

## Research Article

# Understanding the Determinants of Weight-Related Quality of Life among Bariatric Surgery Candidates

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Obesity and its relation to quality of life are multifaceted. The purpose of this paper was to contribute evidence to support a framework for understanding the impact of obesity on quality of life in 42 morbidly obese subjects considering a wide number of potential determinants. A model of weight-related quality of life (WRQL) was developed based on the Wilson-Cleary model, considering subjects' weight characteristics, arterial oxygen pressure (PaO<sub>2</sub>), walking capacity (6-minute walk test, 6MWT), health-related quality of life (HRQL; Physical and Mental Component Summaries of the SF-36 PCS/MCS), and WRQL. The model of WRQL was tested with linear regressions and a path analysis, which showed that as PaO<sub>2</sub> at rest increased 6MWT increased. 6MWT was positively associated with the PCS, which in turn was positively related to WRQL along with the MCS. The model showed good fit and explained 38% of the variance in WRQL.

## 1. Introduction

The obesity epidemic currently facing the developed world [1, 2] is increasing the number of people affected by preventable causes of disability. This epidemic has an impact on the field of rehabilitation as interventions need to be adapted for people with obesity and new approaches need to be developed for people with disability resulting primarily from obesity.

Obesity can and does produce disability [3]. As reviewed elsewhere [4, 5], one physiological issue in the obese that is affected is the respiratory system. Some of the affected respiratory physiology includes altered static lung volumes, lower arterial oxygen pressure (PaO<sub>2</sub>), increased alveolar-to-

arterial oxygen pressure difference (AaDO<sub>2</sub>) at rest, reduced respiratory system compliance with increased elastic loading of the inspiratory muscles, increased work and oxygen cost of breathing, and increased respiratory resistance compared to normal-weight individuals.

Nonetheless, obesity can affect almost all aspects of function and extend to impacting on quality of life (QOL) and health related quality of life (HRQL). The term "weight-related quality of life" (WRQL) is emerging to express the effect of excess weight on an individual's ability to live a fulfilling life [6].

The factors affecting the quality of life of obese people remain to be identified. Body mass index (BMI) explains only about one-third of the variance of WRQL [7, 8]. Few

nonmodifiable factors such as gender [9, 10], race [8, 9], and age [10, 11] have been associated with WRQL. Pain is known to have a strong impact on WRQL [12, 13]. Other potentially modifiable predictors include depression, arthritis, and gastroesophageal reflux [14] along with weight-related stigma [15], but these factors are only a partial representation of the determinants of WRQL. Data also indicate that obese individuals with binge-eating disorder are strongly related to a poorer HRQL, whether these measures are evaluated in those without surgery [16] or postbariatric surgery [17]. However, it is not certain if binge-eating disorder independently affects WRQL. Modifiable factors such as cardiorespiratory fitness confers some HRQL benefits in the obese [18].

Measures of body size have been implicated with respiratory functions including PaO<sub>2</sub> [19–21]. In earlier work on this same group of subjects, we showed that among people with morbid obesity, a high waist-to-hip ratio was associated with poorer arterial blood-gas status. On average, PaO<sub>2</sub> decreases by 5 mmHg and AaDO<sub>2</sub> increases by 5 mmHg as waist-to-hip ratio increases by 0.1 units [20, 21]. Gender plays a role in arterial blood-gas status, but that is only because the waist-to-hip ratio is different between males and females [22]. A recent review has shown that every 5 to 6 kg reduction in weight increases PaO<sub>2</sub> by 1 and decreases AaDO<sub>2</sub> by 1 mmHg [5]. Waist circumference has also been associated with exercise capacity [23] and BMI has been associated with functional walking capacity as measured by the 6-minute walk test (6MWT) (Pearson's  $r = -0.71$ ;  $P = 0.002$ ) [24]. The demonstration that obese women have poorer walking capacities than normal-weight persons and that weight reduction improved walking speed and maximum oxygen uptake (VO<sub>2max</sub>) supports a direct link between weight and mobility [25]. This relationship is likely mediated through respiratory function as research has shown a strong relationship between respiratory function and walking capacity ( $r = 0.5$  to  $0.8$  between VO<sub>2max</sub> and 6MWT) [26]. Walking capacity and VO<sub>2max</sub> [18] have been found to relate to HRQL in obese people [27]. 6MWT correlated well (Spearman's  $\rho$ :  $0.39$  to  $0.49$ ;  $P < 0.01$ ) with the physical function domain of the Medical Outcome Study Short-Form Health Survey (SF-36) [18, 28], which is a well-established generic measure of HRQL. The fact that obese people report decrements up to 30% in most domains of the SF-36 relative to general population norms [14, 29, 30] suggests that through some direct and/or indirect mechanisms, obesity impacts HRQL.

To do justice to the complexity of the relationships underlying WRQL requires a strong theoretical framework for estimating direct and indirect effects of these multiple constructs. In this study, the Wilson-Cleary was the theoretical model used to inform the statistical approach. The Wilson-Cleary model provides a conceptual model that encompasses HRQL and QOL [31]. This model proposes a linear relationship between biological and physiological factors, symptoms status, functional status, general health perception, and quality of life. In addition, characteristics of the individual and of the environment are included as mediating variables.

The aim of this study was to contribute evidence to support a framework for understanding the impact of obesity on quality of life, considering a wide number of potential determinants. The framework of WRQL was tested with linear regressions and a path analysis.

## 2. Materials, Subjects, and Methods

**2.1. Participants.** Morbidly obese persons scheduled for laparoscopic gastric bypass were recruited at the McGill University Health Center (MUHC), Montreal, Canada. They did not have (1) BMI  $\geq 75$  kg/m<sup>2</sup>, (2) a medical contraindication to exercise testing (acute myocardial infarction, cardiac arrhythmia, or use of pacemaker); (3) respiratory, renal, or hepatic failure; (4) metastatic disease; (5) cognitive impairment. All participants signed an informed consent form. The measures were collected at the time of their assessment. The study was approved by the MUHC institutional review board.

### 2.2. Variables

#### 2.2.1. Biological and Physiological Factors:

##### *Waist Circumference and PaO<sub>2</sub> at Rest*

**Arterial Blood Gases.** Arterial blood gases were obtained from radial artery cannulation and sampled after 5 minutes of rest, with the participants sitting upright on a chair. The average of duplicate samples was recorded. Arterial blood-gases were corrected for changes in arterial blood temperature and measured directly via an ABL725 Blood Gas Analyzer (Radiometer, Copenhagen, Denmark). Details of the procedure are described elsewhere [21].

**Aerobic Capacity Test.** A test to determine peak oxygen uptake (VO<sub>2peak</sub>) was performed on an electrically braked cycle ergometer (Velotron Dynafit Pro, Racermate Inc., Seattle, WA). The VO<sub>2peak</sub> test commenced at 5 W and increased by 1 W every 2 to 6 seconds (10 to 30 watts every minute) until volitional exhaustion. The difference in the incremental increase in power output was to make sure all individuals fatigued within 8 to 12 minutes. VO<sub>2</sub> was measured with a metabolic cart (model VMax 229LV, Sensorsmedics, Yorba Linda, CA) using the breath-by-breath option. The mean of the highest three consecutive VO<sub>2</sub> values (averaged over 20-second intervals) was defined as the VO<sub>2peak</sub>.

**2.2.2. Functional Walking Capacity: 6 MWT.** 6MWT is the distance an individual can walk in 6-minutes; it reflects the capacity of an individual to perform daily activities. Typically, the distance walked by people with severe obesity revolves around 440–475 meters [32]. Predicted values for age and gender were estimated using the formula from Gibbons et al. [33].

**2.2.3. Health Related Quality of Life: PCS and MCS.** The SF-36 is a 36-item survey that includes eight domains measuring physical functioning, role limitations due to physical health problems, bodily pain, general health perceptions, vitality,

social functioning, role limitations due to emotional problems, and mental health. A physical and mental component summary (PCS and MCS) can be derived from these items. The summary scales are standardized with a mean of 50 and a standard deviation of ten [34]. The SF-36 is a reliable measure with good internal consistency and good test-retest reliability [35]. A factor analysis supported its construct validity [35]. Its convergent and discriminant validity have also been demonstrated [35]. Hopman et al. have developed Canadian norms for the SF-36 [36].

**2.2.4. Weight-Related Quality of Life: IWQOL-Lite.** The IWQOL-Lite is a self-reported questionnaire designed to assess the impact of obesity on quality of life. It is comprised of 31 items grouped into five dimensions: physical functioning, self-esteem, sexual life, public distress, and work. The measure provides scores for each separate dimension and a total score. The measure has excellent psychometric properties with good internal consistency (ranging from 0.90 to 0.96) [37], good test-retest reliability (0.83 to 0.94) [29], is sensitive to weight change [38, 39], and its scale structure is supported by confirmatory factor analysis [37]. To facilitate interpretation of values for the IWQOL-Lite, the scoring has been reversed and transformed according to the following formula:

Transformed score

$$= \left[ \frac{(\text{maximum theoretical score} - \text{actual score})}{\text{test score range}} \right] \times 100. \quad (1)$$

The score is considered as a continuous variable in the analysis.

**2.3. Statistical Analysis.** A model of WRQL was developed, based on the Wilson-Cleary model and existing evidence. The relationships between variables representing the different components within the Wilson-Cleary model were estimated with linear regressions. The statistical significance and the consistency with the literature in the direction of the coefficients were examined.

We further tested the model of WRQL with a path analysis. Path analysis allows the simultaneous estimation of all relationships between the variables in a single model rather than a series of models. It estimates the effect of each variable on the subsequent one, controlling for prior variables. A variable can be a dependent variable in one relationship and an independent variable in another. The several related relationships between biological, physiological, functional factors, and WRQL were modeled. We included variables that have been shown to have a significant impact on quality of life among people with obesity in previous studies. We used the software MPlus version 4 to confirm the model. The extent to which the data was consistent with the model was then tested with the maximum likelihood estimate method (ML). The full information maximum likelihood (FIML) estimation was used to impute data that were considered missing randomly. The latter is the recommended method as it yields consistent and efficient estimates [39]. To evaluate the fit of

the model as a whole, few goodness-of-fit tests were used following the recommendations of Hu and Bentler [40] and Schermelleh-Engel et al. [41]. The goodness of fit tests assessed how the model accounts for the observed correlations or covariances. First, we used the chi-square test statistic, which should be close to zero [41]. As the chi-square test is highly dependent on sample size, other measures of fit were also used. The root mean square error of approximation (RMSEA) is a measure of approximate fit in the population and is concerned with the discrepancy due to approximation. Values less than 0.05 indicate good fit [41]. In addition, a 90% confidence interval (CI) enabled an assessment of the precision of RMSEA estimate. The lower boundary (left side) of the CI should contain zero for exact fit. RMSEA is regarded as relatively independent of sample size, and favors parsimonious models [41]. Another goodness-of-fit measure used was the standardized root mean square residual (SRMR), which is an overall fit measure based on residuals. A rule of thumb is that SRMR should be less than 0.05 for good fit. The comparative fit index (CFI) and the Tucker-Lewis index (TLI) are based on model comparisons. For both indexes, values greater than 0.97 indicate a good fit relative to the independent model. Because the TLI is not normed, values can be outside the range of 0 to 1.

### 3. Results

Table 1 presents key characteristics of the 42 participants. Functional walking capacity (6MWT) was approximately 60% of age-predicted value. Aerobic capacity (mL/kg/min) was below the 20th percentile. Values considerably lower than norms were reported for all subscales of the SF-36. Their HRQL scores, indicate impairment with the SF-36 physical component being more impacted than the mental component (PCS = 34; norm 52, MCS = 44; norm 51) [36]. The sample had an average value of 46 out of 100 on the IWQOL-Lite. On the IWQOL-Lite, which has been transformed to have 100 indicating excellent quality of life, women reported much lower values than men, reaching statistical significance for overall quality of life, and for the dimensions of public distress and self-esteem. There were no major violations of the normality assumption. 4% of the data was missing with 6 out of 42 participants having 1 or more missing values.

The WRQL model consisted of the linear effect of waist circumference on PaO<sub>2</sub> at rest, PaO<sub>2</sub> at rest on 6MWT, 6MWT on PCS, PCS on IWQOL-Lite, and MCS on IWQOL-Lite. Table 2 (Figure 2) presents univariate linear regression models. The relationships between each individual components of the WRQL model were statistically significant except for the effect of PaO<sub>2</sub> at rest on 6MWT ( $P = 0.0546$ ). Waist circumference was a predictor of PaO<sub>2</sub> at rest, PaO<sub>2</sub> at rest was a predictor of walking capacity, which in turn predicted PCS. Both PCS and MCS were predictors of IWQOL-Lite.

Four models were tested for each outcome. The first model estimated the effect of waist circumference on PaO<sub>2</sub> at rest, the second model estimated the effect of waist circumference and PaO<sub>2</sub> at rest on 6MWT, the third estimated the effect of waist circumference, PaO<sub>2</sub> at rest, and 6MWT on PCS, and finally the fourth estimated the effect of all

TABLE 1: Characteristics of the study population by gender.

	Men ( <i>n</i> = 17)		Women ( <i>n</i> = 25)	
	Mean	SD	Mean	SD
<i>Physiological variables</i>				
Age (years)	43	8.9	38	10.2
Weight (kg)	159	35.5	136*	19.0
Height (m)	1.78	0.07	1.64*	0.07
BMI (kg/m <sup>2</sup> )	50	9.8	51	6.7
Hip (cm)	140	19.2	147	12.7
Waist (cm)	148	18.0	135*	14.5
Waist-to-hip ratio	1.06	0.07	0.92*	0.08
VO <sub>2peak</sub> (mL/kg/min) ( <i>fair</i> = 38 for males, 31 for females)	16.2	(4.9)	14.4	(2.9)
VO <sub>2peak</sub> (L/min)	2.58	0.78	1.96*	0.39
VO <sub>2</sub> at rest (L/min)	0.42	0.10	0.33*	0.06
PaO <sub>2</sub> at rest (mmHg) [99]	83	11.3	91*	9.8
<i>Functional status</i>				
6MWT (M)	429	110.5	414	83.3
<i>SF-36 (0–100)</i>				
Physical functioning [86]	32	27.8	43	24.2
Role physical [82]	49	41.0	47	41.9
Bodily pain [76]	52	28.4	45	23.9
GHP [77]	43	13.8	41	19.5
Vitality [66]	39	13.1	36	16.1
Social functioning [86]	58	26.1	57	29.0
Role emotional [84]	59	44.9	64	40.4
MH [78]	63	17.5	60	19.4
PCS [51]	35	11.3	33	9.8
MCS [52]	44	9.8	44	9.9
<i>Weight-related quality of life (0–100)</i>				
IWQOL overall	55	24.7	40*	21.3
Public distress	56	37.3	37*	20.5
Physical function	45	25.0	36	16.1
Self-esteem	49	29.1	24*	25.6
Sexual life	46	21.0	35	28.7
Work	45	22.9	36	22.6

Abbreviations: BMI, body mass index; 6MWT, 6-minute walk test; MCS, mental component summary; PCS, physical component summary; MHI, Mental Health Index; GHP, general health perception; IWQOL, impact of weight on quality of life—lite. The parentheses in italic are norms for the SF-36 [36], and for PaO<sub>2</sub> [42]. For VO<sub>2peak</sub> (mL/kg/min) the classification of “fair” is the 40th percentile value for age and gender from the American College of Sports Medicine [43]. Statistical difference between men and women, \* *P* value <0.05, \*\* *P* value <0.0001.

these factors together on IWQOL. Tables 3 and 5 shows the results of the multiple linear regression models, which were similar to those obtained from the univariate regression. The total variance of IWQOL-Lite explained by the model with waist circumference, PaO<sub>2</sub> at rest, 6MWT, PCS, and MCS was 28%. These results show the limitations of regression as there is only one outcome variable and the predictors must act independently in order to have an effect. Numerous regressions need to be estimated to assess the relationship between several variables. In the multivariable model, each variable is adjusted for the effects of the others and hence their effects on other variables are not estimable.

A path Analysis was conducted (Table 4). A path coefficient ( $\beta$ ) represents the relative effect of each factor on

subsequent factors, after controlling for all other prior and simultaneous effects. The path analysis supported the findings of the linear regression, all coefficients were statistically significant. The results of the path analysis are represented in Figure 1. According to the path analysis, as waist circumference increased, PaO<sub>2</sub> at rest decreased ( $\beta = -0.234$ ; *P* = 0.0118). As PaO<sub>2</sub> at rest increased, the distance walked in 6-minutes increased ( $\beta = 2.585$ ; *P* = 0.0414). The 6MWT had a positive effect on physical functioning ( $\beta = 0.051$ ; *P* = 0.0008), which in turn was related to better quality of life ( $\beta = 1.148$ ; *P* = < 0.0001). Mental health was also associated with better IWQOL ( $\beta = 0.872$ ; *P* = 0.0052). The total effect of waist circumference on IWQOL-Lite was  $-0.035 [(-0.234) \cdot (2.585) \cdot (0.051) \cdot (1.148)]$ .

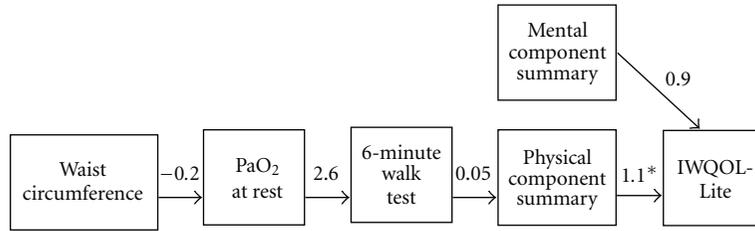


FIGURE 1: The path to quality of life for morbidly obese men and women. The coefficients correspond to the regression coefficient.

TABLE 2: Univariate linear regression models.

Predictors	Outcomes			
	PaO <sub>2</sub> at rest (mmHg)	6MWT (meters)	PCS	IWQOL
Waist circumference (cm)	$\beta = -0.235^*$ $P = 0.019$			
PaO <sub>2</sub> at rest (mmHg)		$\beta = 2.633$ $P = 0.0546$		
6MWT (meters)			$\beta = 0.052^*$ $P = 0.003$	
PCS				$\beta = 1.067^*$ $P = 0.0018$
MCS				$\beta = 0.818^*$ $P = 0.029$

\*Significant at <0.05.

TABLE 3: Multiple linear regression models.

Predictors	Outcomes			
	PaO <sub>2</sub> at rest (mmHg)	6MWT (meters)	PCS	IWQOL
Waist circumference (cm)	$\beta = -0.23^*$ $P = 0.02$	$\beta = 0.9$ $P = 0.5$	$\beta = -0.15$ $P = 0.14$	$\beta = -0.04$ $P = 0.86$
PaO <sub>2</sub> at rest (mmHg)		$\beta = 2.27$ $P = 0.12$	$\beta = -0.19$ $P = 0.25$	$\beta = -0.01$ $P = 0.99$
6MWT (meters)			$\beta = 0.05^*$ $P = 0.00$	$\beta = -0.01$ $P = 0.71$
PCS				$\beta = 1.07^*$ $P = 0.002$
MCS				$\beta = 0.82^*$ $P = 0.03$

The effect of the predictors is estimated in four regression models for four different outcomes. \*Significant at <0.05.

The summary statistics suggested excellent fit of the data ( $\chi^2 = 4.963$ , 9 df,  $P = 0.838$ ; RMSEA estimate = 0.000, RMSEA 90% confidence interval = 0.000–0.101 SRMR = 0.065; CFI = 1.000; TLI = 1.225). The model explained 13% of the variance in PaO<sub>2</sub>, 22% of PCS, 9% of 6MWT, and 38% of IWQOL-Lite.

#### 4. Discussion

About 6% of Americans are morbidly obese [1] and a large proportion have impaired WRQL. Given the impact of obesity, the development of a framework for understanding

and measuring the quality of life of people with obesity is essential. Understanding the determinants of WRQL could enable us to develop targeted biopsychosocial intervention to improve the quality of life of obese people. The interventions would then serve as a catalyst for engaging in behaviours which impact on both weight and on quality of life.

HRQL measures focus mainly on functioning, and fail to consider that people with chronic disease, such as obesity, may have adapted by finding alternative ways to have a satisfactory life. Some authors argue that we are really measuring perceived health and not HRQL with our present measures. That is, to assess HRQL adequately, the measures would have

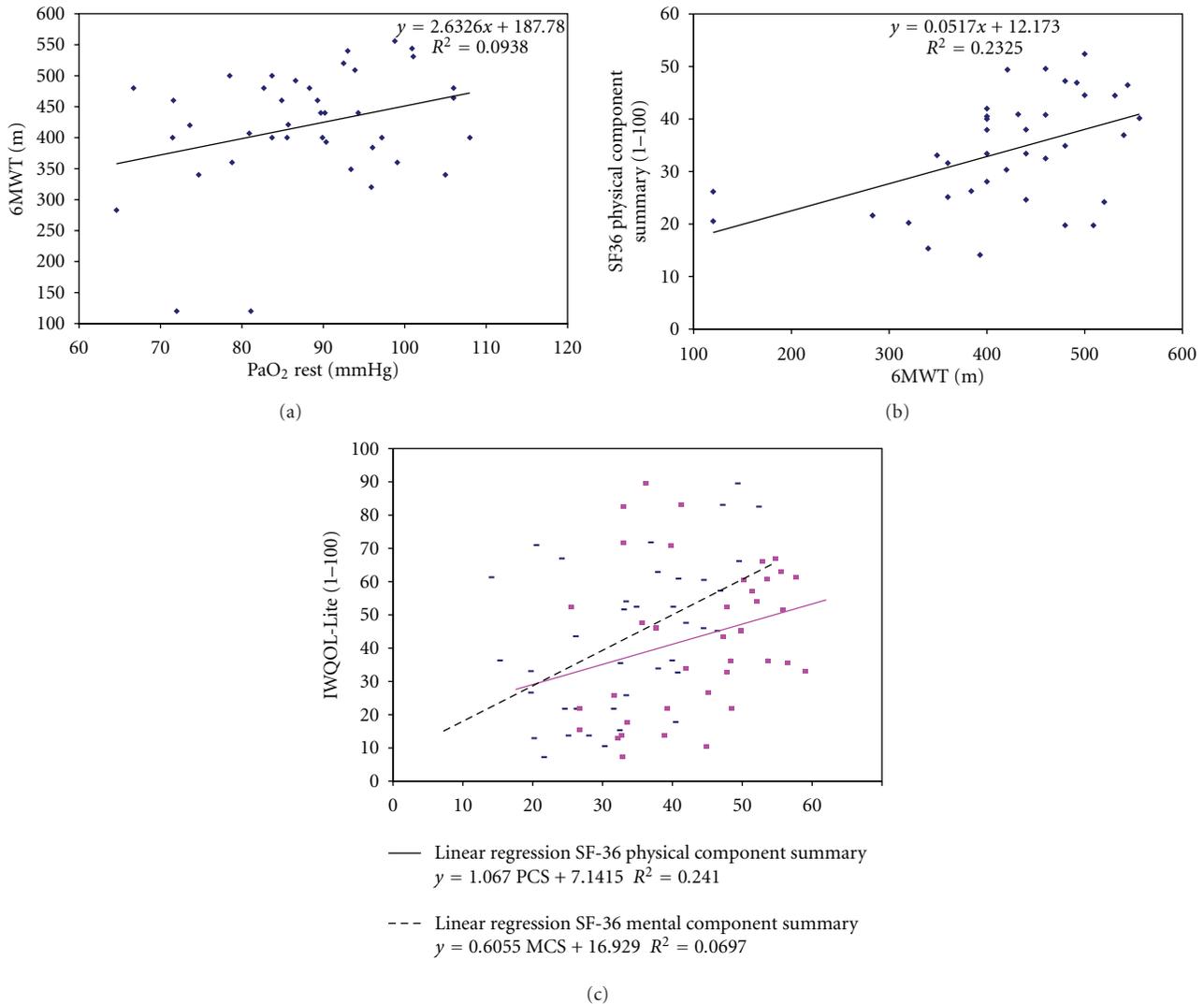


FIGURE 2: Univariate regressions: (a) relationship between  $\text{PaO}_2$  at rest and 6-minute walk test. (b) Relationship between 6-minute walk test and SF-36 Physical Component Summary. (c) In dashed line, the relationship between SF-36 Physical Component Summary (PCS) and IWQOL, and in solid line, the relationship between SF-36 Mental Component Summary (MCS) and IWQOL.

TABLE 4: Subpath estimates from the path analysis.

Estimate of effect	
Waist $\rightarrow$ $\text{PaO}_2$	-0.234* (0.093)
$\text{PaO}_2 \rightarrow$ 6MWT	2.585* (1.265)
6MWT $\rightarrow$ PCS	0.051* (0.015)
PCS $\rightarrow$ IWQOL	1.148* (0.287)
MCS $\rightarrow$ IWQOL	0.872* (0.313)

The values are unstandardized beta coefficients and standard error in brackets.

to incorporate the values and meanings an individual places on a given function [44]. Our study may address this issue. Once the determinants of WRQL have been identified, they can be integrated in the measures of WRQL, which could improve their psychometric properties, and render them more reflective of patients' values rather than solely of their functioning.

The statistical significance of the relationships between the components of the model of WRQL was demonstrated with linear regression. Path analysis was used to further test the model. Path analysis is the optimal approach to test a model as it evaluates an entire hypothesized multivariate model. It allows for the estimation of the direct effect of a variable on another, as well as the indirect effect of a variable on another through an intervening variable. Consequently, path analysis has the capacity to assess complex models. The model revealed by the analysis is consistent with the theory and evidence. It supports the Wilson-Cleary conceptual model of HRQL. As shown here, the measures of body size were all highly correlated, but the model with waist size had the best fit. Based on correlations and regression models, waist-to-hip ratio has been found to predict  $\text{PaO}_2$ , and an increase of waist-to-hip ratio is associated with lower resting  $\text{PaO}_2$  [20, 21]. PCS and MCS from the SF-36 can be considered as indicators of perceived health status, the

TABLE 5: Univariate and multiple linear regression models to predict WRQL.

	Beta coefficient	P value	Adjusted R <sup>2</sup>
<i>Univariate linear regression</i>			
Waist circumference (cm)	-0.180	0.411	-0.008
PaO <sub>2</sub> at rest (mmHg)	-0.057	0.869	-0.025
6MWT (meters)	0.049	0.224	0.013
PCS	1.067	0.002*	0.220
MCS	0.818	0.029*	0.101
<i>Multiple linear regression</i>			0.275
Waist circumference (cm)	-0.041	0.858	
PaO <sub>2</sub> at rest (mmHg)	-0.006	0.987	
6MWT (meters)	-0.015	0.712	
PCS	1.122	0.005	
MCS	0.918	0.015	

Abbreviations: PaO<sub>2</sub>, arterial blood gases at rest; 6MWT, 6-minute walk test; PCS, physical component summary; MCS, mental component summary.

\*Significant at <0.05.

capacity to exercise should theoretically impact an individual's perceived health status. Both SF-36 and IWQOL-Lite are HRQL measures: one is generic while the other is obesity specific. Both measures are expected to be associated.

There are some limitations to our study. The analysis was conducted on a small sample size. The determination of the minimum sample size required in path analysis is complex. Unlike in a linear regression, where the sample size depends on the ratio of subjects to variables, in a path analysis it depends on the number of parameters to be estimated. There is little empirical basis for any particular recommendations. The model estimated is simple consisting of six variables and 5 paths (sample size of 42 for 13 free parameters). The variables are normally distributed, and there were no convergence problems or improper solutions, such as negative variance estimates or Heywood cases. There may be other valid alternative models, and some relationships may have been excluded from the model by lack of power, but the relationships included are undeniably significant. In addition, a path analysis (sometimes called causal modeling) tests theoretical propositions about cause and effect without manipulating variables. In this study the propositions are supported by this method of decomposing correlations but the result does not prove that the causal assumptions are correct. Therefore the results should be considered as preliminary and need to be cross-validated in other samples. The model explained 38% of the variance of IWQOL-Lite, which may appear small but can be expected considering the complexity of WRQL and the limited spectrum of variables available on this sample. The use of latent variable representing many observed indicators may help to explain more variance in future studies. Other variables such as weight history, readiness for change, and physical activity habits would be interesting to examine. Furthermore, the presence of binge-eating disorder was not evaluated, which could have affected the results. Finally, the analysis is based on the Wilson-Cleary model which proposes linear relationships between variables. This linear model may not be optimal to capture the network of factors around WRQL.

In conclusion, waist circumference, PaO<sub>2</sub>, functional walking capacity, and mental health were predictors of WRQL. Health professionals should address these factors.

## Disclosure

The paper has not been published elsewhere and is not under simultaneous consideration by another journal. Previous reports of the same or very similar work has not been published. N. Christou is a consultant for Ethicon Endo-Surgery Inc. and has stock ownership in Weight Loss Surgery.

## Conflict of Interests

The authors have no financial or other relationships that might lead to a conflict of interest, and the paper has been read and approved by all the authors.

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