European Journal of Human Movement, 2018: **41**, 103-123

EFFECTS OF PHYSICAL ACTIVITY PROGRAMS IN SEVERE OBESITY, BEFORE AND AFTER BARIATRIC SURGERY: A CURRENT FRAMEWORK

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ABSTRACT

Bariatric surgery is considered the gold-standard therapeutic intervention for severe obesity, a form of obesity that is steadily increasing in Western societies. However, surgery must be accompanied by interventions aimed at changing the patients' lifestyle, with special emphasis on increasing their physical activity levels. The optimal characteristics of physical activity programs for bariatric surgery patients are largely unknown. This review summarizes the main effects on body composition and physical condition of physical activity programs developed, both in patients awaiting bariatric surgery or after surgery. Recent research shows that in addition to moderate-to-vigorous aerobic exercise (the form of exercise commonly recommended for this population), strength training may help to avoid the loss of fat-free mass associated to surgery and the extreme dietetic restrictions usually prescribed to these patients. However, heterogeneity in: a) study design; b) components of the physical activity program; c) sample characteristics; d) outcomes measured; and e) time of recruitment, still limits the possibility of obtaining a clear picture of the effects of physical activity programs in this population.

Keywords: severe obesity, bariatric surgery, physical activity, exercise, weight loss

EFECTOS DE LOS PROGRAMAS DE ACTIVIDAD FÍSICA EN LA OBESIDAD SEVERA, ANTES Y DESPUÉS DE LA CIRUGÍA BARIÁTRICA: UNA VISIÓN ACTUAL

RESUMEN

La cirugía bariátrica se considera la intervención terapéutica por excelencia para la obesidad severa, un tipo de obesidad que continúa incrementando en las sociedades occidentales. Sin embargo, la cirugía debe acompañarse con intervenciones cuyo objetivo sea el cambio de estilo de vida de los pacientes, con especial atención en el incremento de sus niveles de actividad física. Las características óptimas de los programas de actividad física en pacientes bariátricos son en gran parte desconocidas. En esta revisión, se resumen los principales efectos sobre la composición corporal y la condición física de programas de actividad física desarrollados en pacientes a la espera de cirugía bariátrica y después de la cirugía. Investigaciones recientes muestran que, junto al ejercicio aeróbico de intensidad moderada a vigorosa (el tipo de ejercicio comúnmente recomendado en esta población), el entrenamiento de fuerza podría ayudar a evitar la pérdida de masa libre de grasa asociada con la cirugía y las restricciones dietéticas extremas normalmente prescritas en estos pacientes. Sin embargo, la heterogeneidad en: a) el diseño del estudio; b) los componentes del programa de actividad física; c) las características de la muestra; d) los resultados medidos; y e) el momento de reclutamiento, todavía limitan las posibilidades de obtener una visión clara de los efectos derivados de programas de actividad física en esta población.

Palabras clave: obesidad severa, cirugía bariátrica, actividad física, ejercicio, pérdida de peso

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Submitted: 09/10/2018 *Accepted:* 09/12/2018

INTRODUCTION

Severe obesity in the context of the current "obesity pandemic"

Obesity, defined as a body mass index (BMI) equal or above 30 kg·m^{-2} of body surface, is a non-communicable disease which develops due to the interaction of individual genetic, environmental and behavioural factors (Egger & Swinburn, 1997). In the last decades, Western societies have suffered a global phenomenon characterized by an increase in technological advances, economic growth and global trade liberalization. However, although globalization has improved quality of life and reduced the level of poverty in many countries, it has promoted a more sedentary lifestyle and a greater consumption of carbonated beverages and processed foods which are high in energy but low in nutritional value (Popkin, Adair, & Ng, 2017). The sudden environmental massive exposure of population to these potentially "obesogenic" factors, among others, has caused a sustained increase of mean BMI since the 70's, changing the trends existing up to that moment (Rodgers, Woodward, Swinburn, & Dietz, 2018). The Non-Communicable Disease Risk Factor Collaboration (2017) has recently reported that during the last 30 years the mean BMI of the global population has been consistently increasing worldwide. Consequently, the current prevalence of obesity estimated in one out of every three individuals of the world's population, especially in women (The Non-Communicable Disease Risk Factor Collaboration, 2017; Hruby & Hu, 2015), is reaching alarming values.

Obesity is commonly associated with several comorbidities, such as type 2 diabetes mellitus (T2DM), hypertension, dyslipidaemia, hypercholesterolemia, altered immune response, and several types of cancer. Together, obesity and its associated comorbidities increase the risk of both all-cause and cause-specific mortality (Gul, Balkhi, & Haq, 2018), therefore reducing life expectancy and quality of life. Consequently, this "obesity pandemic" is also contributing to the continuous rise of economic costs of health care systems. According to Von Lengerke and Krauth (2011), obesity accounted for excess health care costs between 117 and 1,873 euros per person in European countries, which particularly increased due to severe obesity (Von Lengerke & Krauth, 2011).

Severe obesity (or class III obesity) is defined by a BMI ≥ 40 kg·m^{-2} of body surface. Its prevalence has increased over time paralleling the prevalence of obesity. Nowadays, the global prevalence of severe obesity ranges between 0.6 and 1.6% for men and women, respectively. Therefore, if current trends continue, it is expected that in less than 10 years the prevalence of severe obesity will surpass 6 and 9% (men and women, respectively) of the global population (The Non-Communicable Disease Risk Factor Collaboration, 2017; Thomas et al., 2014). This would menace the economic sustainability of health care systems. While at the moment preventive global actions are claimed to reduce the obesity pandemic (Rodgers et al., 2018; The Lancet Public Health, 2018), efforts are being also directed to treat the already obese patients due to the failure of these global actions. Obesity management is particularly challenging in the case of severe obesity.

Current management of severe obesity: bariatric surgery

The current management of severe obesity in clinical settings relies mostly on the combination of bariatric surgery (BS) and interventions aimed at modifying the individual's lifestyle. Several drugs are also being studied to treat obesity, with limited evidence of efficacy (Bray, Frühbeck, Ryan, & Wilding, 2016). Consequently, obesity pharmacotherapy is only recommended as and adjunctive treatment in selected patients (Jensen et al., 2014).

Since the advancement of laparoscopic surgical techniques, BS has become the gold-standard therapeutic option for patients with severe obesity (Herpertz, Kessler, & Jongen, 2017), or for patients with BMI ranging between 30-35 kg·m^2 with associated T2DM (Bray et al., 2016). BS not only causes weight loss but also a remission of the associated metabolic alterations, thus also being called "metabolic surgery". The most common surgical techniques are sleeve gastrectomy and Roux-en-Y gastric bypass. While sleeve gastrectomy combines a restrictive mechanism and a reduction of the appetite-related gastric hormones ghrelin and/or glucagon-like peptide 1 (Puzziferri & Almandoz, 2018), gastric bypass also produces a reduction of intestinal food absorption (Khwaja & Bonanomi, 2010). In terms of excess weight loss, gastric bypass seems to be slightly superior to gastrectomy (Khwaja & Bonanomi, 2010; Neylan, Kannan, Dempsey, Williams, & Dumon, 2016), but due to the surgical complexity of the former, the latter is gaining momentum (Neylan et al., 2016).

Effects on body composition and physical condition of physical activity programs applied to bariatric surgery patients

Independent of their eligibility for BS, interventions aimed at modifying the lifestyle of severely obese individuals remain a cornerstone of the treatment, both before and after surgery. Behavioural interventions comprise one or more components relating to diet, physical activity and/or behaviour change therapies (Bray et al., 2016; Stewart & Avenell, 2016). Given that most patients show an insufficient level of preoperative physical activity and remain insufficiently active postoperatively, increasing physical activity is one of the major aims common to all these interventions.

The characteristics of physical activity programs (PAPs), including the frequency, intensity, type and duration of exercise remain largely undefined. The general recommendations of physical activity for health are used instead, i.e., ≥ 150 min·week^{-1} of moderate-to-vigorous aerobic exercise is set as a common target to be attained (Bray et al., 2016; Jensen et al., 2014). Although emphasis is placed on aerobic exercise, recent systematic reviews have shown that other modalities of exercise have been tried (Al-Hazzaa, 2016; Filou et al., 2017; Moya et al., 2014) in the context of BS. However, due to the wide heterogeneity of study design, sample characteristics, surgical procedures used, time of recruitment, and outcomes measured, only a patchy, superficial picture of the effects of PAPs in BS can be obtained. Given that PAPs can be introduced before BS or postoperatively, in this non-exhaustive narrative review we summarize the main effects of PAPs depending on the moment of their implementation.

Physical activity programs in patients awaiting bariatric surgery.

Although the evidence is still limited, the introduction of PAPs in patients awaiting for BS has been suggested because it is expected that: a) they may decrease the risk of intraoperative complications through preoperative weight loss (Hutcheon et al., 2018); and, b) they may reduce the hospital stay and postsurgical complications associated with a reduced cardiorespiratory fitness (Al-Hazzaa, 2016; Baillot et al., 2014). Additionally, it has been reported that one year after surgery, a preoperative PAP can increase the engagement in physical activity and maintain the weight loss caused by the BS (Baillotet al., 2017a).

Simple interventions, such as a 6 session face-to-face educational program on behavioural strategies to perform home-based walking exercise, can increase moderate-to-vigorous daily physical activity in patients awaiting for BS (Bond et al., 2015a; Bond et al., 2015b). However, severe obese adults awaiting BS usually present physical and psychological barriers that prevent them from exercising (such as chronic knee pain, breathing arrhythmia or exercise intolerance) which limit them to engage in and maintain a regular autonomous physical activity (King & Bond, 2014). Consequently, supervision of PAPs by exercise professionals seems to be needed for this population.

Other modalities of exercise different from aerobic exercise have been tried in patients awaiting BS in the last years. For example, in a series of studies by Baillot et al. (2013, 2014, 2016, 2017a & 2017b) the effect of a PAP combining endurance and strength exercise on weight loss before BS was studied. A pilot study (Baillot, Mampuya, Comeau, Méziat-Burdin, & Langlois, 2013) analysed the effect of a 12-week PAP combining 30 min of endurance activities at an intensity ranging 55-85% of heart rate reserve (HRR) with 20-30 min of strength exercises. Participants attended 3 sessions per week, and missed sessions were completed at home. Results showed that PAP alone induced significant weight loss (0.1 - 5.2 kg), decreased fat mass (FM) and BMI, and increased physical fitness before BS. Besides, they mentioned that the motivation to participate in regular moderate physical activity and the involvement in various intensities of physical activity seem to increase close to the date of the BS. Similar effects on body composition were obtained in their later studies, in which they applied the same PAP in a larger sample size (Baillot et al., 2016) and via a “telehealth” system (Baillot, Boissy, Tousignant, & Langlois, 2017b), although they didn’t find differences in the physical condition among intervention groups in the latter. The results of Baillot et al. (2013) are also supported by independent observations by Sánchez Ortega, Sánchez Juan and Alfonso García (2014). They carried out a structured program consisting in aerobic and strength exercises sessions combined with a hypocaloric diet and a weekly food educational talk. Their results showed significant weight loss, and reductions in BMI, fat mass percentage (FM%) and visceral fat percentage, thereby reducing cardiometabolic risk before BS. Besides, fat-free mass percentage (FFM%) significantly increased, but non-significant improvements were shown in physical fitness. Similarly, Marcon et al. (2017) demonstrated that after a twice a week, 4-month supervised PAP of low-intensity aerobic exercise combined with stretching exercises, participants showed significant reductions in body weight, BMI, systolic blood pressure, Framingham Risk Score and glycaemia, while physical fitness also improved significantly before BS. In contrast, in a control group that received only a behavioural intervention all these variables worsened.

The effects of resistance training in patients awaiting BS have been recently studied in a series of papers by Delgado Floody et al. (2015a, 2015b, 2015c & 2015d). They implemented a PAP with overload until muscle failure in 60 min sessions and analysed its effects on lipid profile and glycaemia (Delgado Floody et al., 2015a), preoperative conditions (Delgado Floody et al., 2015b, 2015c), and anthropometric variables (Delgado Floody et al., 2015d). The PAP was combined with psychological therapy and diet recommendations. Their results showed significant improvements in weight loss, FM% and physical fitness, but non-significant reductions were obtained in BMI, waist and hip circumferences, basal glycaemic and lipid profile. Paradoxically, HDL-cholesterol decreased. Consequently, PAPs aimed at increasing muscle mass seem effective in the maintenance of body weight in the medium and long term. At our group we are also starting to investigate these effects (Picó-Sirvent & Moya-Ramón, 2018). A detailed summary of all these interventions may be found in table 1.

TABLE 1
Summary of the studies analysed in this review in which a physical activity program before bariatric surgery is applied.

Ref.	**Sample**	**Physical activity program**				**Multidisciplinary intervention**	**Results**	
		Volume	**Intensity**	**Frequency**	**Type**		**Anthropometry & health status**	**Fitness & quality of life**
Baillot et al., 2013	PreSET W (n=8) M (n=4)	12 weeks, or 2 weeks preBS due to specific diet	AE: 55 to 85% HRR SE: lb progression for men and woman	3 sessions Missed sessions completed at home	AE: dance and aerobic exercises, ball games, badminton SE: 3 mini-circuits (upper/lower body, and trunk) with dumbbells, elastic bands, and sticks Monthly aquagym session included in PreSET	Weekly group educational sessions. Individual counselling sessions of 15’ with the dietician and PA specialist every 6-8 weeks	*↓ BW, FM, BMI	*↑ PF6, ACT, HST; *↓ FI, EMBPA; *↑ QL, EM, SI, SL
Baillot et al., 2016	PreSET (n=15) UC (n=14)	Warm-up: 10 min AE: 20-30 min SE: 2-3x12-15 reps					PreSET$_{C}$: *↓ FM% PreSET$_{NC}$: *↓ FM% SC: ≠	PreSET$_{C}$: **↑ PF6, HST, ACT, SI, EMBPA; *↑ VPA PreSET$_{NC}$: *↑ VPA SC: ≠
Baillot et al., 2017b	TelePreSET (n=6) PreSET (n=12) UC (n=11)	Cool-down: 10 min		2 supervised sessions in telehealth 1 unsupervised session			TelePreSET: ≠ PreSET: *↓ FM% UC: ↓ PF6; ≠	TelePreSET: ↑ PF6, ACT, STS PreSET: ↑ PF6, ACT, HST UC: ↓ PF6
Sánchez Ortega et al., 2014	W (n=6) M (n=4)	8 weeks Session: 60 min SE: 2-3 series of 10-15 reps	Not reported	2 sessions	AE: climbing stairs, games, “functional” exercises SE: self-load and dumbbells	Weekly food educational talk Hypocaloric diet of 1250-1800 kcal/day, with 500-1000 kcal restriction	*↓ BW, BMI, FM%, VF%; *↑ FFM%	*↑ PF6

TABLE 1 (CONT.)

Ref.	Sample	Physical activity program: Volume	Intensity	Frequency	Type	Multidisciplinary intervention	Results: Anthropometry & health status	Fitness & quality of life
Marcon et al., 2017	EX (n=22) EXCBT (n=17) CG (n=18)	4 months AE: 20 min STCH: 5 min	RPE from 2 to 4	2 supervised sessions	AE: walking STCH: arm, leg, trunk and neck muscles	Exer + CBT group participated in a support group program for lifestyle modification, once a week (1 h) immediately after the exercise session	EX: **↓ BW, BMI; *↑ HR_{rest}, HDL; *↓ SBP, FRS, GL EXCBT: **↓ BW, BMI; **↑ HR_{rest}; ↓ SBP, FRS, GL; *↑ HDL, TG CG: *↑ BW, HR_{rest}, GL, TG; *↓ HDL	EX: **↑ PF6, VO_2 est EXCBT: ↑ PF6; ≠ VO_2 est CG: ↓ PF6; ≠ VO_2 est
Delgado Floody et al., 2015a	W (n=9) M (n=1)	3 or 4 months Session: 60 min Warm-up: 10 min 3 series of 60 s, with 2 min rest STCH: 5 min	Until muscle failure	3 sessions	RT: forearm, trunk, pectorals, shoulder, knee, plantiflexors	Individualized and group educational sessions, 1 h before and/or exercise, about nutritional and psychological work (anxiety, depressive and self-image)	*↓ BW, BMI, FM%; ↓ WC; ↓ TCH, TG, LDL, GL, HDL	*↑ PF6
Delgado Floody et al., 2015b	W (n=10) M (n=4)						*↓ BW, BMI, FM%, WC, BGL	*↑ PF6; *↓ DP
Delgado Floody et al., 2015c	W (n=19)						*↓ BW, BMI, WC, FM%, GL	*↑ PF6
Delgado Floody et al., 2015d	W (n=25) M (n=3)					Not reported	*↓ BW, BMI, WC, HC	Not measured

*PreSET: Pre-Surgical Exercise Training; UC: usual care; TelePreSET: PreSET via telehealth; EX: exercise; EXCBT: exercise combined with cognitive-behavioural therapy; M: men; W: women; AE: aerobic exercise; SE: strength exercise; STCH: stretching; BS: Bariatric surgery; HRR: heart rate reserve; RPE: rate of perceived exertion; BW: body weight; BMI: body mass index; FM: fat mass; FM%: fat mass percentage; VF: visceral fat; FFM%: fat-free mass percentage; WC: waist circumference; HC: hip circumference; DP: depression; EM: emotions; EMBPA: embarrassment during physical activity; FI: fear of injury; QL: quality of life; reps: repetitions; SI: social interactions; SL: sexual life; SBP: systolic blood pressure; FRS: Framingham Risk Score; BGL: basal glycaemia; GL: glycaemia; HDL: high density lipoprotein; LDL: low density lipoprotein; TCH: total cholesterol; TG: triglycerides; ACT: arm curl test; HST: half-squat test; PF6: physical fitness by 6MWTD (6 minutes-walk test distance); VO_2 est: oxygen uptake estimated; VPA: vigorous physical activity; ≠: no change; * intragroup differences ($p < 0.05$); ** among intervention and control group differences ($p < 0.05$).*

Physical activity programs in patients after bariatric surgery.

BS is highly effective in reducing body weight and FM (Colquitt Jill, Pickett, Loveman, & Frampton Geoff, 2014), as well as T2DM (Warren et al., 2015). These effects are mainly observed during the first months after surgery and progress up to one year after surgery. Since that moment on, a weight regain tendency commonly appears (Herpertz et al., 2017). This phenomenon shows a great interindividual variability, with some individuals starting to regain weight 6 months after surgery, whilst in some other cases weight loss lasts for longer periods of time, even decades (Stewart & Avenell, 2016). Consequently, several guidelines recommend post-operative support, but do not advise for specific interventions (Stewart & Avenell, 2016).

In general, it is accepted that weight loss at 6 months after surgery seems to be caused directly by BS per se, and it is independent of any other intervention (Filou et al., 2017). Therefore, PAPs are considered to stabilize weight loss in the long-term after BS (Filou et al., 2017). Greater levels of aerobic physical activity (200 - 300 min·week^{-1}) are recommended to maintain weight loss or minimize weight regain in the long term after BS (Jensen et al., 2014). Some recent works also support this view but expand the effects of early delivery or PAPs after BS to physical condition-related outcomes, and not only to weight loss. For example, Hassannejad, Khalaj, Mansournia, Rajabian Tabesh and Alizadeh (2017), implemented a non-supervised PAP starting on the first month after surgery and extending for 12 weeks. Participants were asked to walk a total time of 150 to 200 min·week^{-1}, 3-5 days·week^{-1} and were educated about following a standard high-protein diet prepared/recommended by a trained nutritionist. Besides, a second intervention group was asked to carry out the same aerobic intervention combined with strength exercises using elastic bands. By the end of the intervention, patients in both groups showed a significant decrease of body weight, FM and FM%, and an increase in aerobic functional capacity, in comparison with a control group. However, lower extremity functionality measured with the sit-to-stand test improved similarly in the three groups after surgery, thus suggesting that at this early stage weight loss, rather than exercise, accounts for most of this effect. Similarly, Morana, Collignon and Nocca (2018), performed a functional rehabilitation program consisting in endurance training at the estimated maximal fat oxidation intensity, combined with strengthening and proprioception exercises, twice a week, for a total of 20 90-min sessions. PAP was delivered to BS patients two months after surgery. After the intervention, participants showed significant reductions in excess weight loss percentage, FM%, and waist and hip circumferences, as well as a significant increase in FFM% and in the self-reported physical activity level through the Baecke questionnaire. Likewise, Campanha-Versiani et al. (2017), implemented a twice weekly PAP during 36 weeks of combined weight-bearing and aerobic exercises (in this order of presentation) 1 month after BS. PAP caused significant reductions in anthropometric measurements, but as an unexpected result, a reduction of bone mineral density and bone mass was noticed. Our own observations support the idea that early introduction of PAP after surgery may reduce cardiovascular risk factors, improve glycaemic control and contribute to maintain FFM% (Hernández García et al., 2015a, 2015b; Hernández García, Aracil, García Valverde, Guillén García, & Moya-Ramón, 2016).

Given the fact that weight loss in the first semester after BS seems to be caused mainly by the surgical intervention per se, it seems interesting to know the effect of PAPs delivered by this time point. In this regard, the recent reports of Mundbjerg et al. (2018a & 2018b) have studied the effects of a supervised PAP delivered at 6 months after surgery. Participants were evaluated before the intervention as well as at 6, 12 and 24 months after surgery. The PAP combined aerobic exercise with resistance training, two weekly 40 min sessions each, during 26 consecutively weeks. Compared to the control group, the PAP did not improve anthropometry, abdominal fat, blood pressure, heart rate, glucose, insulin resistance and total cholesterol significantly, neither at the end of the intervention, nor at the retention measurement taken one year after (Mundbjerg et al., 2018b). In contrast, in the retention evaluation body weight and BMI were significantly lower in the intervention group (Mundbjerg et al., 2018a, 2018b). Additionally, glycated glucose tended to be lower in the intervention group at the retention measurement (Mundbjerg et al., 2018b). In addition, the PAP significantly improved VO_{2max}, hip adduction and the score at the stair climb test by the end of the intervention. However, these improvements were lost at the retention evaluation (Mundbjerg et al., 2018a).

Introduction of PAPs at later times after surgery also seem to impact weight control and physical function in BS patients. In the recent report by Herring et al. (2017), a PAP consisting in 3 weekly sessions, 60 min each, of aerobic exercise at moderate intensity and a 12-week resistance training, was combined with a standard, individual lifestyle advice session. Patients were recruited between 12 and 24 months after BS. Their results showed significant improvements in physical function, and reductions of body weight, FM, systolic blood pressure and heart rate at rest, in comparison with a control group that followed the usual follow-up care. The effects on anthropometric variables and systolic blood pressure persisted in a retention evaluation conducted 12 weeks after ending the intervention. In contrast, spontaneous moderate-to-vigorous physical activity and resting heart rate were not different among groups at the retention evaluation. A detailed summary of all these interventions may be found in table 2.

TABLE 2
Summary of the studies analyzed in this review in which a physical activity program after bariatric surgery is applied.

Ref.	Sample	Physical activity prescription				Time after BS	Multidisciplinary interventions	Results	
		Volume	Intensity	Frequency	Type			Anthropometry & health status	Fitness & quality of life
Hassannejad et al., 2017	AG ASG CG	12 weeks AE: 150-200 min per week SE: 20-30 min	AE: 12-14 RPE SE: green or blue for W and M	AE: 3-5 days SE: 3 sessions	Non-supervised sessions AE: walking SE: elastic band STCH: shoulder and hip (extension, flexion, abduction and adduction)	1 month	Education about having standard high-protein diet by a trained nutritionist	AG: *↓ BW, FM, FM% ASG: *↓ BW, FM, FM% CG: ↓ BW, FM, FM%	AG: *↑ 12MWRT; ↑ STST ASG: *↑ 12MWRT; ↑ STST CG: ↑ 12MWRT, STST
Morana et al., 2018	n = 23	20 sessions Session: 90 min AE: 20 min the first 6 sessions, 30 min the 7th to 10th, and 30 min the 11th to 20th changing machine each 15 min	AE: 60% HRmax estimated, assumed as Fatmax intensity SE: not reported	2 sessions	AE: circuit training SE: rower for the upper and lower limbs, and pulling an elastic band for core PE: single-leg stance with ball throws against a wall	2 months	Not applied	*↓ Excess weight loss %, waist and hip circumferences, HR_{rest}; FM%; *↑ FFM%	*↑ Physical activity level of the Baecke questionnaire

TABLE 2 (CONT.)

Ref.	Sample	Physical activity prescription: Volume	Intensity	Frequency	Type	Time after BS	Multidisciplinary interventions	Results: Anthropometry & health status	Fitness & quality of life
Campanha-Versiani et al., 2017	EG (n=18) CG (n=19)	36 weeks Session: 60 min SE: 8 exercises, 1-3 sets of 10-12 reps AE: 25 min	SE: 10RM, revaluated each 6 weeks AE: 70-80% HRmax	2 sessions	SE: bench press, posterior shoulder, seated leg curl and leg press AE: treadmill	1 month	Vitamin supplementation with Centrum®, and individualized dietary and nutrition advice to an appropriated calorie balance (60 g/protein/day)	EG: *↓ BMD and anthropometrics CG: *↓ BMD, greater than in EG; *↓ anthropometric	Not measured
Mundbjerg et al., 2018a	EG (n=32) CG (n=28)	26 weeks Session: 40 min AE: 15 min SE: 10 min, 20-10 reps AT optional: 15 min	AE: 50-70% VO_{2max} SE: 60-75% RM	2 sessions	AE: bike training SE: lateral raises, lateral pull-downs and chest press AE optional: stair climbing, rowing or treadmill	6 months	Not applied	Not measured	EG: **↑ VO2max, MS_{H-ADD}, SCT; ↑ MS_{H-ABD}, MS_{S-ADD}, MS_{S-ABD} CG: ≠
Mundbjerg et al., 2018b								EG: ↓** DBP, BMI, BW; **↑ HDL CG: ↓ BMI, BW	Not measured

TABLE 2 (CONT.)

Ref.	Sample	Physical activity prescription: Volume	Intensity	Frequency	Type	Time after BS	Multidisciplinary interventions	Results: Anthropometry & health status	Fitness & quality of life
Herring et al., 2017	EG (n=12) CG (n=12)	12 weeks Session: 60 min AE: 35-45 min SE: 2 exercises, 3 sets of 12 reps + 30-60 s rest	AE: 64-77% HRmax (12-14 RPE) SE: 60% RM	3 sessions	AE: personalised for each individual SE: leg press, abdominal twists, leg extensions	Between 12 and 24 months	A standard, individual lifestyle advice session (30-60') to discuss topics such as regular physical activity, diet information and goal settings.	EG: **↓ BW, FM, SBP, HRrest CG: ↓ BW, FM	EG: **↑ ISWT, STST CG: ↑ ISWT

*AG: aerobic group; ASG: aerobic and strength group; CG: control group; EG: experimental group; M: men; W: women; AE: aerobic exercise; SE: strength exercise; STCH: stretching; BS: Bariatric surgery; HR_{max}: maximal heart rate; RPE: rate of perceived exertion; BW: body weight; BMI: body mass index; FM: fat mass; FM%: fat mass percentage; FFM%: fat-free mass percentage; WC: waist circumference; HC: hip circumference; BMD: bone mineral density; SBP: systolic blood pressure; DBP: diastolic blood pressure; HDL: high density lipoprotein; HRR: heart rate reserve; VO_2 max: maximal oxygen uptake; 12MWRT: 12-min walk-run test; ISWT: incremental shuttle walk test; MS_{H-ABD}: maximal strength in hip adduction; MS_{S-ABD}; maximal strength in shoulder abduction; MS_{S-ADD}: maximal strength in shoulder adduction; PE: proprioception exercise; SCT: stair climb test; STST: sit-to-stand test; * intragroup differences (p <0 .05); ** among groups differences (p < 0.05).*

Psychosocial effects of physical activity programs applied to bariatric surgery patients

In addition to their effects on weight loss and physical function, PAPs in the context of BS may also produce psychological effects on severely obese individuals. For example, anxiety and depression are emotional states which derive in excess eating consumption in patients awaiting BS, so its presence should be taken into account during the development of PAPs. A systematic review by Jiménez-Loaisa, Beltrán-Carrillo, González-Cutre and Cervelló (2015) showed that BS usually has positive effects in health-related quality of life, depression and anxiety levels, psychiatric symptoms, self-esteem, body image and social relationships in patients that undergo this surgery. Postoperative weight loss reached, and the subsequent increased perceived physical functioning may account, at least partly, for the increased physical activity levels and social life. However, a lack of knowledge on physical activity prescription recommendations was identified to optimise its benefits (Jiménez-Loaisa et al., 2015). Similarly, Delgado Floody et al. (2015b) observed that a 12-week PAP in which resistance training was combined with nutritional and psychological advice sessions significantly decreased depression levels, without affecting anxiety levels. Similarly, in their review Filou et al. (2017) showed that patients undergoing BS had decreased depression and anxiety levels, and their quality of life increased after an aerobic exercise program.

Additionally, a significant decrease in the fear of injury and embarrassment during physical activity as well as improvements in perceived quality of life, emotions, social interactions and sexual life were observed after a PAP combining aerobic and strength exercises (Baillot et al., 2013). There was a non-significant change in confidence in athletic ability and in beliefs in exercise benefits (Baillot et al., 2013), although weekly, vigorous physical activity levels increased significantly (Baillot et al., 2016).

Discussion and Conclusions

This non-exhaustive review aimed to frame the current general knowledge on the effects of PAPs on BS patients. From our point of view, current knowledge on the effects of PAPs on BS patients is still limited but has increased progressively during the last years. However, as pointed out some years ago (Moya et al., 2014) heterogeneity in this field is still remarkably high and comes mainly from: a) study design; b) PAPs characteristics, including the timing for their implementation; and c) outcomes to be measured.

Regarding heterogeneity from study designs, most interventional studies were characterized by small sample sizes, with patients usually coming from a single centre. In the studies on patients awaiting BS, the absence of control groups is noticeable. Additionally, the surgical technique practiced by the enrolled participants is variable. Most of them underwent Roux-en-Y gastric bypass or sleeve gastrectomy, which influence weight loss through different biologic mechanisms. Consequently, due to the relative paucity of severe obese individuals selected for BS, one possibility to overcome these sources of heterogeneity could be to foster the development of collaborative multicentre studies in the future.

In practice, changing physical activity patterns of severe obese adults is challenging because of the barriers associated with excess body weight, which affects functional capacity and, consequently, their possibilities to reach the recommended daily level of physical activity (King & Bond, 2014). Thus, development of PAPs in this population should be supervised by expert exercise professionals, who are able to adjust the program characteristics to the evaluation and progression of the individuals, and to provide feedback to motivate and engage them. Given that after stopping PAPs their effects usually revert, it may be suggested that expert exercise professionals should be included in the multidisciplinary teams working with BS patients along the whole process, in order to stimulate the acquisition of healthy lifestyle which would let patients carry out their daily activities autonomously. However, several questions are still under discussion to optimize the effects of PAPs before and after BS.

Introduction of PAPs for each patient awaiting for surgery, i.e., not exclusively for BS candidates, is starting to be called "prehabilitation" (Fry, Hallway, & Englesbe, 2018). Weight loss before surgery by PAPs produces significant improvements in lung function and gas exchange, which can substantially reduce morbidity and mortality in individuals with severe obesity (Delgado Floody et al., 2015b). Additionally, having a physically active lifestyle before surgery could also contribute to maintaining FFM and basal metabolic rate, which are usually reduced after BS because of decreased energy intake conditions and have been shown to predict weight regain (Guida et al., 2018). To reach these objectives, aerobic exercise is the most common form of exercise recommended to patients awaiting BS due to its easier transfer capacity to daily life activities. However current interventional studies summarized in this review combined different type of exercises and workloads to improve functional capacity through weight loss and physical fitness improvements. Consequently, other modalities of exercise in the context of patients awaiting BS are gaining momentum. For instance, resistance training until muscle failure can contribute to maintaining FFM during intense weight-loss periods before BS (Delgado Floody, Jerez Mayorga, Caamaño Navarrete, Osorio Poblete, et al., 2015). Our preliminary data suggest that maintenance of FFM may, in turn, contribute to mitigate the reductions in basal metabolic rate caused by weight loss (Picó-Sirvent, Aracil, Sarabia-Marín, Pastor, & Moya-Ramón, 2018).

Concerning the optimal intensity for each exercise modality, there is still little information. Given the limited time for development of PAPs in patients awaiting BS, high-intensity interval training (HIIT) may be considered a suitable option. HIIT and moderate intensity continuous training have already been applied in obese individuals and have been associated with similar body fat reduction rates (Keating, Johnson, Mielke, & Coombes, 2017). However, in the context of severe obese adults awaiting BS, HIIT effects are mostly unknown because this modality of exercise is generally assumed as not suitable for patients with moderate-to-high cardiovascular risk (Al-Hazzaa, 2016). Consequently, more research in this field would be welcome. In addition to the above described effects of PAPs developed before surgery on body composition and physical condition, psycho-social outcomes such as improving adherence and beliefs related to physical activity benefits should be also taken into account, because they can affect the individual's motivation and self-confidence to practice autonomously.

The role of PAPs after BS has been studied more in the literature than the role of PAPs before BS. According to the recent review of Filou et al. (2017) weight loss in the months immediately after surgery is caused by the surgery per se, and seems to be independent of PAPs. However, the role of PAPs on other outcomes, such functional capacity and psycho-social well-being at these initial stages after surgery remains poorly studied. Latter introduction of PAPs after surgery (12-24 months) are effective for improving and/or maintaining the effects of BS, that tend to revert by that time. In a similar way to pre-surgery PAPs, aerobic exercise is commonly accepted as the indicated exercise modality after surgery, but interventional studies using different aerobic and strength exercise combinations have been carried out in the last years. Interestingly, most of them introduced resistance training at an intensity of 60-70% of one maximal repetition to maintain FFM, which seems to be related to basal metabolic rate, an independent predictor of future weight gain (Guida et al., 2018). Although physical activity before surgery has been suggested as a lifestyle intervention which could provide low surgical risk and a better recovery process (Sánchez Ortega et al., 2014), these claims seem to be insufficiently demonstrated in BS. To our knowledge, there is only one publication in which a PAP was applied preoperatively and its effects on spontaneous physical activity were measured one year after BS (Baillot et al., 2017a). Given that weight loss could be extended until 24 months after the surgical intervention (Schauer, Ikramuddin, Gourash, Ramanathan, & Luketich, 2000), prolonged follow-up periods are needed to demonstrated the effect of interventions developed before BS on postsurgical outcomes. In addition, we have not found any study that compares different effects related to physical activity depending on the type of surgical procedure.

Therefore, in order to obtain a clearer effect of the role of PAPs they should be accurately designed and be reproducible in any context. Relevant outcomes, that would allow mechanistic explanations, should be outlined, and measurement instruments and protocols should be standardized. Last, but not least, some disagreement can be found concerning the appropriate timing for introducing PAPs in the context of BS. On the one hand, Sánchez Ortega et al. (2014), proposed that the optimal timing for introducing PAPs could be before surgery for two reasons: 1) to gradually accustom patients to the changes that must be introduced in their lifestyle; and 2) to estimate their degree of motivation to strengthen the psychological treatment prior to surgery. On the other, Stewart and Avenell (2016), consider that the optimal time to initiate them could be by one year after surgery, when patients have adjusted to the physiological changes associated with BS and may be readier to incorporate lifestyle changes into their behaviour. Consequently, from a translational point of view, all these gaps have yet to be filled before PAPs could be definitely incorporated to the clinical standards of treatment of severe obese patients in the context of BS.

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