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Can Routine Clinical Tests for Protein Intake and Physical Function Predict Successful Weight Loss?

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Background: Protein intake and physical activity have a substantial impact on body composition and weight loss outcomes after bariatric surgery. The 24-h dietary recall and 6-min walk test (6mWT) are frequently used to monitor protein intake and physical activity, respectively. Despite its frequent use, it is unknown whether these tests can predict long-term weight loss.

Methods: This retrospective study included 85 patients who underwent laparoscopic Roux-en-Y gastric bypass. Protein intake was recorded using the 24-h dietary recall and physical function was measured using the 6mWT. Data about total weight loss (TWL) and nonresponse (i.e., insufficient weight loss and weight regain) were collected up to 5 years. Multiple regression analyses were performed to examine the predictive value of the 24-h dietary recall and 6mWT on weight loss outcomes.

Results: The mean protein intake 1 year postoperatively was 68.1 ± 15.0 g/day and the mean distance covered during the 6mWT was 591.7 ± 67.9 m. Both the 24-h dietary recall and 6mWT were not significantly associated with TWL and neither with nonresponse.

Conclusions: The 24-h dietary recall and 6mWT are poor predictors for long-term weight loss outcomes after gastric bypass. Despite the well-known advantages of these clinical tests, other monitoring tests are suggested for future research.

Keywords: bariatric surgery, gastric bypass, 24-h dietary recall, 6-minute walk test, weight loss

Introduction

BARIATRIC SURGERY IS considered the most effective treatment in patients with morbid obesity as it promotes significant long-term weight loss and reduces obesity-related comorbidities.^{1–3} Despite its frequent success, 20–30% of patients do not respond well to bariatric surgery.^{4,5} These patients may experience insufficient weight loss, defined as primary nonresponse, or regain an excessive amount of weight after sufficient weight loss, defined as secondary nonresponse.⁶ In the etiology of nonresponse, studies provided evidence for surgical components like a dilated gastric pouch and/or anastomosis, as well as for physiological components like gender, preoperative body mass index (BMI), and preoperative age.^{7,8} In addition to these components it is thought that nutritional noncompliance and physical inactivity may contribute to the development

of nonresponse.^{9,10} The mechanisms behind this are discussed below.

The recommended protein intake in patients following bariatric surgery is 60–120 g/day or 1.1–1.5 g/kg of ideal body weight.^{11–13} An inadequate amount of protein intake could reduce the feelings of satiety and result in a loss of fat-free mass rather than fat mass.^{14–16} This may, in turn, induce a decrease in the resting metabolic rate and negatively alter weight loss outcomes.^{14–16} In terms of physical activity and bariatric surgery, guidelines recommend patients to perform both resistance and endurance training on moderate-to-vigorous intensity for 150–250 min/week to prevent weight regain and 300 min/week to maintain weight loss.^{12,14,17} Low activity levels can only moderately contribute to the positive effects of physical activity, which are an increased total energy expenditure, preservation of fat-free mass and enhancement and/or maintenance of postsurgical weight loss.^{9,12,18}

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In light of weight loss outcomes, it is of high clinical importance to thoroughly monitor protein intake and physical function. The 24-h dietary recall method is a well-known instrument for nutritional assessment,¹⁹ whereas the 6-min walk test (6mWT) is a commonly described instrument for assessment of a patients' functional capacity.^{20,21} Both the 24-h dietary recall method and 6mWT are fast, inexpensive, and easy executable tests.^{19,20,22} Because of these clinical advantages, it is presumed that the tests are frequently used in today's practice. Despite this, it is unknown how well these clinical tests can actually predict long-term weight loss after bariatric surgery. Therefore, this study aimed to determine the predictive value of the 24-h dietary recall and 6mWT on long-term weight loss outcomes.

Materials and Methods

Study population

Data of patients who underwent primary laparoscopic Roux-en-Y gastric bypass (RYGB) in a European bariatric center of excellence in 2014 were retrospectively analyzed. Patients were included if their body weight was noted 18 months after surgery and 2, 3, 4, or 5 years after surgery; and if their protein intake (24 h recall) and physical function (6-min walk test) were reported 1 year postoperatively. Patients who underwent a primary banded RYGB or one-anastomosis gastric bypass were excluded for the sake of uniformity. Patients with a previous history of bariatric surgery such as laparoscopic adjustable gastric banding or Mason gastroplasty were excluded as well. At last, patients were excluded if they underwent revisional bariatric surgery due to nonresponse, as this interfered with weight loss outcomes. Ethics approval has been obtained from the Medical Ethics Committee of our center, reference number N20.045, date of approval 10-04-2020. For this type of study, formal consent from all individual participants was not required. The study was conducted according to the guidelines of the Declaration of Helsinki, and was approved by the Ethics Committee of the Máxima Medical Center (protocol code N20.045, date of approval 10-4-2020). Clinical Trial Registration is not applicable.

Standard pre- and postoperative care

All patients were screened for primary bariatric surgery in our center by a multidisciplinary team in accordance with the International Federation for the Surgery of Obesity and Metabolic Disorder guidelines.²³ An individual preoperative treatment with the dietician, physiotherapist, and/or medical psychologist was offered in addition to the regular program if the multidisciplinary team decided that this was necessary. The postoperative program included individual and group visits with a dietician and physical therapist with the aim to adopt a healthy lifestyle. Patients were advised to consume three meals and three healthy snacks per day, drink 1.5–2 L throughout the day, and add 30 g protein (whey) powder to their meals or drinks during the first 3 weeks after surgery. Furthermore, patients were advised to adhere to the Dutch Physical Activity Guidelines²⁴ and were, 4 weeks postoperatively, invited to participate in a training program at our center. Patients were offered two training sessions per week for 5–6 weeks, each session consisting of 30-min endurance training and 30-min resistance training. The intensity of the

resistance training is calculated from one repetition maximum (1RM), starting from 50% to 60% of 1RM up to 70–80% of 1RM, while the intensity of the endurance training is calculated from steep ramp test (SRT) and 6mWT, aiming levels of Borg scale 13–15. Patients were annually monitored for a period of 5 years with standard biochemical testing for vitamin deficiencies.

Twenty-four-hour dietary recall

The 24-h dietary recall method was routinely used 1 year postoperatively to estimate protein intake. During a 30-min assessment with a clinical dietician, patients were orally questioned about their diet from the past 24 h (from midnight to midnight) of, preferably, a weekday. Based on current guidelines, patients were categorized as “adequate protein intake” if their protein intake was ≥ 60 g/day, whereas patients were categorized as “inadequate protein intake” if their protein intake was < 60 g/day.^{13,14}

Six-minute walk test

The 6mWT was routinely performed preoperatively and 1 year postoperatively to determine physical function. The test was executed according to a standardized protocol.²⁵ Patients were instructed to walk at their own pace as far as possible for 6 min by going back and forth in an at least 25-m long corridor. Outcomes were total distance covered in meters (m) and heart rate at rest and immediately after the test ended. The percentage of the predicted value of the distance covered was calculated as follows²⁶: $[(218 + 5.14 * \text{height (cm)} - 5.32 * \text{age (years)} - 1.8 * \text{weight (kg)} + 51.31 * \text{sex (1-male, 0-female)})]$. Numbers of $< 82\%$ were considered aberrant based on normative values of an obese population.²⁷ After the 6mWT, leg cramps and shortness of breath (dyspnea) were rated by the Borg scale. This is a 15-point scale ranging from 6 (“nothing at all”) to 20 (“very, very severe”). Patients were categorized as “high physical function” if the predicted percentage was $\geq 82\%$, whereas patients were categorized as “low physical function” if their predicted percentage was $< 82\%$.

Body weight and obesity-related comorbidities

Body weight was measured during preoperative screening and hospital consultation 12 and 18 months, and 2, 3, 4, and 5 years postoperative. The presence of obesity-related comorbidities (hypertension, diabetes, dyslipidemia, obstructive sleep apnea syndrome (OSAS), and osteoarthritis) was assessed as well. Weight loss was described as % total weight loss (%TWL), and was calculated as $[(\text{preoperative weight} - \text{postoperative weight}) / \text{preoperative weight}] \times 100\%$. The %TWL at 2 and 3 years after RYGB were averaged into %TWL at midterm, and %TWL at 4 and 5 years after RYGB were averaged into %TWL at long term. The percentage of weight regain was calculated as percentage kilogram (kg) gained after reaching the lowest postoperative weight (nadir weight). Nonresponse rates were defined as the following: primary nonresponse if the patients' %TWL was less than 15% within the first 18 months after surgery, and secondary nonresponse if the patients' %TWL was more than 15% plus a regain of more than 15% after 24 months, with respect to nadir weight following RYGB.²⁸

TABLE 1. BASELINE CHARACTERISTICS OF THE STUDY POPULATION

	n=85
Gender, no. (%)	
Female	69 (81.2)
Male	16 (18.8)
Age ^a (years) ^b	45.8 ± 10.2 (23–66)
Preoperative weight (kg) ^c	124.0 (104.3)
Preoperative BMI (kg/m ²) ^c	42.0 (34.6)
Preoperative comorbidities, no. (%)	
Hypertension	37 (43.5)
Type II diabetes	11 (12.9)
Dyslipidemia	18 (21.2)
OSAS	17 (20.0)
Osteoarthritis	8 (9.4)
No comorbidities	33 (39.0)
Preoperative individual treatment, no. (%)	
Intern	25 (29.4)
Dietician	7 (8.2)
Physiotherapist	0 (0.0)
Medical psychologist	20 (23.5)
Extern	1 (1.2)
Complications, no. (%)	
Short term <30 days	1 (1.2)
Long term >30 days	7 (8.2)

^aAge at time of surgery.

^bExpressed in mean ± SD (range).

^cExpressed in median (IQR 25–75).

OSAS, obstructive sleep apnea syndrome; BMI, body mass index; SD, standard deviation; IQR, interquartile range.

Statistical analyses

Descriptive statistics were computed for patient characteristics. Quantitative data are presented as mean with standard deviation (range) or median with interquartile range, and categorical data are expressed in numbers and percentages. Data were checked for normality using the Kolmogorov–Smirnov test. A paired t-test, or Wilcoxon signed-rank test in case of a non-normal distribution, was performed to compare pre- and postmeasurements of physical function. A two-stage hierarchical multiple linear regression analysis was conducted to examine the contribution of protein intake (postoperatively

assessed) and physical function (both preoperatively and postoperatively assessed) on %TWL at midterm and %TWL at long term. Both analyses were performed with protein intake and physical function as categorical and continuous variable. Furthermore, a two-stage hierarchical multiple logistic regression analysis was performed to examine the relation between protein intake and physical function on secondary nonresponse. To test whether associations were independent of other predictors, potential confounders were included as covariates (i.e., age, gender, preoperative BMI, preoperative individual treatment, and long-term complications). Statistical significance was set at $p \leq 0.05$. All analyses were performed using the program Statistical Package for Social Sciences version number 22.0 (IBM SPSS 22.0; Chicago, IL).

Results

Study population

A total of 227 patients were assessed. Four patients were excluded due to revisional surgery (2 patients underwent shortening of the common limb; 1 patient received a gastric ring; 1 patient underwent resizing of the stoma). Furthermore, 138 patients were excluded due to missing values in essential variables at various time points. In total 85 patients, of which 69 (81.2%) were female, were included in the study. Mean age was 45.8 ± 10.2 years and median BMI preoperatively was 42.0 kg/m^2 (interquartile range = 34.6). These and other patients’ demographics are presented in Table 1.

Protein intake and physical function

Mean protein intake 1 year after surgery was $68.1 \pm 15.0 \text{ g/day}$ and the mean distance covered during the 6mWT was $591.7 \pm 67.9 \text{ m}$. In total, 61.2% of the patients were grouped into “adequate protein intake” and 38.8% of the patients were grouped into “inadequate protein intake”. Moreover, 37.6% of the patients were grouped into “low physical function”, whereas 62.4% was grouped into “high physical function” (Table 2).

Weight outcomes

The follow-up rate was 96% at midterm and 85% at long term. The percentage of TWL was $34.7\% \pm 8.6\%$ at 1.5 years,

TABLE 2. PHYSICAL FUNCTION AT BASELINE AND 1 YEAR FOLLOW-UP

	N	Baseline	n	1 year follow-up	p-value
SRT Steep ramp test (Watt) ^a	85	160.0 (220.0)		N/A	
6 mWT Distance covered (m) ^b	85	520.7 ± 78.0 (300.0–688.0)	85	591.7 ± 67.9 (432.0–778.0)	<0.001 ^c
Predicted percentage (%) ^b	85	81.7 ± 9.9 (48.0–107.0)	85	83.4 ± 8.0 (65.0–103.0)	0.068
Heart rate at rest (beats/min) ^b	84	87.3 ± 14.5 (55.0–139.0)	73	75.3 ± 12.5 (51.0–102.0)	<0.001 ^c
Heart rate after effort (beats/min) ^b	85	126.5 ± 18.8 (85.0–195.0)	71	107.5 ± 19.3 (65.0–162.0)	<0.001 ^c
Borg score for dyspnea ^a	85	12.0 (13.0)	77	11.0 (3.0)	<0.001 ^c
Borg score for leg fatigue ^a	85	13.0 (12.0)	77	11.0 (11.0)	<0.001 ^c
Physical function ^a	85	46 (54.1)	85	53 (62.4)	0.162
High physical function, no (%)		39 (45.9)		32 (37.6)	
Low physical function, no. (%)					

^aExpressed in median (IQR 25–75).

^bExpressed in mean ± SD (range).

^cPaired t-test: significant difference compared with baseline, $p \leq 0.05$.

^dHigh physical function if predicted percentage is $\geq 82\%$; low physical function if predicted percentage is $< 82\%$.

SRT, steep ramp test; 6mWT, 6-minute walk test; N/A, not assessed.

TABLE 3. WEIGHT LOSS AND (NON) RESPONSE RATES

	n	
%TWL		
1.5 years ^a	n = 85	34.7 ± 8.6 (18.4–55.9)
2–3 years (midterm) ^a	n = 82	33.3 ± 9.5 (14.2–53.7)
4–5 years (long term) ^a	n = 72	29.6 ± 10.4 (10.7–51.1)
Weight regain (%) ^a	n = 80	10.5 ± 5.8 (0.14–25.4)
Primary nonresponse, no. (%)	n = 85	0 (0)
Secondary nonresponse, no. (%) ^b	n = 85	18 (21.2)
Time to secondary nonresponse (years) ^c	n = 85	5.0 (1.0)

^aExpressed in mean ± SD (range).

^bSecondary nonresponse is defined as a %TWL >15% and a weight regain of >15% after 24 months.

^cExpressed in median (IQR 25–75).

TWL, total weight loss.

33.3% ± 9.5% at 2–3 years, and 29.6% ± 10.4% at 4–5 years after surgery (Table 3). Based on the aforementioned criteria for nonresponse, no patients were classified as primary nonresponse, whereas 18 patients (21.2%) were classified as secondary nonresponse. Time to develop secondary nonresponse varied from 4 to 5 years.

Predictors of weight loss and nonresponse

A stepwise multiple linear regression analysis revealed that both the 24-h dietary recall and 6mWT were not significantly associated with %TWL at midterm ($p=0.203$ and $p=0.948$) nor with %TWL at long term ($p=0.963$ and $p=0.855$) (Table 4). Being female ($\beta=0.34$; $p=0.003$) and having a greater preoperative BMI ($\beta=0.31$; $p=0.006$) resulted in a higher %TWL at midterm. Moreover, having a

greater preoperative BMI ($\beta=0.35$; $p=0.006$) resulted in a higher %TWL at long term. Remarkably, multiple linear regression analysis showed similar results when including protein intake and physical function as continuous variables. When focusing on secondary nonresponse, a multiple logistic regression analysis revealed that protein intake and physical function were not significant predictors (Table 5). Due to the small group of patients with secondary nonresponse ($n=18$), it was not possible to further assess predictors specifically in this subgroup.

Discussion

Knowledge on strategies on how to maximize weight loss and reduce the rate of nonresponse after bariatric surgery is crucial. Protein intake and physical function are well-known factors that have a substantial impact on weight loss outcomes⁹ and therefore, a routine assessment of these factors is advised.^{14,18} The 24-h dietary recall and 6mWT are feasible tests in today's clinical practice to assess protein intake and physical function, although it is unknown what their predictive value is. The present study was designed to investigate this predictive value on TWL and nonresponse up to 5 years after RYGB.

In contrast to our initial hypothesis, it was found that protein intake as estimated by 24-h dietary recall was not predictive of TWL. There are three likely causes for this finding. First of all, in this study, the 24-h dietary recall has been used to estimate protein intake only, while there is evidence that a certain amount of carbohydrates along with protein is necessary to preserve fat-free mass.^{15,29} It has also been suggested that energy restriction, rather than the protein diet's content, affects weight outcomes.^{30,31} In detail, caloric intake is known to be reduced in the immediate postoperative phase, but in a subset of patients, energy intake gradually increases over time, which is thought to hinder weight loss

TABLE 4. MULTIPLE LINEAR REGRESSION ANALYSIS FOR PREDICTORS OF PERCENTAGE OF TOTAL WEIGHT LOSS AT MIDTERM AND LONG-TERM

	%TWL midterm (n = 82)		%TWL long-term (n = 72)	
	B	p-value	β	p-value
Unadjusted model ^a				
Protein intake (adequate vs. inadequate) ^b	-0.106	0.348	0.021	0.863
Physical function (high vs. low) ^c	0.045	0.639	0.053	0.663
Adjusted model ^d				
Protein intake (adequate vs. inadequate) ^e	-0.134	0.203	0.005	0.963
Physical function (high vs. low) ^f	0.007	0.948	0.022	0.855
Age	0.030	0.774	0.038	0.757
Gender (female vs. male)	0.344	0.003 ^g	0.180	0.156
Preoperative BMI	0.308	0.006 ^g	0.349	0.006 ^g
Preoperative individual treatment (yes vs. no)	-0.079	0.467	-0.003	0.978
Long-term complication (yes vs. no)	0.034	0.743	-0.024	0.841

Dependent variables: %TWL midterm and %TWL long-term.

^aUnadjusted model: protein intake and physical function.

^bProtein intake (g/day) entered as a continuous variable: $\beta=-0.061$; $p=0.594$ and $\beta=-0.147$; $p=0.223$.

^cPhysical function (predicted percentage) entered as a continuous variable: $\beta=0.061$; $p=0.594$ and $\beta=0.050$; $p=0.667$.

^dAdjusted model: protein intake and physical function, age, gender, preoperative BMI, preoperative individual treatment, and long-term complication.

^eProtein intake (g/day) entered as a continuous variable: $\beta=0.046$; $p=0.671$ and $\beta=-0.074$; $p=0.541$.

^fPhysical function (predicted percentage) entered as a continuous variable: $\beta=0.209$; $p=0.208$ and $\beta=0.214$; $p=0.253$.

^g $p \leq 0.05$.

BMI, body mass index.

TABLE 5. MULTIPLE LOGISTIC REGRESSION ANALYSIS FOR PREDICTORS OF SECONDARY NONRESPONSE

	Secondary nonresponse (n=85)		
	Odds ratio	95% CI	p-value
Unadjusted model ^a			
Protein intake (ref = inadequate) ^b	2.09	0.65–6.72	0.219
Physical function (ref = low) ^c	0.36	0.12–1.07	0.066
Adjusted model ^d			
Protein intake (ref = inadequate) ^c	2.68	0.72–9.97	0.142
Physical function (ref = low) ^f	0.32	0.09–1.16	0.082
Age	0.95	0.89–1.01	0.081
Gender (ref = male)	2.87	0.49–16.48	0.237
Preoperative BMI	0.89	0.77–1.02	0.101
Preoperative individual treatment (ref = no)	3.85	1.04–14.2	0.043 ^g
Long-term complication (ref = no)	0.27	0.02–4.18	0.346

Dependent variable: secondary nonresponse, defined as a %TWL >15% and a weight regain of >15% after 24 months.

^aUnadjusted model: protein intake and physical function.

^bProtein intake (g/day) entered as a continuous variable: OR = 1.01; 95% CI 0.97–1.04, *p* = 0.798.

^cPhysical function (predicted percentage) entered as a continuous variable: OR = 0.93; 95% CI 0.87–1.00, *p* = 0.053.

^dAdjusted model: protein intake and physical function, age, gender, preoperative BMI, preoperative individual treatment, and long-term complication.

^eProtein intake (g/day) entered as a continuous variable: OR = 1.00; 95% CI 0.96–1.05, *p* = 0.859.

^fPhysical function (predicted percentage) entered as a continuous variable: OR = 0.92; 95% CI 0.85–1.01, *p* = 0.073.

^g*p* ≤ 0.05.

CI, confidence interval; ref, reference.

and increase the risk on weight regain.³² Lastly, when inquiring the diet of the last 24 h, there is a great demand on the short-term memory of the patients resulting in an under- or overestimation of the real protein intake. Taken together, presumably both protein and carbohydrate, as well as the energetic value of the diet are of important value when predicting weight loss outcomes.

Another important finding of this study was that physical function as estimated by 6mWT was not predictive of TWL. Yet again, there are several possible explanations for this result. The first explanation could be that this study exclusively focused on physical function, whereas physical activity participation was not taken into account. It is conceivable that the higher the physical activity, the higher the level of physical function; however, contrasting reports have been described focusing on this association.^{31,33} A second explanation could be that physical function was measured only once postoperatively, which gives a limited amount of information about the patient's physical status. Third, there is a possible ceiling effect in the 6mWT for patients with normal or high exercise capacities presurgery, limiting the ability to detect performance improvements from pre- to postoperative. Lastly, there are many external factors (e.g., motivation, coaching effort) that could have influenced the outcomes of the 6mWT.

This retrospective study has multiple limitations that should be mentioned. Because of missing information, 63% of patients were excluded which may have influenced the generalizability of the study population. Nevertheless, the sample size was calculated in retrospect and showed that the current sample size was sufficient (*n* = 84). Additionally, since we do not have analyzed data about excluded patients, the results might be prone to selection bias. Moreover, the 24-h dietary recall was measured only once postoperatively, which may have resulted in an unreliable measurement. On top of that, our study solely focused on the predictive effect of lifestyle factors (protein intake and physical function) on weight loss outcomes, whereas weight loss outcomes are suggested to have a multifactorial etiology with several patient (e.g., mental health) and surgery-specific factors playing a role.⁹

Hereafter, in the context of nutritional surveillance, the 24-h dietary recall should be performed at least twice to obtain a reliable estimation of habitual protein intake.^{34–36} When looking for an alternative, multiple days of dietary records (e.g., 5-day food diary) optionally with pictures may be a valid choice as it will provide an optimal nutritional (protein) assessment.³⁶ In context of physical surveillance, an ergospirometry to measure peak oxygen uptake (VO₂peak) should be preferred as it assesses exercise capacity more reliable without a ceiling effect.¹⁸ For this study, these assessments were not available presumably because they are more time consuming, require more equipment, and are more expensive hampering their clinical use. In the assessment of physical status, it could be questioned whether it is sufficient to only perform this measurement before an exercise prescription, or it should be performed longitudinally. When performed postoperatively, the outcome can be used for further counseling as well as weight regain prevention.

Conclusions

There is emerging evidence that successful long-term weight loss is not maintained in a subset of patients after bariatric surgery. This study focused on the predictive value of protein intake and physical function, measured by the 24-h dietary recall and 6mWT, on long-term weight loss outcomes after RYGB. The results showed that neither the 24-h dietary recall, nor the 6mWT were significant predictors. These tests are therefore in common practice not feasible to predict successful long-term weight loss. Despite this, they are likely to be useful for their intended purposes, which are the examination of an eating pattern and the measurement of physical function. It is suggested to determine the clinical relevance of other monitoring tests, such as a 5-day food diary or ergospirometry, to predict and optimize weight loss after bariatric surgery.

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