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Original Article

Impairments of postural control, functional performance and strength in morbidly obese patients awaiting bariatric surgery in comparison to healthy individuals

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Abstract. [Purpose] There is a lack of information evaluating specific markers of performance in patients awaiting bariatric surgery. We aimed to assess the postural control, functional performance, strength and endurance performance for morbidly obese patients awaiting bariatric surgery compared to lean controls. [Subjects and Methods] All parameters were assessed by modified Y-balance test, timed-up-and-go-test, maximum strength testing on resistance exercise equipment and cardio-pulmonary exercise testing on a cycle ergometer in 10 morbidly obese patients awaiting bariatric surgery and 10 age- and sex-matched lean controls. [Results] It was found that significant differences existed for overall modified Y-balance test in morbidly obese patients awaiting bariatric surgery versus lean controls (0.37 ± 0.03 vs. 0.47 ± 0.02 cm.cm^{-1}), timed-up-and-go-test (9.33 ± 1.23 vs. 7.85 ± 1.73 sec) and several variables of cardio-pulmonary exercise testing. Overall absolute strength expressed in kilogram was similar, yet when relativized to body weight strength differences were notable (0.4 ± 0.17 vs. 0.83 ± 0.32 kg.kg^{-1}). [Conclusion] The results of this study demonstrate the need for comprehensive functional assessment prior to surgery with an identified demand for subsequent tailored physical training prescription that should begin before surgery.
Key words: Bariatric surgery, Functional performance, Postural control

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INTRODUCTION

It has been shown that a decrease in physical activity is linked to several morbidities[1]. Furthermore, decreased physical activity is associated to an increase in body mass, in particular fat mass, leading to obesity which reduces physical function[2–4]. With the increasing incidence of obesity, bariatric surgery has become the last therapeutic tool to reduce body weight (BW) after all other conservative approaches have failed[3].

This type of surgery is mainly performed laparoscopically today. By rerouting or removing parts of the gastrointestinal

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tract a restriction of calorie intake or a malabsorption of nutrients is induced, leading to weight-loss[5]. Recent research around bariatric surgery found a loss in total BW and in adipose tissue. However, these positive outcomes were also linked to a loss of lean mass and bone mineral density[6]. This triangular relationship of low bone mineral density, diminished muscle mass and high fat mass called 'osteosarcopenic obesity' is a major concern following bariatric surgery[7]. Early exercise interventions before and after bariatric surgery are advocated to improve physiological functioning by generating an active lifestyle, especially after surgery when patients are losing weight but are still considered sedentary[8]. The main problem is that current exercise guidelines around bariatric surgery recommend an increase in physical activity that primarily aim to improve aerobic exercise capacity. Not only that this recommendation seems to be very general, also these guidelines are based on recommendations for healthy individuals[9, 10]. Yet, it seems inadequate to prescribe exercise in MOP similar to what is recommended in healthy individuals as additional markers of performance might differ between these groups. This existing dearth in research around exercise in patients undergoing bariatric surgery has previously been highlighted by Pouwels et al[11]. However, not only the effects of exercise around surgery are of interest, but also the performance at baseline. This crucial information is essential to determine potential physiological impairments at early stages to prescribe exercise accordingly in line with patients' individual needs. Different studies have investigated aerobic fitness measured by peak oxygen uptake (VO_{2peak}) as an important determinant for postoperative morbidity or mortality in this cohort; however other markers of physical performance could bear the same potential[12, 13]. But first it is important to evaluate differences in physical performance in patients awaiting bariatric surgery compared to their healthy counterparts. Therefore, this study aimed to comprehensively assess postural control, functional performance, maximum strength capacity and endurance performance in morbidly obese patients awaiting bariatric surgery (MOP) and to compare these to age- and gender-matched lean controls (CON). As hypothesis we expected to see physiological differences in all applied testing procedures between our groups.

SUBJECTS AND METHODS

A total of twenty participants, 10 MOP (7 females/3 males, age: 45 ± 12 years, weight: 119 ± 12 kg, height: 166 ± 7 cm, BMI: 43.4 ± 5.0 $kg.m^{-2}$ (min: 37.3 $kg.m^{-2}$; max: 52.0 $kg.m^{-2}$)), and 10 CON (age: 45 ± 13 years, weight: 66 ± 8 kg, height 169 ± 5 cm BMI: 22.8 ± 2.4 $kg.m^{-2}$ (min: 18.8 $kg.m^{-2}$; max: 27.0 $kg.m^{-2}$)) were enrolled in this study. MOP were recruited at the surgery clinic, while all measurements were conducted at an outpatient clinic. At this site CON were recruited and matched by age and gender to their MOP counterparts. All participants were asked by an investigator if they were less physically active as recommended by the World Health Organization (WHO)[10]. These guidelines recommend a minimum of 150 minutes of moderate-intensity aerobic physical activity, or at least 75 minutes of vigorous-intensity aerobic physical activity per week. The following study-relevant treated comorbidities in the morbidly obese group were known: seven participants had arterial hypertension, three participants had hypercholesteremia, two participants had mild coronary heart diseases, two participants had hyperthyreosis, two participants had depression and one participant had type 2 diabetes mellitus. Those physical examinations were assessed at one hand by the surgery clinic and on the other hand by a physician at the outpatient clinic. Also, CON underwent a physical examination at the outpatient clinic conducted by an experienced physician, yet no comorbidities were found. Presented data were analyzed retrospectively after the study was approved by the local ethics committee and patients gave their written informed consent (No. 44/2015). The study was performed accordingly to Good Clinical Practice (GCP) and the Declaration of Helsinki (DoH).

The study consisted of one visit to an outpatient clinic. After arriving overnight fasted at approximately 08:00 AM, participants were examined by a study physician. Anthropometric measurements were performed, including body height, BW and assessment of fat-free mass (FFM). Afterwards, participants performed a timed-up-and-go-test (TUGT), modified Y-balance test (mYBT), and a maximum strength test on machines.

A mYBT was used for evaluating postural control. The test was conducted according to research by Gribble et al[14]. The measured reach distance and dynamic balance ability are indicators of sensorimotor function and have been shown to represent injury risk[15]. The mYBT test was performed with participants standing in the middle of a Y-intersection of three lines on the floor in a 135° angle. Previous research has shown that differences between the widely accepted Star Excursion Balance Test (SEBT) and the YBT are due to the elevated stance during YBT which we wanted to eliminate by using a test-protocol similar to the SEBT[16]. Participants were asked to reach as far as possible along each line, without touching the floor and move back into the starting position. After four familiarization trials, excursion distances of the reaching leg were normalized to body height in the anterior, posteromedial, and posterolateral directions for the right and left leg[14]. A mistake was recorded if the patient did the movement incorrectly, was unable to move back into the starting position or touched the ground. The number of mistakes per participant was recorded at the end of the test. The main outcome was reached distance relativized to body height between groups ($cm.cm^{-1}$).

The TUGT is a widely used test to assess lower extremity function and functional performance[17]. The distance of the TUGT was defined by 3 m from the front legs of a straight-backed armchair to a fixed line on the floor. Participants were instructed to sit while laying their arms on the arm rests. After a starting signal, participants stood up and walked, turned around after 3 m, returned to the chair, and sat down with arms again on the arm rests. The main outcome was the time (sec) needed for walking the 6-m distance. The time was stopped with a digital stopwatch by the same investigator throughout the measurements[18]. Furthermore, all participants used regular furniture, since no special bariatric furniture/chairs were needed.

The maximum strength test started after a 5-min warm-up period on a cycle ergometer with 20 W (530 C, Cybex, Cybex International, Inc., USA) which represents the lowest exercise intensity in a commonly used cardio-pulmonary exercise (CPX) protocol[19]. Participants performed then a familiarization trial for each exercise before the following strength test on resistance machines (Cybex, Cybex International, Inc., USA) without any applied weight. Then, an 11-repetition maximum test was conducted in the process of achieving the appropriate weight (break between trials 1 min 30 sec). This method was adapted according to recommendations by the American Heart Association (AHA)[20]. Strength tests were performed in a seated position for latissimus dorsi muscle (latissimus pull), deltoid muscle (shoulder press), quadriceps femoris muscle (leg press), in a supine position for pectoral muscle (bench press) and in a prone position for biceps femoris muscle (prone hamstring curl). Strength values were subsequently relativized to BW or FFM to allow to detect body mass related differences in both study groups[2].

Afterwards all participants performed a CPX test until volitional exhaustion [21, 19]. This kind of test is an important clinical tool to evaluate exercise capacity[22]. At the beginning of the test, participants had to sit quietly on the cycle ergometer for 3 min (0 W) before they started the warm-up period of 3 min with cycling at a workload of 20 W. Then, the workload was increased by 15 W every minute until volitional exhaustion, determined if the participants was pedalling for 5 s below 40 rpm[23]. Finally, 3 min active recovery at 20 W followed by 3 min passive recovery (0 W) were conducted. In all tests, capillary blood samples were taken from the ear lobe at rest, every minute at the end of each workload, as well as at the end of the active and passive recovery periods. Lactate concentrations were determined by means of a fully enzymatic-amperometric method (Biosen S-line, EKF Diagnostics, Germany). Thresholds were analyzed for lactate and respiratory data. Both the first (LTP_1) and the second (LTP_2) lactate turn point were determined from the CPX test by means of a computer-based linear regression break point analysis[21]. LTP_1 was defined as the first increase in blood lactate concentration above baseline, and LTP_2 was defined as the second abrupt increase of blood lactate between LTP_1 and peak power (P_{peak}). Pulmonary gas exchange variables were collected continuously by breath-by-breath measurement and averaged over 5 s (ZAN 600, ZAN, Germany). Ventilatory threshold was determined via V-slope method by two independent exercise physiologists according to Wasserman et al[24]. Heart rate was measured continuously via chest belt telemetry during all tests and also averaged over 5 s (PE 4000, Polar Electro, Finland). A 12-lead ECG and blood pressure measurements (every 2 min) were obtained in all tests for safety reasons.

All data were normally distributed and were presented as mean ± standard deviation (SD), with a significance level of $p \leq 0.05$. Unpaired-t-tests were performed to compare groups for results of TUGT, mYBT, maximum strength testing and CPX testing. Data were analyzed using Prism software version 7.0 (GraphPad, USA). Statistical power was determined post-hoc from the main outcome of overall postural control (mYBT, $cm.cm^{-1}$) with a power of 0.99 (G-power 3.1.9.2., HHU-Düsseldorf, Germany).

RESULTS

Significant differences were found for the overall analysis of mYBT (Fig. 1, A–D). However, no significant differences were found for numbers of mistakes between groups, however a trend towards a higher number of mistakes in MOP was observed (MOP 3.3 ± 3.0 vs. CON 1.9 ± 1.3, p=0.19). In addition, MOP needed significantly longer during TUGT (MOP 9.33 ± 1.23 vs. CON 7.85 ± 1.73 sec, p=0.04).

No significant differences for overall strength were found when comparing different muscle groups for absolute values of maximum strength capacity (p=0.50). BW normalized data revealed significant differences for overall strength and all other exercises, except shoulder press (p=0.64). When normalized to FFM overall strength showed significant differences in comparison of groups (p=0.03). Significant differences were also found for single muscle groups ($p \leq 0.05$), except for bench press (p=0.095) and shoulder press (p=0.06) (Table 1).

Variables determined during CPX testing showed significant differences for absolute values, BW and FFM relativized values. Metabolically, only in peak lactate concentration (La_{peak}) significant differences were found between both groups (p=0.025). Also, no significant differences were found for absolute oxygen uptake at LTP_2 (VO_{2LTP2}) (p=0.51) and VO_{2peak} (p=0.37) (Table 2).

DISCUSSION

This is the first study detailing clear differences of lower postural control (mYBT), lower functional performance (TUGT), lower strength measures when relativized to body mass specific parameters and exercise capacity (CPX) in MOP compared to matched CON[2]. To strengthen the consistency of the CON, the results we have found for mYBT, TUGT, maximum strength and cardio-pulmonary functioning are also in line with reference values expected for healthy individuals (e.g. TUGT: 7.1–9.0 sec)[14, 25–27].

Intriguingly, in our study overall absolute strength values were found to be similar between groups, which is contrary to the findings of Tomlinson et al[28]. In their study it was found that obese individuals have greater absolute strength, especially in lower limbs due to a chronic overload on the antigravity muscles (e.g. quadriceps)[28]. It was postulated that the increase in BW evokes a stimulus similar to resistance training, which therefore leads to chronic training adaptions[2, 28].

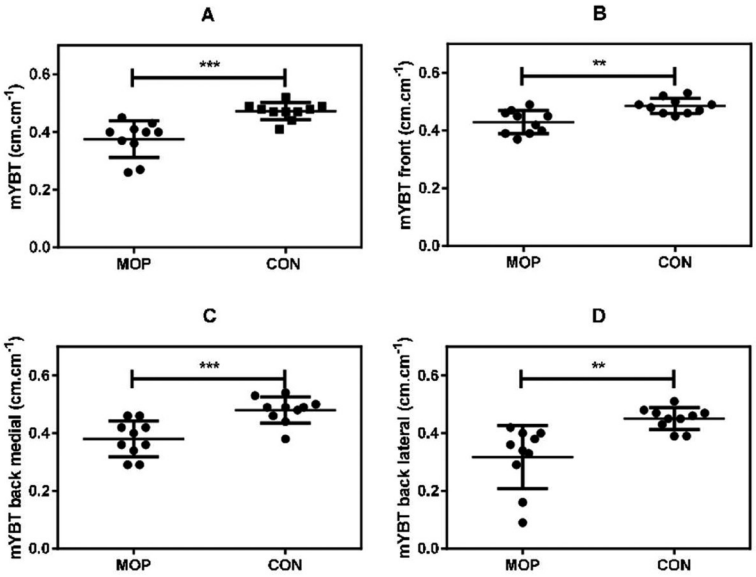

Fig. 1. Differences in modified Y-balance test between groups.
Postural control determined via overall modified Y-balance test (mYBT) relative to body height (A), front mYBT relative to body height (B), medial mYBT relative to body height back (C) and back lateral mYBT (D). Significance levels: $^{**}p<0.01$, $^{***}p<0.001$. MOP: morbidly obese patients awaiting bariatric surgery; CON: age- and gender-matched lean controls.

Table 1. Absolute maximum strength, maximum strength relative to body weight and maximum strength relative to fat-free mass

	MOP	CON
Strength overall (kg)	48.43 ± 20.42	55.09 ± 23.25
Latissimus pull (kg)	48.97 ± 12.6	49.24 ± 19.49
Bench press (kg)	20.93 ± 20.7	24.69 ± 15.67
Shoulder press (kg)	10.59 ± 13.53	14.19 ± 9.82
Leg press (kg)	152.6 ± 33.08	154.1 ± 60.88
Prone hamstring curl (kg)	25.33 ± 17.99	33.19 ± 13.11
Strength overall ($kg.kg^{-1}$) BW	0.4 ± 0.17**	0.83 ± 0.32
Latissimus pull ($kg.kg^{-1}$) BW	0.41 ± 0.11**	0.74 ± 0.26
Bench press ($kg.kg^{-1}$) BW	0.17 ± 0.15*	0.37 ± 0.21
Shoulder press ($kg.kg^{-1}$) BW	0.08 ± 0.09	0.21 ± 0.12
Leg press ($kg.kg^{-1}$) BW	1.29 ± 0.08**	2.34 ± 0.28
Prone hamstring curl ($kg.kg^{-1}$) BW	0.21 ± 0.04***	0.50 ± 0.05
Overall strength ($kg.kg^{-1}$) FFM	0.63 ± 0.68*	1.02 ± 1.06
Latissimus pull ($kg.kg^{-1}$) FFM	0.64 ± 0.14*	0.91 ± 0.30
Bench press ($kg.kg^{-1}$) FFM	0.26 ± 0.23	0.44 ± 0.24
Shoulder press ($kg.kg^{-1}$) FFM	0.11 ± 0.15	0.26 ± 0.16
Leg press ($kg.kg^{-1}$) FFM	1.81 ± 0.68**	2.88 ± 0.98
Prone hamstring curl ($kg.kg^{-1}$) FFM	0.33 ± 0.22**	0.61 ± 0.21

MOP: morbidly obese patients awaiting bariatric surgery; CON: age- and gender-matched lean controls; BW: body weight; FFM: fat free mass. Significance levels: $^{*}p<0.05$, $^{**}p<0.01$, $^{***}p<0.001$. Values are given as mean ± SD.

However, when participants' strength scores were relativized to body mass and FFM, maximum strength was lower compared to CON. Impairments in strength, especially in lower limbs has previously been shown to be a limiting factor in postural control. Especially, when postural control is measured via the SEBT, lower strength influences performance as the mYBT was also considered as slightly strenuous by our patients[29].

Table 2. Determined variables during cardio-pulmonary exercise testing

	MOP	CON
HR_{LTP2} (bpm)	94 ± 37***	153 ± 27
La_{LTP2} (mmol.l^{-1})	3.75 ± 1.26	3.74 ± 0.98
P_{LTP2} (W)	94.56 ± 36.81*	134.3 ± 41.87
P_{LTP2} BW (W.kg^{-1})	0.81 ± 0.32***	2.04 ± 0.58
P_{LTP2} FFM (W.kg^{-1})	1.25 ± 0.41***	2.52 ± 0.66
VO_{2LTP2} (l.min^{-1})	1.76 ± 0.50	1.92 ± 0.55
VO_{2LTP2} BW (ml.kg^{-1}.min^{-1})	15.03 ± 3.91***	29.09 ± 7.21
VO_{2LTP2} FFM (ml.kg^{-1}.min^{-1})	23.56 ± 5.19***	36.03 ± 8.49
HR_{peak} (bpm)	155 ± 26*	177 ± 21
La_{peak} (mmol.l^{-1})	6.61 ± 2.68*	9.37 ± 2.35
P_{peak} (W)	134 ± 50*	188 ± 55
P_{peak} BW (W.kg^{-1})	1.15 ± 0.47***	2.86 ± 0.80
P_{peak} FFM (W.kg^{-1})	1.52 ± 0.67***	3.53 ± 0.90
VO_{2peak} (l.min^{-1})	2.12 ± 0.67	2.43 ± 0.82
VO_{2peak} BW (ml.kg^{-1}.min^{-1})	18.04 ± 6.23***	36.96 ± 11.95
VO_{2peak} FFM (ml.kg^{-1}.min^{-1})	28.22 ± 8.09*	45.23 ± 12.14

HR: Heart rate; La: Lactate; LTP_2: Lactate turn point 2; P: Power output; BW: Body weight; FFM: Fat free mass; VO_2: Oxygen uptake. Significance levels: *p<0.05, **p<0.01, ***p<0.001. Values are given as mean ± SD.

Results coincide with Teasdale et al., who hypothesized an anterior change in body mass to be responsible for impairing postural control[30]. However, this cannot be confirmed by the results derived from our study. Functional performance measured via TUGT showed slower walking-speed in MOP compared to CON, which accompanied with poorer results in postural control might increase the prevalence of falling in patients undergoing bariatric surgery[7]. More research is needed assessing differences of obese compared to lean individuals in a view of general physiological impairments evaluated by postural control, functional performance, maximum strength and endurance performance to detail the differences between those groups.

The results obtained from CPX testing are in line with previous research and underpin the evidence of impaired cardiorespiratory performance in patients awaiting bariatric surgery[2, 12]. We were unable to determine the LTP_1 in more than 50% all included MOP since the resting lactate values were elevated making an analysis impossible[31]. Even though the number of participants appears to be small sufficient power was given, which was analyzed via post-hoc power analysis. However, future research should consequently investigate the effects of different anthropometric or metabolic variables on physiological performance in this specific ever-growing group of patients, due to the small number of participants it might be critical to transfer our results directly to the general population of MOP. Our findings display a general impairment in functional performance in MOP. We recommend a renewed emphasis on pre-operative exercise training in MOP based on our results. Although, aerobic exercise has a key role to play in morbidity and mortality risk reduction around surgery[9], a more holistically tailored exercise prescription is warranted[2]. A focus on postural control and strength-related exercise prescription is absolutely necessary to increase lean mass, as it has been shown that pre-operative increased FFM promotes post-operative weight loss[32]. In conclusion, we demonstrated impairments in performance, that recent perioperative aerobic exercise prescriptions are not addressing[9, 33]. Our results suggest a reconsideration of exercise prescription in patients awaiting bariatric surgery prior to their operation date, to prescribe exercise according to the patients' needs and not similar to the general population.

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