

Original Article

Effects of bariatric surgery on knee osteoarthritis, knee pain and quality of life in female patients

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Abstract

Objectives: Bariatric surgery is an effective intervention for severe obesity and associated comorbidities. We compared symptoms, joint space and life quality of morbidly obese patients with symptomatic knee osteoarthritis before and after bariatric surgery. **Methods:** 34 patients with knee osteoarthritis were evaluated with standing anteroposterior and lateral radiography, medial and lateral joint distances of the knees, Visual Analog Scale (VAS), Western Ontario and McMaster Universities Arthritis Index (WOMAC) questionnaire and the Short Form 36 (SF-36) before and 6 months after surgery. **Results:** Mean patient age was 48.53 ± 6.91 years. Mean body mass index was 46.97 ± 6.04 kg/m² and 34.41 ± 5.62 kg/m² before and after surgery, respectively. SF-36 subscales were significantly higher after surgery ($p < 0.05$), while mean VAS values and WOMAC scores were significantly lower postoperatively ($p < 0.001$). Right knee medial and left knee lateral joint distance measurements were significantly higher postoperatively ($p < 0.05$). BMI change, in linear regression analysis had no significant effect on VAS, WOMAC, SF-36 and knee lateral and medial joint distance measurements. **Conclusions:** Although bariatric surgery might improve pain, life quality and functionality of knee osteoarthritis in early period, improvement is not directly related to weight loss amount.

Keywords: Bariatric Surgery, Knee Osteoarthritis, Knee Pain, Obesity, Quality of Life

Introduction

Obesity is one of the most important preventable public health problems worldwide. The prevalence of the condition has doubled since 1980, due mostly to lifestyle changes in recent years. In 2014, 39% of people aged 18 and over were overweight, and 13% were obese¹. If the prevalence of obesity continues to increase at this rate; by 2030, nearly half of the adult population will live with the condition². Obesity and especially morbid obesity (body mass index [BMI] of >40) is a risk factor for several diseases and premature death³. The risk of cardiovascular diseases (heart disease and stroke),

diabetes, some cancers and musculoskeletal disorders (especially osteoarthritis [OA]) increases with obesity¹.

Osteoarthritis is associated with advanced age, however, people with a BMI of greater than 30 kg/m² have a 20-fold increased risk of knee OA compared with non-obese people, regardless of age^{4,5}. Obesity is a modifiable risk factor for knee OA, and a meta-analysis of the effect of weight loss on knee OA has revealed that a 5% reduction in weight within a 20-week period can result in symptomatic relief⁶.

Bariatric surgery is an effective weight loss intervention for severe obesity and the comorbidities associated with the condition⁷. The present study aimed to compare the symptoms, joint space width and quality of life of morbid obese patients with symptomatic knee OA before and after bariatric surgery. Sleeve gastrectomy was used in this study, and is the preference of most bariatric surgeons due to the shorter learning curve and reduced risk of complications compared with other techniques. In this restrictive procedure, the greater curvature of stomach is detached from the greater omentum, and approximately 2/3 of the greater curvature side of the stomach is resected with staples. This causes

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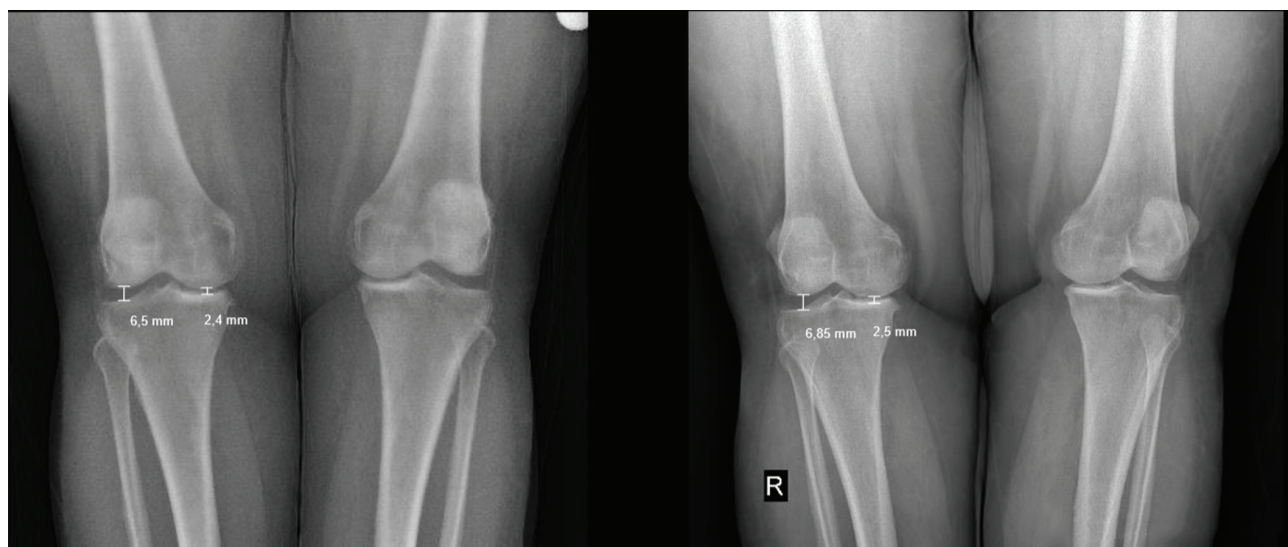


Figure 1. Representative X ray images showing medial and lateral joint distances of a patient before and after surgery.

reduction of the stomach volume and decreased appetite due to reduced levels of ghrelin, a hormone which is secreted from the fundal part of the stomach⁸.

Materials and methods

This study was carried out in the Bağcılar Training and Research Hospital Physical Medicine and Rehabilitation (PMR) and General Surgery Department between November 2014 and September 2016. Bariatric surgery candidates were selected according to the 1991 National Institutes of Health (NIH) consensus statement⁹ by a committee consisting of general surgeons, endocrinologists, physical medicine and rehabilitation specialists and psychiatrists. Severely obese patients (BMI>35 kg/m²) with at least one comorbidity (hypertension, type 2 diabetes, obstructive sleep apnea or BMI>40 kg/m²) were selected for surgery. All operations were performed laparoscopically by the same surgeon. Sleeve gastrectomy (SG) was performed for all patients.

Patients

Patients who presented with bilateral knee pain lasting at least six months were referred to the PMR outpatient clinic where they were examined by a PMR specialist. Thirty-four patients (32 female, 2 male) between the ages of 37 and 66 were diagnosed with knee OA according to American College of Rheumatology classification criteria¹⁰. The exclusion criteria were: prior hip, knee or ankle surgery which caused malalignment; leg length difference; inflammatory arthritis; intraarticular injection or physical therapy treatment for arthritis in the last six months.

Ethical statement

The present study conforms with the World Medical Association Declaration of Helsinki-Ethical Principles for Medical Research Involving Human Subjects. The study and its protocols were approved by local ethics committee of the Bağcılar Training Hospital (approval number 2014/283). Informed content was obtained from all participants.

Outcome measurements

All patients were examined by the same PMR specialist and were evaluated using standing anteroposterior and lateral knee X-ray with standardized techniques. Kelgren Lawrence grade 2 and 3 knee OA patients were included. For imaging, patients were asked to stand with equal weight distribution on both legs, with both feet fixed at an external rotation of 10° and knees bent at 30°. For the posteroanterior view, the X-ray beam was directed parallel to the tibial plateau at a 10° caudal beam alignment. The X-ray tube, knee and imaging plate distances were the same for all patients, and one technician acquired all the images. Exposed imaging plates were digitized using Philips Digital Radiography. (Model: DigitalDiagnost Single Detector, serial number: SN 11000573, Hamburg, Germany, 2011, software version: 2) Medial and lateral joint space widths were measured in triplicate in the mid-portion of the medial and lateral compartments of each knee by the same radiologist to account for intra-observer reliability. The mean values were considered to represent the joint space width¹¹ (Figure 1). The Visual analog scale (VAS)¹², Turkish version of the Western Ontario and McMaster Universities Arthritis Index (WOMAC)

questionnaire¹³ and Turkish version of the short form 36 (SF-36)¹⁴ were assessed before and 6 months after surgery. The VAS is a common tool which utilizes a 10 cm scale to measure pain intensity, and WOMAC is extensively used to evaluate knee and hip OA in terms of pain, stiffness and physical functioning. The SF-36 is a 36 item self-reported survey of patient health. The form has eight sections covering vitality, physical functioning, bodily pain, general health perceptions, physical role functioning, emotional role functioning, social role functioning and mental health¹⁴. Together, these tools were used to evaluate and record pain intensity, functionality and quality of life.

Statistical analysis

The SPSS (IBM Corp. Released 2012. IBM SPSS Statistics for Windows, Version 21.0. Armonk, NY: IBM Corp.) program was used for statistical analysis. Continuous variables are presented as mean, standard deviation, minimum and maximum values. The normality of continuous data was evaluated with the Shapiro Wilk test, and pre- and postoperative values were compared using the Wilcoxon signed-rank test or paired t-test. Correlations were evaluated using Pearson and Spearman correlation analyses. The level of significance was set at $\alpha=0.05$. Regression analysis assumptions were tested before performing regression analysis. Square root transformations were applied for non-normally distributed variables and it was observed that the variables exhibited normal distribution. Linearity test was used to determine the linear relationship between dependent and independent variables and it was found that there were linear relationships between variables ($p>0.05$). Independent variables are body mass index of patients, dependent variables are VAS, WOMAC, SF 36 and joint space width.

Results

In total, 34 patients fulfilled the inclusion criteria for the study. Four patients did not want to complete follow up due to living in other cities. The mean age of the 30 patients who completed the study was 48.53 ± 6.91 years. Demographic data of the study participants are summarized in Table 1. The mean BMI before bariatric surgery was 46.97 ± 6.04 kg/m², which decreased to 34.41 ± 5.62 kg/m² after surgery, representing a mean decrease of 27.38%.

Mean values of the SF-36 scores in the pre- and postoperative periods are shown in Table 2. All eight subscales of the survey were significantly higher 6 months after bariatric surgery compared with the preoperative period ($p<0.05$). With regards to preoperative period, the mean VAS value for the knee was 6.23 ± 2.11 . This decreased to 3.57 ± 2.53 after bariatric surgery ($p<0.001$). The WOMAC scores were also significantly lower in the postoperative period compared with the preoperative period ($p<0.001$).

Results of radiographic measurements are detailed in Table 3. The mean right knee medial joint space widths were

Table 1. Demographic characteristics of study participants.

N = 30	
Age, years	48,53±6,91 (49:67)
Level of education	
Elementary school	17 (56.70)
Secondary school	2 (6.70)
High School	8 (26.70)
University	3 (10)
Profession	
Housewife	19 (63.30)
Worker	5 (16.70)
Retired	3 (10)
Nurse	2 (6.70)
Designer	1 (3.30)
Additional diseases	
Hypertension	6 (20)
Diabetes mellitus	8 (26.70)
Hyperlipidemia	1 (3.30)
Sleep Apnea Syndrome	2 (6.70)
Coronary disease	2 (6.70)
Hypothyroidism	1 (3.30)
Asthma	1 (3.30)

Continuous data are presented as mean ± standard deviation (miminum:maximum), and categorical data are presented as number (%).

significantly higher postoperatively compared with those that were recorded preoperatively ($p=0.004$). However, no significant differences were found between the pre- and postoperative mean values of right knee lateral joint space width ($p=0.094$). With regards to the left knee, mean medial joint space widths were not significantly different in the preoperative and postoperative periods ($p=0.078$), although the lateral joint space widths were significantly higher postoperatively compared with those measured in the preoperative period ($p=0.0001$).

The correlations between BMI and WOMAC, VAS and knee joint space width in the preoperative period were analyzed (Table 4). No significant correlation of BMI with VAS or WOMAC scores was observed ($p>0.05$), and BMI was not significantly correlated with the right and left knee medial and lateral joint space widths ($p>0.05$). However, WOMAC and VAS scores were significantly positively correlated. ($r=0.656$ $p=0.0001$). The WOMAC scores were not significantly correlated with the right and left knee medial and lateral joint space width values ($p>0.05$). The mean VAS scores and left and right knee medial and lateral joint space widths were not significantly correlated ($p>0.05$).

In order to determine the effect of the change between BMI preoperative and postoperative period on preoperative and postoperative difference of other variables, simple linear regression analysis was performed in which BMI was independent and other variables were dependent variables.

Table 2. Short Form 36 Subscales before and 6 months after surgery.

Subscale	Preoperative score	Postoperative score	p-value
Physical functioning	37.50 (0:60) 32.67±19.06	85 (0:100) 79±24.82	<0.001*
Physical role limitation	0 (0:100) 28.67±37.35	100 (0:100) 79±33.85	<0.001*
Pain	36.50 (0:74) 37.97±22.11	79 (12:100) 74.83±26.29	<0.001*
General health	45 (0:87) 45.63±22.18	72 (20:100) 67.83±23.99	0.001*
Vitality	37.50 (5:85) 39.43±23.74	62.50 (20:100) 61.67±22.33	0.006*
Social functioning	37.25 (0:100) 40.57±32.67	100 (12:100) 82.69±26.06	<0.001*
Emotional role limitation	33 (0:100) 33.66±37.14	66 (0:100) 67.77±30.77	0.001*
Mental health	50.2 (12:96) 54.80±20.26	65,6 (32:100) 68.73±19.24	0.017

*Data are presented as median (minimum:maximum). Italicized data represent means, presented as xxx ± xxx. *: statistically significant.*

Table 3. Preoperative and postoperative Visual Analog Scale and Western Ontario and McMaster Universities Arthritis Index scores and knee joint space widths.

Parameter	Preoperative score/value	Postoperative score/value	p-value
WOMAC	46.50 (11:75) 42.40±20.01	11.50 (0:83) 24.23±24.43	<0.001*
VAS	7 (2:10) 6.23±2.11	3 (0:9) 3.57±2.53	<0.001*
Right knee medial joint space width	4.40±1.04 (3.36-5.44)	4.77±1.0 (3.77-5.77)	0.004*
Right knee lateral joint space width	5.36±1.30 (4.06-6.66)	5.62±1.25 (3.77-5.77)	0.094
Left knee medial joint space width	4.21±1.26 (2.95-5.47)	4.52±1.33 (3.19-5.85)	0.078
Left knee lateral joint space width	5.10±1.06* (4.04-6.16)	5.65±0.96* (4.69-6.55)	<0.001*

*Notes: Visual Analog Scale (VAS) and Western Ontario and McMaster Universities Arthritis Index (WOMAC) scores are presented as means (minimum:maximum); joint space widths are presented as means ± standard deviation. Italicized data represent xxx and are presented as xxx ± xxx. For joint space widths, italicized data represent xxx and are presented as xxx ± xxx (xx-xx). Abbreviations: VAS, Visual Analog Scale; WOMAC, Western Ontario and McMaster Universities Arthritis Index. *: statistically significant*

As a result of the analysis, it was found that BMI change had no significant effect on other variables (Table 5).

Discussion

Obesity influences the health-related quality of life of individuals, and the physical problems have a greater impact on the quality of life than mental problems in people who suffer from this condition¹⁵. In the present study, quality of

life was measured using the SF-36 scale before and 6 months after surgery. Physical functioning, physical role limitation, pain, general health, social functioning, emotional role limitation, mental health and vitality scores of the participants were found to improve after the operation. Improvements in mental health and vitality were not statistically significant, which is in agreement with the literature^{16,17}.

Obesity is a modifiable risk factor for knee OA, as mechanical loading across the articular cartilage leads to

Table 4. Correlation analysis of preoperative body mass index and other variables.

		Age	BMI	WOMAC	VAS
Age	R	1	0.226	-0.256	-0.037
	p		0.231	0.173	0.845
BMI	R	0.226	1	-0.175	-0.265
	p	0.231		0.355	0.157
WOMAC	R	-0.256	-0.175	1	0.656*
	p	0.173	0.355		0.0001*
VAS	R	-0.037	-0.265	0.656*	1
	p	0.845	0.157	0.0001*	
Right knee medial joint space width	R	-0.088	0.087	-0.194	-0.118
	p	0.644	0.649	0.305	0.536
Right knee lateral joint space width	R	0.197	0.321	-0.334	-0.279
	p	0.298	0.083	0.071	0.136
Left knee medial joint space width	R	-0.068	0.195	-0.171	-0.061
	p	0.719	0.302	0.367	0.748
Left knee lateral joint space width	R	0.118	0.069	-0.105	-0.014
	p	0.534	0.717	0.581	0.943

Abbreviations: BMI, body mass index; VAS, Visual Analog Scale; WOMAC, Western Ontario and McMaster Universities Arthritis Index.
*Statistical significant correlation.

Table 5. Regression analysis of BMI change in preoperative and postoperative period on VAS, WOMAC, SF 36 subscales change in preoperative and postoperative period.

	β	p	R ²
VAS	-0,265	0,157	0,070
WOMAC	-0,175	0,355	0,031
SF 36 Physical Functioning	-0,046	0,808	0,002
SF 36 Physical Role Limitation	0,061	0,749	0,004
SF 36 Pain	0,129	0,496	0,017
SF 36 General Health	0,031	0,869	0,001
SF 36 Vitality	-0,076	0,691	0,006
SF 36 Social Functioning	-0,343	0,063	0,118
SF 36 Social Role Limitation	0,002	0,993	0,000
SF 36 Mental Health	0,040	0,836	0,002

Abbreviations : VAS, Visual Analog Scale; WOMAC, Western Ontario and McMaster Universities Arthritis Index; SF 36, Short Form 36.
*Statistical significant correlation.

eburnation, degradation and degeneration of the joint¹⁸. Reijman et al in the Rotterdam Study investigated BMI as a strong independent determinant of knee OA, and found that high BMI was associated with progression of knee OA¹⁹. As well as mechanical loading, obesity contributes to OA because adipose tissue is a metabolic, endocrine organ. The tissue secretes adipocytokines including leptin, resistin and adiponectin, which are thought to increase joint degradation^{20,21}. Insulin resistance and metabolic changes are also related to proinflammatory cytokine production and the generation of a chronic inflammatory state in OA²².

In the Framingham Osteoarthritis Study, weight changes were recorded over 10 years to evaluate the effects of long-term weight change on OA. Among people with BMI>25, weight loss was associated with a significantly decreased rate of OA, whereas weight gain was associated with a slightly increased rate. For women with a BMI<25, neither weight loss nor gain affected the risk for the disease. Several studies have demonstrated the benefits of weight loss when symptoms of OA are already present. For example, Hooper et al. reported that the WOMAC and SF-36 scores of 48 obese patients with musculoskeletal symptoms improved when they

were assessed at 6 and 12 months after bariatric surgery²³. Edward et al. evaluated 24 patients with knee pain 6 and 12 months after bariatric surgery, and also reported that the Knee Injury and Osteoarthritis Outcome Score (KOOS) and WOMAC score had decreased significantly²⁴. The present study supports these results, as our results demonstrate that rapid weight loss due to bariatric surgery can lead to improvements in the symptoms of knee OA. However, in a retrospective assessment of 15 patients, Trafo et al. observed that an increased number of bariatric surgery patients underwent total joint arthroplasty²⁵. The authors concluded that rapid weight loss might increase the risk of requiring total joint arthroplasty, as improvement of symptoms may enable a more physically active lifestyle, which can put additional stress on damaged joints and accelerate OA progression. In this study, rapid weight loss was considered as a risk factor for OA progression. We found that the physical functioning and physical limitations of the patients improved, as observed by Trafo et al.²⁵; however, progression was not observed in radiographic findings. This could be due to the shorter follow up period of the present study.

Hamdi et al. studied the effects of rapid weight loss in 30 patients, and found positive effects on sports function but no effect on knee pain, stiffness or daily function²⁶. In the present study, the VAS and WOMAC scores of the patients were significantly lower 6 months after surgery, which is in agreement with similar studies^{23,24}. However, BMI was not correlated with these scores as found in our study

Overall, the quality of life of the patients in this study improved due to changes in their physical and physiological conditions that were brought about by weight loss. This may have an additive effect on pain scores. In fact, a previous study found the sensitivity and pain-detection thresholds of obese participants were higher than those of non-obese participants, which may be due to higher quality of life and altered pain perception. Furthermore, the pain thresholds of patients who underwent surgery had higher pain detection threshold²⁷. This may provide an explanation for the reduction in VAS and WOMAC scores after bariatric surgery that was recorded in the present study.

In a study including 78 obese patients, Anandacoomarasamy et al. reported that there was no association between weight loss and cartilage thickness in the lateral compartment during 12 months of magnetic resonance imaging (MRI) follow up; but reduced cartilage thickness was observed in the medial femoral compartment²⁸. Abu-Abeid et al. evaluated 59 patients who underwent bariatric surgery using conventional radiology, and reported a statistically significant increase in the left and right knee joint medial space widths 3 months after surgery²⁹. The patients of the previous studies included both men and women, which could account for the discrepancies with our results as a reduction in BMI is associated with increased joint space width in women. In the present study, the BMI of patients decreased considerably (but remained in the obese category) and all joint spaces were found to be increased. However, only the right knee medial and left

knee lateral joints showed statistically significant changes, which may be due to the small sample size and short follow up period of our study. Our results indicate that joint space width is not correlated with VAS and WOMAC scores, in contrast to the findings of Abu Abeid et al.²⁹.

The present study has some limitations which should be noted. First, body fat and muscle composition of the patients were not evaluated. Toda et al. have demonstrated that decreasing body fat and increasing physical activity are more important than weight loss for physical function³⁰; therefore, we will consider evaluating the physical activity level before and after surgery in future studies. Second, the small sample size, lack of male patients and short follow-up period are also limitations of this study. These limitations may affect the statistics of the results and prevent us from drawing firm conclusions with regards to long term outcomes. Future studies involving a larger sample size and more equal numbers of males and females are needed to dedicate the effect of bariatric surgery on knee osteoarthritis.

In conclusion, we observed that bariatric surgery might be efficacious for improving knee pain, functionality and quality of life in female patients in early period but efficacy is not directly related to weight loss amount. Further studies are needed to study the long-term effects of bariatric surgery on knee OA and the musculoskeletal system.

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References

1. who.int [internet]. World Health Organization: Obesity and Overweight fact sheet c2016 [cited 14.02.2018] Available from: <http://www.who.int/mediacentre/factsheets/fs311/en/>
2. Dobbs R, Sawers C, Thompson F, Manyika J, Woetzel JR, Child P et al. Overcoming obesity: An initial economic analysis. McKinsey Global Institute: Jakarta, Indonesia, 2014.
3. Whitlock G, Lewington S, Sherliker P, Clarke R, Emberson J, Halsey J et al. Body-mass index and cause-specific mortality in 900 000 adults: collaborative analyses of 57 prospective studies. *Lancet* 2009;373(9669):1083-96.
4. Dillon CF, Rasch EK, Gu Q, Hirsch R. Prevalence of knee osteoarthritis in the United States: arthritis data from the Third National Health and Nutrition Examination Survey 1991-94. *J Rheumatol* 2006;33(11):2271-9.
5. March LM, Bagga H. Epidemiology of osteoarthritis in Australia. *Med J Aust* 2004;180(5 Suppl):S6-10.
6. Christensen R, Bartels EM, Astrup A, Bliddal H. Effect of weight reduction in obese patients diagnosed with knee osteoarthritis: a systematic review and meta-analysis.

- Ann Rheum Dis 2007;66:433-9.
7. Colquitt JL, Pickett K, Loveman E, Frampton GK. Surgery for weight loss in adults. *Cochrane Database Syst Rev* 2014;8:CD003641.
 8. Warner DL, Sasse KC. Technical details of laparoscopic sleeve gastrectomy leading to lowered leak rate: Discussion of 1070 consecutive cases. *Minim Invasive Surg* 2017;2017:4367059
 9. NIH Conference. Gastrointestinal surgery for severe obesity. Consensus Development Conference Panel. *Ann Intern Med* 1991;115:956-61.
 10. Altman R, Asch E, Blosch D, Bole G, Borenstein D, Brandt K et al, Development of criteria for the classification and reporting of osteoarthritis: Classification of osteoarthritis of the knee. Diagnostic and Therapeutic Criteria Committee of the American Rheumatism Association. *Arthritis Rheum* 1986;29(8):1039-49.
 11. Anas I, Musa TA, Kabiru I, Yisau AA, Kazaura IS, Abba SM et al. Digital radiographic measurement of normal knee joint space in adults at Kano, Nigeri The Egyptian Journal of Radiology and Nuclear Medicine 2013;44(2):253-8.
 12. Katz J, Melzack R. Measurement of pain. *Surg Clin North Am* 1999;79:231-52.
 13. Tüzün EH, Eker L, Aytar A, Daşkapan A, Bayramoğlu M. Acceptability, reliability, validity and responsiveness of the Turkish version of WOMAC osteoarthritis index. *Osteoarthritis Cartilage* 2005;13(1):28-33.
 14. Demiral Y, Ergor G, Unal B, Semin S, Akvardar Y, Kivircik B, et al. Normative data and discriminative properties of short form 36 (SF-36) in Turkish urban population. *BMC Public Health* 2006;6:247.
 15. Doll HA, Peterson SE, Stewart-Brown SL. Obesity and physical and emotional well-being: associations between body mass index, chronic illness, and the physical and mental components of the SF-36 questionnaire. *Obes Res* 2000;8:160-70.
 16. Lindekilde N, Gladstone BP, Lübeck M, Nielsen J, Clausen L, Vach W, et al. The impact of bariatric surgery on quality of life: a systematic review and meta-analysis. *Obes Rev* 2015;16:639-51.
 17. Hachem A, Brennan L. Quality of Life Outcomes of Bariatric Surgery: A Systematic Review. *Obes Surg* 2016;26(2):395-409.
 18. Guilak F, Fermor B, Keefe FJ, Kraus VB, Olson SA, Pitsesky DS et al. The role of biomechanics and inflammation in cartilage injury and repair. *Clin Orthop Relat Res* 2004;423:17-26.
 19. Reijman M, Pols HAP, Bergink AP, Hazes JMW, Belo JN, Lievense AM et al. Body mass index associated with onset and progression of osteoarthritis of the knee but not of the hip: The Rotterdam Study. *Ann Rheum Dis* 2007;66(2):158-62.
 20. Dumond H, Presle N, Terlain B, Mainard D, Loeuille D, Netter P et al. Evidence for a key role of leptin in osteoarthritis. *Arthritis Rheum* 2003;48:3118-29.
 21. Chen TH, Chen L, Hsieh MS, Chang CP, Chou DT, Tsai SH. Evidence for a protective role for adiponectin in osteoarthritis. *Biochimica et Biophysica Acta* 2006;1762:711-8.
 22. Sowers MFR, Karvonen-Gutierrez CA. The evolving role of obesity in knee osteoarthritis *Curr Opin Rheumatol* 2010;22(5):533-7.
 23. Hooper MM, Stellato TA, Hallowell PT, Seitz BA, Moskowitz RW. Musculoskeletal findings in obese subjects before and after weight loss following bariatric surgery. *Int J Obes* 2007;31:114-20.
 24. Edwards C, Rogers A, Lynch C, Pylawka T, Silvis M, Chinchilli V et al. The effects of bariatric surgery weight loss on knee pain in patients with osteoarthritis of the knee. *Arthritis* 2012;2012:504189.
 25. Trafo D, Eric BA, Smith L, Shah V, Shikora S. Total weight loss associated with increased physical activity after bariatric surgery may increase the need for total joint arthroplasty. *Surg Obes Relat Dis* 2014;10(2):335-9.
 26. Hamdi A, Albaghdadi AT, Alnowiser A, Anas A, Altaf A. Bariatric surgery improves knee function and not knee pain in early postoperative period. *J Orthop Surg Res* 2018;13(1):82.
 27. Dodet P, Perrot S, Auvergne L, Hajj A, Simoneau G, Declèves X et al. Sensory Impairment in obese patients? Sensitivity and pain detection thresholds for electrical stimulation after surgery-induced weight loss, and comparison with a nonobese population. *Clin J Pain* 2013;29(1):43-9.
 28. Anandacoomarasamy A, Leibman S, Smith G, Catterson I, Giuffre B, Fransen M, et al. Weight loss in obese people has structure-modifying effects on medial but not on lateral knee articular cartilage. *Ann Rheum Dis* 2012;71:26-32.
 29. Abu-Abeid S, Wishnitzer N, Szold A, Liebergall M, Manor O. The influence of surgically-induced weight loss on the knee joint. *Obes Surg* 2005;15(10):1437-42.
 30. Toda Y, Toda T, Takemura S, Wada T, Morimoto T, Ogawa R. Change in body fat, but not body weight or metabolic correlates of obesity, is related to symptomatic relief of obese patients with knee osteoarthritis after a weight control program. *J Rheumatol* 1998;25(11):2181-6.