

## The Evaluation of Workplace Obesity Intervention Program using Six Sigma Methodology

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## ABSTRACT

**Background:** This study was performed to develop, evaluate, and implement an effective obesity intervention program using the DMAIC (Define, Measure, Analyze, Improve, Control) methodology.

**Methods:** A workplace obesity intervention program involving 100 obese male workers (% body fat  $\geq$  25% and BMI  $\geq$  25 kg/m<sup>2</sup>) was conducted five times (20~30 minutes each time) for 12 weeks. The intervention involved a face-to-face counseling.

**Results:** The selected critical to quality (CTQ) according to the Define phase was % body fat. The subjects' mean % body fat, measured during Measure phase, was 27.8% and the sigma level was 0.54 $\sigma$ . According to the analyse phase, the total energy intake ( $r = 0.417$ ;  $P < 0.001$ ) and frequency of exercise ( $r = -0.317$ ;  $P < 0.01$ ) were considered as potential factors influencing % body fat. Therefore, these factors were implemented in the intervention protocol. By performing six sigma methodologies, % body fat was significantly decreased from 27.8% to 26.2%, and the sigma level was improved from 0.54 $\sigma$  to 1.27 $\sigma$ .

**Conclusions:** The six sigma methodology was well suited for implementing a more efficient and cost-effective intervention, for enhancing the quality of the intervention, and for facilitating the successful adoption of the process and protocol into practice.

**Key words:** Obesity, Six sigma, Workplace, Intervention, Cost-effective

### 식스 시그마 기법을 적용한 직장인 비만중재프로그램의 운영효과

**연구배경:** 식스 시그마의 한 기법인 DMAIC (정의, 측정, 분석, 개선, 관리)를 이용하여 효과적인 비만중재프로그램을 개발, 평가, 시행하기 위해 본 연구를 수행하였다.

**방법:** 체지방률이 25% 이상이고, 체질량지수가 25 kg/m<sup>2</sup> 이상인 비만 직장인 남성 100명을 대상으로, 12주간 면대면 상담(20~30분)을 총 5회 실시하였다.

**결과:** 정의단계에서 선정된 주요 품질특성(critical to quality, CTQ)은 체지방률이었으며, 측정단계에서 대상자들의 체지방률을 측정된 결과 평균 27.8%, 시그마 수준은 0.54 $\sigma$ 였다. 분석 단계에서 총 에너지 섭취량( $r = 0.417$ ;  $P < 0.001$ )과 운동 빈도( $r = -0.317$ ;  $P < 0.01$ )가 체지방률에 영향을 주는 잠재인자로 선정되었으며, 이를 중재프로그램 프로토콜에 적용하였다. 식스 시그마를 적용한 비만중재 프로그램을 실시한 후, 체지방률은 27.8%에서 26.2%로 유의하게 감소하였으며( $P < 0.01$ ), 시그마 수준은 0.54 $\sigma$ 에서 1.27 $\sigma$ 로 향상되었다.

**결론:** 식스 시그마는 중재프로그램의 효율성과 비용효과를 상승시키고, 적합한 프로그램 과정과 프로토콜을 성공적으로 적용하도록 하여 중재 프로그램의 목표를 달성하기 위해 적합한 기법이다.

**중심단어:** 비만, 식스 시그마, 사업장, 중재, 비용효과

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## Introduction

Obesity is associated with type 2 diabetes, hypertension, cardiovascular disease, certain forms of cancer, osteoarthritis and premature death<sup>1-3)</sup>; it is also associated with higher rates of absenteeism and lower productivity levels in workplaces.<sup>4,5)</sup> Abdullah et al.<sup>6)</sup> reported that obese people had a higher risk of type 2 diabetes by seven fold compared to normal weight people, according to the meta-analysis combining 18 prospective cohort studies, and more than 80% of the people with type 2 diabetes are overweight or obese.<sup>7)</sup> Also, the prevalence of obesity (defined as a body mass index (BMI)  $\geq 25$  kg/m<sup>2</sup>) in Korean adults has increased from 26.0% in 1998 to 31.3% in 2009.<sup>8)</sup> Consequently, obesity-related mortality, direct costs (medical care expenditures, traffic costs), and indirect costs (loss of productivity caused by premature death and lost workdays) have increased.<sup>9,10)</sup> In the workplace, obesity is an important driver of costs associated with absenteeism, sick leave, disability, injuries, and healthcare claims.<sup>11)</sup>

Workers' health is an essential element in determining the long-term success of a company and whether the company will thrive.<sup>12)</sup> The physical and social environments of a workplace influence individual worker's food choices and physical activity behaviors.<sup>13-15)</sup> The workplace is considered an important setting for obtaining or promoting a healthy lifestyle, since a majority of the adult population can be reached at the workplace<sup>16)</sup>. These reasons have prompted previous studies, which have investigated workplace intervention programs, to be applied in the workplace to prevent or lessen the risk of obesity and diabetes.<sup>17-20)</sup> A critical literature review of 72 data-based studies provided further evidence that worksite health programs lower health care costs.<sup>21)</sup> Furthermore, recent intervention strategies to efficiently manage risk of obesity and diabetes have been attempted.<sup>22,23)</sup> A more substantial and successful intervention program demands an organized process.

The six sigma methodology, introduced by Motorola and subsequently popularized by Jack Welch and General Electric (GE) in the 1990s, is a 'process excellence' tool, the target for continuous improvement.<sup>24)</sup> Six sigma is an effectiveness approach that uses mathematic techniques to understand, measure, and reduce process variation. Six sigma measures quality in terms of defect rates and sets

a target error rate of no more than 3.4 defects per million opportunities, or 6 standard deviations from the process mean. It achieves this by providing a methodology for improving the key steps of a process while reducing errors to an extremely low level.<sup>24,25)</sup> This methodology has been designed and applied in health-related fields to improve performance as in shortening patient's waiting time or other turnaround times<sup>25,26)</sup>, developing influenza vaccination process for employees<sup>27)</sup>, increasing patient satisfaction with pain management<sup>28)</sup>, and improving quality of the healthcare process.<sup>29-31)</sup> However, few studies have been conducted intervention program using six sigma.

This paper summarizes the steps of obesity intervention procedures that appear to be crucial, not only to the protocol of the intervention, but also to its successful outcome.

## Methods

### 1. Study Design

The methodology followed in this study analysis utilized DMAIC tools (Define, Measure, Analyze, Improve, Control) as the principal gadget of the six sigma approach of problem-solving and process improvement (Fig. 1).

The first step of the process is the Define phase. In this phase, all factors that play a role in the process and desired goals are defined and those that are critical to quality (CTQ) are identified. The CTQ items of the obesity intervention programs were identified by a matrix diagram analysis. Then, the SIPOC criteria (supplier, input, process, output, and customer) were used to identify all relevant elements of a process to improve the project.

The next step in the DMAIC methodology, the Measure phase, validated the measurement system by Gage Repeatability & Reproducibility (Gage R&R), and carried out the measurement of the CTQ's current six sigma level by process capability and the goal setting by literature review.

After establishing the measurement of the CTQ, in the Analyze phase, the core cause factors that could influence CTQ were identified by a logic tree; the factors that had maximal influence on variation in the process and output were analyzed in terms of significance by regression and correlation.

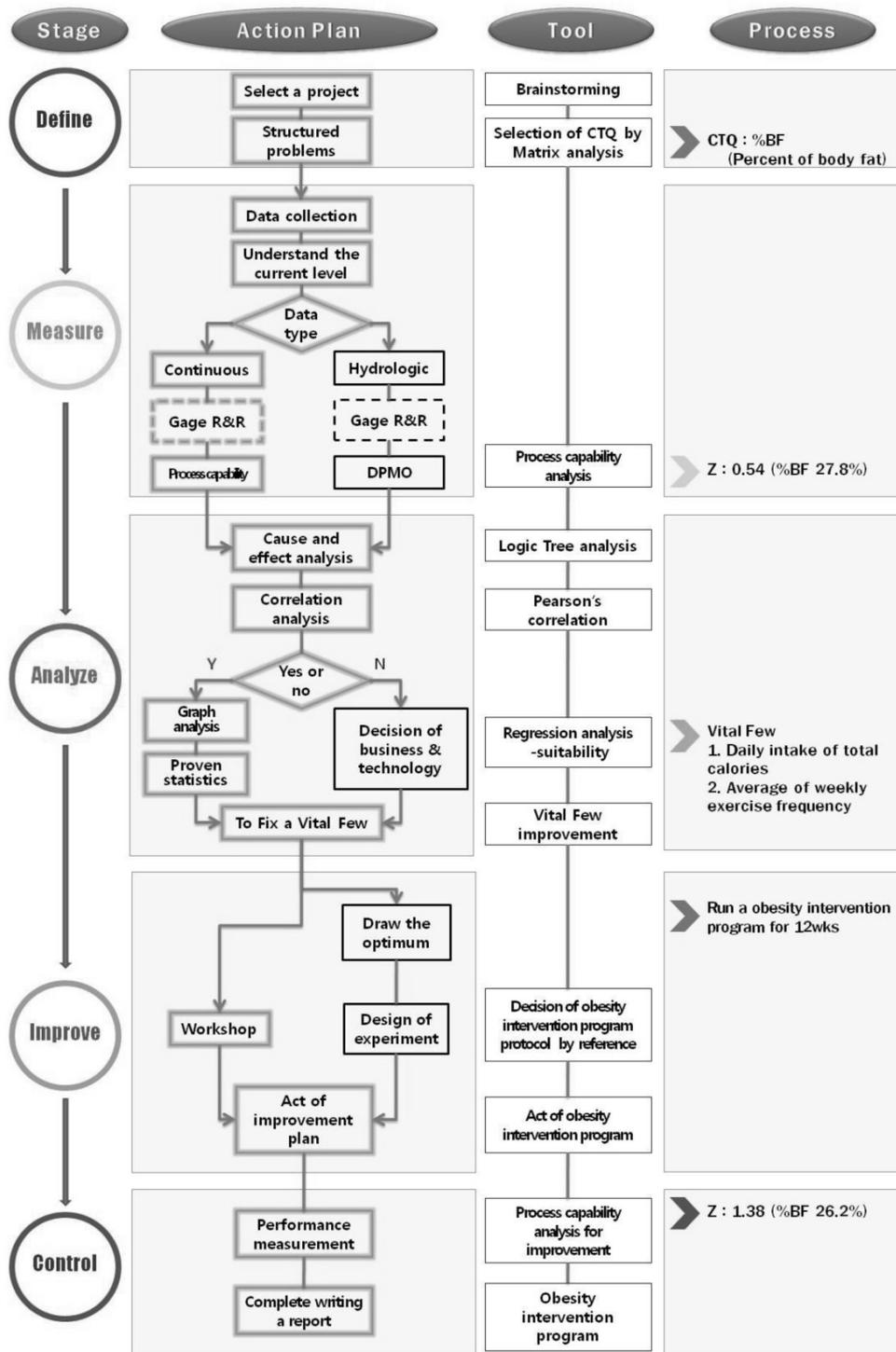


Fig. 1. Flowchart of six sigma methodology in this study.

In the Improve phase, strategies were formulated for improving the factors identified as having the highest significance in the previous step. With the deduced optimal improvement plans, an obesity intervention program protocol was established, educational materials were produced, and the obesity intervention program was

conducted for 12 weeks.

The last phase of this study was the Control phase. In this phase, the obesity intervention program protocol was standardized, and plans were made to improve output. The study was carried out from January to October, 2010.

## 2. Study Subjects

In this study, 100 obese (percent of body fat (%BF)  $\geq$  25% and BMI  $\geq$  25 kg/m<sup>2</sup>) subjects were screened and recruited from male workers who participated in an annual regular health check-up in 2009. World Health Organization Western Pacific Regional Office guidelines define overweight as  $23 \leq$  BMI  $<$  25 kg/m<sup>2</sup> and obesity as BMI  $\geq$  25 kg/m<sup>2</sup>.<sup>32)</sup> Participants were considered to have completed the 12 weeks program if they did not formally drop out. This study was approved by the Institutional Review Board of the Asan Medical Center (Seoul, Korea, 2008) and all subjects provided written and informed consent.

## 3. Measurements

Anthropometric characteristics including height and waist circumference (WC) were measured by an experienced research staff. Body composition measurements of the subjects were carried out by segmental bioelectric impedance (BIA-530; Jawon Medical, Seoul, Korea). Weight, lean body mass (kg) and %BF were measured. The BMI was calculated by dividing the weight (kg) by the height (m) squared.

Dietary intakes were analyzed using a computerized food frequency questionnaire (FFQ) originally developed by the Korea Centers for Disease Control and Prevention and later modified by our institution for industrial workers.<sup>32)</sup> The FFQ was designed to collect information regarding the subjects' usual food intake over the past year.

Lifestyle- and health-related variables were collected by using questionnaires. Questionnaires included questions on physical activity (including exercise), smoking status, drinking habit, hours of sleep and skipping the meal.

## 4. Statistical Analyses

Statistical analysis was performed using Minitab version 15.0 (Minitab Inc., Pennsylvania, USA). Changes due to intervention were tested by a paired t-test. Pearson's correlation and linear regression analysis were

used to measure the influence on change of %BF. Statistical analyses were two-sided and a *P*-value  $<$  0.05 was considered to be statistically significant.

## Results

In this study, we analyzed the potential CTQs as BMI, waist circumference, %BF and lean body mass during brainstorming sessions. Percent body fat (%BF) was defined as a CTQ according to the matrix diagram, since %BF had the highest total score (data not shown). This study process began with the selection of subjects and was completed with an effective analysis of an obesity intervention program.

To verify a measurement system of %BF by the two-factor random effect model, we conducted duplicate measurements by two assessor using two body composition analyzer in 2010. The total Gage R&R was 1.82, and *P*-value of interaction between assessors and body composition analyzers was 0.002. Assessor and body composition analyzer had no affect on the value of %BF (data not shown).

As a result of the %BF measurements of the 100 subjects, the sigma level was 0.54 $\sigma$  and the mean was 27.8%. Taking into consideration the duration and intensity of the intervention program, a goal was set for 1.3% decrease in %BF based on literature review and brainstorming sessions.

Using a logic tree, diet factors (total energy intake, high-fat intake, alcohol intake, vegetable intake, and fruit intake), physical activity factors (frequency of exercise, degree of exercise, and ordinary activity) and lifestyle factors (hours of sleep, skipping breakfast, drinking habit, smoking) were selected as core cause factors that affect potentially CTQ. The analysis of correlation between %BF with core cause factors indicated that total energy intake ( $r = 0.417$ ;  $P < 0.001$ ) and frequency of exercise ( $r = -0.317$ ;  $P = 0.001$ ) were significantly associated with %BF (Table 1). Finally, total energy intake and frequency of exercise was selected as vital few. The protocol of the

**Table 1.** Selected Vital Few using correlation and linear regression analysis

Vital Few	Correlation	Linear regression	<i>P</i> -value	Final improvement proposal
	<i>r</i>	$\beta$		
Total energy intake	0.417	0.001	$<$ 0.001	Decrease food intake and increase energy output
Frequency of exercise	-0.317	-0.661	0.001	Increase the number of frequency of exercise

obesity intervention program was planned to reflect vital few by reviewing approximately 200 literatures on obesity- and diabetes-related intervention study protocols and by brainstorming (Table 2). The obesity intervention program consisted of five, 20~30 min face-to-face counseling sessions over a 12 week period. Each participant was motivated to reduce food intake and increase the frequency of exercise. The subjects received information on food choices, physical activity, and lifestyle modification during each session.

The age of the recruited subjects for the trial (mean  $\pm$  standard deviation) was  $44.44 \pm 7.40$  years. The 12-week intervention significantly decreased BMI, waist circumference, %BF, total energy intake ( $P < 0.05$ ), and increased lean body mass along with the frequency of exercise ( $P < 0.05$ ) (Table 3). Percent body fat was significantly decreased from 27.84% to 26.17%, and the sigma level was improved from  $0.54\sigma$  to  $1.27\sigma$  ( $P = 0.002$ ) (Fig. 2).

To sustain the improved outcome and further improve

**Table 2.** Protocol of obesity intervention program

Session	Session title	Activity title	Goal of each session
1	Welcome to workplace obesity intervention program	Checking current health status Understanding obesity related health problems	
2	Leading dietary changes	Tip the calorie balance Calorie prescription Recommendation of food choice	Decrease total energy intake
3	Change of lifestyle	Finding daily habits that leads to obesity Tips of accurate drinking habits to reduce calorie intake Tips of increase physical activity in ordinary life	Decrease total energy intake Decrease total energy intake Increase energy output and exercise
4	Increasing physical activity	Appropriate exercise with obesity Easy stretching moves for office workers	Increase energy output and exercise
5	Maintaining healthy habits	Importance of maintaining changes for health habits My new lifestyle, living with friends and family	

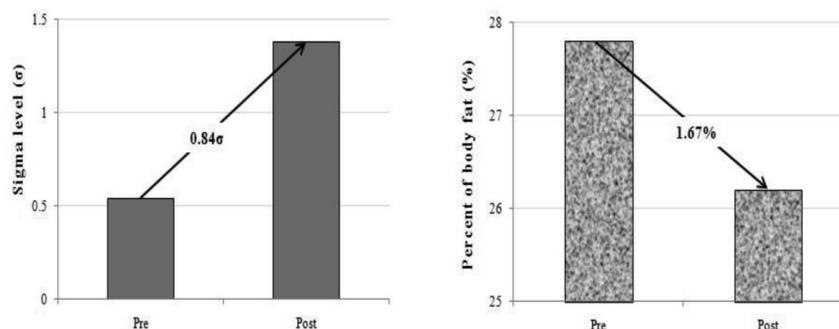
**Table 3.** Effects of obesity intervention on potential CTQs and Vital Fews

	Pre	Post	<i>P</i> value
Age (years)	$44.44 \pm 7.40$		-
BMI ( $\text{kg}/\text{m}^2$ )	$27.23 \pm 2.64$	$26.84 \pm 2.66$	$< 0.001$
WC (cm)	$89.94 \pm 6.79$	$88.71 \pm 6.09$	$< 0.001$
%BF (%)	$27.84 \pm 2.76$	$26.17 \pm 2.61$	0.002
LBM (kg)	$52.70 \pm 5.37$	$53.12 \pm 5.55$	$< 0.001$
Total energy intake (kcal)	$2279.79 \pm 860.08$	$1862.49 \pm 517.80$	$< 0.001$
Frequency of exercise (days/week)	$1.84 \pm 1.29$	$2.12 \pm 1.53$	0.016

Data were means  $\pm$  SD.

*P* value was measured by paired t-test.

BMI, body mass index; WC, waist circumference; %BF, percent of body fat; LBM, lean body mass.



**Fig. 2.** Changes of sigma level and percent of body fat.

it, we conducted an e-mail-based follow-up program. During the follow-up program period, brief (one-page) health care education information was provided by e-mail every 2 weeks, for a total of 10 times. After the program, a complete protocol of obesity intervention program was produced.

## Discussion

This study was initiated with the purpose of improving efficiency and quality of obesity intervention program by using the six sigma approach. Recent six sigma studies, in the health-related field, mostly have been conducted to improve health service. Our results indicate that the six sigma methodology can be usefully applied to an obesity intervention program.

BMI is a quick and easy measurement that the general public can understand and use. Also, it is routinely and very conveniently used. Many intervention studies have targeted weight or BMI loss.<sup>19,34-36</sup> Weight loss is the major nutrition and lifestyle intervention for overweight and obese diabetics.<sup>37</sup> However, attempts at weight control can have ensuing adverse effects that include weight cycling.<sup>38</sup> Furthermore, BMI can not distinguish between lean and fat body mass.<sup>39</sup> Consequently, a more direct measurement of body composition has been suggested.<sup>40</sup>

The distribution of body fat is also a well-established predictor of cardiovascular disease<sup>41</sup>, stroke<sup>42</sup>, diabetes<sup>43</sup>, and metabolic syndrome.<sup>44</sup> BMI is not reliable or sufficient for identifying obese individuals, where as %BF is superior to BMI in correctly classifying obesity based on accurate estimates of body fat.<sup>45</sup> Also, a study found that %BF, fat free mass, and blood total cholesterol were significantly decreased in no-weight cycling group compared with the weight cycling group after a 12-week weight control program.<sup>46</sup> However, no significant changes were observed between no-weight cycling group and weight cycling group in weight and BMI. Accumulating evidence favors the view that those with high %BF have a lower basal metabolic rate, which makes it difficult to maintain long-term stable body weight, thereby provoking weight regain. Accordingly, our study targeted %BF reduction to prevent weight cycling after an intervention program.

One study analyzed the influence of moderate intensity

exercise, consisting of walking for 60 minutes five times per week for 12 weeks, on obesity and cardiopulmonary function in subjects with diabetes to determine the effect on abdominal fat.<sup>47</sup> A significant decrease in abdominal fat area and improvement of cardiopulmonary function were noted, and %BF was significantly decreased from 36.86% to 33.37% (-3.49%). In another study, a low-calorie diet effectively reduced abdominal visceral fat without reduction of femoral muscle or dietary quality in obese type 2 diabetic subjects.<sup>36</sup> Yet another study reported a reduction in %BF of -0.1% after a 12-week workplace nutrition education program.<sup>48</sup> Presently, %BF was significantly decreased (-1.67%); the change was lower than that achieved using strong dietary restriction and exercise training.

Lifestyles are difficult to change, but lifestyle modification is the best way to improve and sustain health. In this study, each subject had five sessions with an experienced staff during the intervention period. This approach had merit; the repeated contact built a sense of closeness and trust among the subjects. The staff members were therefore able to clearly identify problems of the subjects and formulate behavioral modification strategies that were individualized and so were more likely to succeed.

One limitation is that this study did not assess the direct cost savings or revenue generated after implementing six sigma. Although the actual cost was not measured, improvement of the sigma level has been established in other studies to reduce cost and increase cost-effectiveness.

This study has several strong points as well. To our knowledge, this is the first study to extensively evaluate a protocol of intervention program using six sigma. Intervention program requires continuous and systematic innovation to provide cost-effective, timely, and high-quality operation. However, most obesity intervention studies focused on outcomes, such as decrease of weight and BMI, while few studies focused on intervention formation process. This may be because intervention formation process are often more difficult to measure. Therefore, this study bridged the gaps on intervention formation process between demands of theories and experience in the field and balanced the requirements of intervention staff and subjects by key steps of six sigma methodology. Moreover, after evaluation, the protocol of

the intervention program will be implemented broadly in the workplace without burdens of high cost and managed effectiveness. This study will also serve as a guideline for the establishment of intervention programs using six sigma methodology in order to apply it at different types of companies and implement it to high risk group of diseases.

The results of this study suggest the need to establish a more efficient intervention program which is scientific and systematic, and to adopt good guidelines for various aspects of intervention's practices.

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