss with a dose–response relationship to obtain greater benefits, including strength training two to three times per week (1,3).

Implications for research

This review emphasizes the need for more research assessing the effect of PA and PF in subjects with class II and III obesity, having undergone or awaiting BS. To improve the current evidence-based knowledge, long-term RCTs with appropriate sample sizes and high methodological quality studies are required. Even though we have included four studies comparing exercise modalities in subjects with class II and III obesity, given the insufficient evidence, future research should investigate the optimal modalities of PA (type, duration, frequency, intensity) to maintain weight loss or improve health. Weight loss and its maintenance are important outcomes in subjects with obesity; however, future research should investigate the effect of PA interventions or practice on health outcomes beyond weight loss. Comparison between gender (only one study), age categories, obesity class (only one study), metabolic status, type of surgery performed, responders and non-responders could be other avenues to develop. To improve applicability of the results, studies have to be performed in several ethnic groups and countries because of cultural, biological and genetics differences. Finally, studies proposing PA interventions should also include assessment of implementation outcomes (compliance, adverse outcomes and satisfaction) and cost-effectiveness analyses to support health professionals, healthcare managers and policy makers in decision-making about these interventions.

Conclusion

Although the number of studies is growing to support the importance of PA and PF in the medical and surgical management of subjects with class II and III obesity, insufficient evidence prevents us to draw any strong conclusion. Nevertheless, results are encouraging and suggest potential benefits of PA and of good PF in this specific population. Long-term RCTs are needed in subjects with class II and III obesity and in the subgroup of BS patients to determine the effect of PA beyond weight loss or maintenance to produce evidence-based guidelines.

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Supporting information

Additional Supporting Information may be found in the online version of this article, http://dx.doi.org/10.1111/obr.12171

Table S1. Key words used for the electronic search.
Table S2. Quality assessment results categorized by design in overall studies included.

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