

Excessive 5-year weight gain predicts metabolic syndrome development in healthy middle-aged adults

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between MetS outcome and excessive WG in the total population, as well as in both genders.

RESULTS: In total, 175 (12.6%) participants fulfilled MetS criteria within five years. In comparison to the control group, mild-WG adults had an insignificant risk for MetS development while adults having moderate-WG had a 3.0-fold increased risk for progression to MetS [95% confidence interval (CI), 1.8-5.1], and this risk was increased 5.4-fold (95% CI, 3.0-9.7) in subjects having severe-WG. For females having moderate- and severe-WG, the risk for developing MetS was 3.6 (95% CI, 1.03-12.4) and 5.5 (95% CI, 1.4-21.4), respectively. For males having moderate- and severe-WG, the odds ratio for MetS outcome was respectively 3.0 (95% CI, 1.6-5.5) and 5.2 (95% CI, 2.6-10.2).

CONCLUSION: For early-middle-aged healthy adults with a five-year weight gain over 5%, the severity of weight gain is related to the risk for developing metabolic syndrome.

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Abstract

AIM: To quantitatively examine the impacts of an easy-to-measure parameter - weight gain - on metabolic syndrome development among middle-aged adults.

METHODS: We conducted a five-year interval observational study. A total of 1384 middle-aged adults not meeting metabolic syndrome (MetS) criteria at the initial screening were included in our analysis. Baseline data such as MetS-components and lifestyle factors were collected in 2002. Body weight and MetS-components were measured in both 2002 and 2007. Participants were classified according to proximal quartiles of weight gain (WG) in percentages (%WG \leq 1%, 1% < %WG \leq 5%, 5% < %WG \leq 10% and %WG > 10%, defined as: control, mild-WG, moderate-WG and severe-WG groups, respectively) at the end of the follow-up. Multivariate models were used to assess the association

Key words: Excess weight gain; Metabolic syndrome; Middle-aged adults; Follow-up; Worker population

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INTRODUCTION

Measuring body weight is noninvasive, inexpensive and reliable both in terms of clinical and self-health monitoring^[1]. Analyses from the general population have revealed excessive weight gain (WG) as an important risk factor for developing metabolic syndrome (MetS)^[2,3]. MetS is also becoming an important concern in workplaces^[4-6] for its impacts on both the health condition^[7] and productivity^[8] of employees. Excessive WG is common in the early-middle-aged population^[9,10] who account for the majority of the workforce. However, there was a lack of a comprehensive follow-up survey for examining the possible quantitative association between WG severity and the risk for MetS development in the early-middle-aged worker population. Improving our knowledge of the impacts of WG on MetS development is helpful to health promotion in workplaces. Since periodic routine health checkups are compulsory for employees at many worksites in Taiwan, we had an opportunity to conduct a workplace-based follow-up observation for MetS development. We used this approach to evaluate the impacts of excessive WG on MetS development among early-middle-aged employees.

MATERIALS AND METHODS

Participants

A flowchart of the experimental protocol is shown below in the Figure 1. In 2002 and 2007, 1648 eligible employees of an electronic manufacturing company underwent compulsory health checkups in accordance with the *Labor Health Protection Regulation of the Labor Safety and Health Act*. The final analysis of this follow-up study only included subjects who did not fulfill MetS criteria in 2002. In total, 256 employees were excluded from the study because they had been screened previously for MetS. Final records from a total of 1384 workers (338 female and 996 male workers, aged 18 to 58 years with a mean age of 32.3 years) made up the cohort for the study and for the endpoint analysis. Most of the employees of this electronics manufacturing company were residents of northern Taiwan.

The health examination was open to all registered employees during every working day within a one-month period. All of the employees were recommended to avoid vigorous physical exercise for three days before their health examination. The subjects' identities were anonymous and were not linked to the data. This analytical study, limited to health checkup records, followed the ethical criteria for human research and the study protocol (TYGH09702108) was reviewed and approved by the Ethics Committee of the Tao-Yuan General Hospital, Taiwan.

Demographics, lifestyle data, and biological measurements

In 2002, the examinees completed a questionnaire about their baseline personal history, including their lifestyle factors.

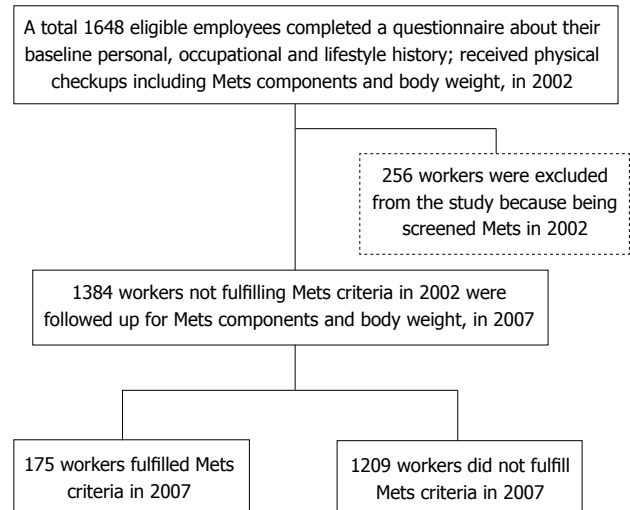


Figure 1 Flowchart of experimental protocol.

Physical examinations and blood tests were performed on all participants in both 2002 and 2007. The participants arrived at the health care unit of the factory in the morning, between 07:30 and 09:30 h, after an overnight 8 h fast. The physical examination records included measurements of waist circumference, weight, height and blood pressure. All the measuring apparatuses were routinely calibrated. Waist circumference was measured midway between the lowest rib and the superior border of the iliac crest. After being seated for 5 min, sitting blood pressure was measured with the dominant arm using digital automatic sphygmomanometers (model HEM 907, Omron, Japan) two times with a 5 min interval; the mean of these readings was used in the data analysis. After the physical examination, participants were placed in a reclined position, and venous blood (20 mL) was taken from an antecubital vein of the arm for subsequent tests. Blood specimens were centrifuged immediately thereafter, and were frozen and shipped on dry ice to a central clinical laboratory in the Tao-Yuan General Hospital (certified by ISO 15189 and ISO 17025). Glucose, triglyceride and high-density lipoprotein (HDL) cholesterol analyses were conducted by a Hitachi autoanalyzer model 7150 (Hitachi, Tokyo, Japan).

Weight gain evaluation

Weight gain (WG) was calculated as a percentage by the formula: $[(\text{body weight}_{2007} - \text{body weight}_{2002}) / \text{body weight}_{2002}]$ and was represented as %WG. Participants were classified into four subgroups according to their proximal quartiles of increased weight gain ($\%WG \leq 1\%$, $1\% < \%WG \leq 5\%$, $5\% < \%WG \leq 10\%$ and $10\% > \%WG$, defined as: control, mild-WG, moderate-WG and severe-WG groups, respectively) at end of the follow-up examination.

Metabolic syndrome

The MetS designation was made if three or more of the following five criteria were fulfilled: central obesity (waist

Table 1 Baseline characteristics of subjects without metabolic syndrome and five-year occurrence rates of metabolic syndrome

Baseline data	Overall	Female	Male
	N = 1384	n = 388	n = 996
Measurements; mean (standard deviation)			
Age (year)	32.3 (6.5)	32.8 (7.9)	32.1 (5.9)
Body weight (kg) ^a	63.7 (10.9)	54.2 (8.0)	67.4 (9.6)
Body mass index (kg/m ²) ^a	23.0 (3.0)	22.0 (3.1)	23.4 (2.9)
Waist (cm) ^a	75.6 (8.6)	68.5 (6.9)	78.3 (7.6)
Systolic blood pressure (mmHg) ^a	117.0 (14.3)	111.5 (13.4)	119.2 (14.1)
Diastolic blood pressure (mmHg) ^a	71.7 (9.2)	68.6 (8.9)	72.9 (9.0)
Fasting blood glucose (mg/dL)	94.3 (13.2)	93.8 (8.2)	94.5 (14.8)
Triglycerides (mg/dL) ^a	102.5 (78.0)	75.1 (39.3)	113.1 (86.3)
HDL cholesterol (mg/dL) ^a	50.5 (11.8)	55.6 (12.5)	48.6 (11.0)
Prevalent rates (%)			
Central obesity	3.90%	4.60%	3.60%
Hyperglycemia	20.50%	20.10%	20.70%
High blood pressure ^a	17.70%	8.50%	21.30%
Hypertriglyceridemia ^a	13.70%	4.10%	17.50%
Low-HDL cholesterolemia ^a	24.40%	35.30%	20.20%
Lifestyle			
Physical exercise; ≥ 3 times a week ^a	32.10%	25.50%	34.60%
Habitual drinker ^a	7.20%	0.30%	9.90%
Having snacks before sleeping (\geq third a week) ^a	39.50%	31.70%	42.50%
Having snacks between meals (\geq third a week) ^a	46.50%	61.10%	40.90%
Ever been a smoker (yes vs no) ^a	32.20%	5.20%	42.70%
MetS development within 5 years^a	12.60%	8.80%	14.20%

^a $P < 0.01$, t -test for continual variables between genders; χ^2 test was conducted for categorical variables between genders; HDL: high density lipoprotein cholesterol.

circumference > 90 cm for males and > 80 cm for females based on Taiwanese criteria^[11,12]; High blood pressure (systolic blood pressure ≥ 130 mmHg or diastolic blood pressure ≥ 85 mmHg); hyperglycemia (fasting sugar ≥ 100 mg/dL); hypertriglyceridemia (triglycerides ≥ 150 mg/dL); and low-HDL-cholesterolemia (high density lipoprotein cholesterol (HDL) < 40 mg/dL for males, < 50 for females). The last three factors were defined based on modified National Cholesterol Education Program Adult Treatment Panel III criteria^[11-13]. We defined subjects with a MetS outcome as those who did not fulfill MetS criteria in 2002 but did meet those criteria in 2007.

Lifestyle factors

To determine whether a subject had ever been a smoker, subjects were first asked if they smoked for at least half year [potential responses were: (1) Never; (2) Currently smoke; and (3) Used to smoke but no longer do] and were then asked further questions to determine how frequently they smoked. We defined a smoker or former smoker as a subject who answered “yes” to question 2 or 3 and consumed at least 6 cigarettes a day for over one year. To determine whether the subject typically consumed snacks, subjects were asked whether they typically had snacks before sleeping and whether they typically consumed snacks between meals. If the subjects answered yes to either of these questions, they were then asked further questions to determine how frequently they snacked. In the present study, by an arbitrary definition, workers were considered to habitually snack if they consumed more than three snacks per week. The subjects were con-

sidered to routinely undergo physical exercise if they exercised more than three times every week. To identify habitual drinkers, workers were first asked if they typically consumed alcohol [(1) No; (2) Yes] then were asked about frequency and quantity that they drink. Habitual drinkers were identified as those subjects who consumed alcohol one or more times per week, and those who consumed more than 40 g/d for males and 20 g/d for females^[14] on average over a year.

Statistical analysis

Baseline characteristics and abnormal rates were compared between the control group and subgroups of workers who gained weight over the five year period using an ANOVA or a χ^2 test for categorical or continual variables as appropriate. After adjusting for age, gender, MetS-components and lifestyle factors, models of multivariate logistic regression were used to estimate the adjusted odds ratios and 95% confidence intervals (CI) of risk factors to predict the development of MetS in the total population and in both genders independently. A P -value < 0.05 was considered to be statistically significant. SAS version 8.0 (SAS Institute, Cary, NC, USA) was used for all statistical analyses.

RESULTS

Table 1 demonstrates the baseline data for the overall population and for each gender independently. The measurements of the baseline MetS-components as well as the lifestyle factors were significantly different between

Table 2 Summary of baseline characteristics of variables for the total population and five-year occurrence rates of metabolic syndrome according to the severity of weight gain (*N* = 1384)

Baseline data	WG within 5 years			
	Control %WG ≤ 1%	Mild 1% < %WG ≤ 5%	Moderate 5% < %WG ≤ 10%	Severe %WG > 10%
	<i>n</i> = 341	<i>n</i> = 337	<i>n</i> = 387	<i>n</i> = 391
Measurements; mean (standard deviation)				
Age (year) ^b	33.5 (6.8)	33.3 (6.4)	32.4 (6.4)	29.7 (5.7)
Body weight (kg)	64.4 (10.5)	63.9 (11.8)	63.6 (11.0)	62.9 (10.3)
Body mass index (kg/m ²)	23.3 (2.8)	23.1 (3.0)	23.0 (3.2)	22.6 (2.9)
Waist (cm)	76.0 (8.2)	75.8 (8.9)	75.8 (9.1)	74.5 (8.0)
Systolic blood pressure (mmHg) ^a	118.9 (14.5)	116.4 (14.4)	117.0 (15.0)	115.7 (13.3)
Diastolic blood pressure (mmHg) ^b	73.3 (9.4)	71.7 (9.3)	71.5 (9.8)	70.2 (7.8)
Fasting blood glucose (mg/dL) ^a	95.8 (15.1)	94.5 (7.9)	93.9 (7.4)	92.8 (19.5)
Triglycerides (mg/dL) ^b	115.4 (118.8)	105.5 (65.0)	98.8 (55.9)	89.9 (52.2)
HDL cholesterol (mg/dL)	49.2 (11.0)	50.6 (12.7)	50.8 (12.6)	51.6 (10.7)
Prevalent rates (%)				
Lifestyle factors				
Physical exercise; > 3 times a week	34.90%	30.90%	31.30%	31.30%
Habitual drinker	6.20%	7.10%	8.50%	3.90%
Having snacks before sleeping (≥ third a week) ^b	34.00%	35.90%	44.20%	43.30%
Having snacks between meals (≥ third a week)	46.60%	43.60%	47.00%	48.90%
Ever been a smoker (yes <i>vs</i> no)	31.10%	29.70%	33.10%	34.80%
MetS development within 5 years	9.10%^b	9.50%^b	15.80%^b	16.00%^b

^a*P* < 0.05; ^b*P* < 0.01; An ANOVA was conducted, adjusting for age, using a Tukey's test. A trend test was conducted for categorical variables. WG: weight gain; HDL: high density lipoprotein cholesterol.

the two genders. Also, as shown at the bottom of Table 1, 12.6 % of total population developed MetS within five years; this value was 8.8% for female and was significantly higher for male workers, at 14.2%.

Among the four WG subgroups (Table 2), the baseline measurements of body weight, body mass index, waist circumference and most lifestyle factors were not significantly different, except that workers who had moderate and severe weight gain tended to snack before sleeping. The mean age of the severe-WG subgroup was lower than that of the other subgroups and the severe-WG subgroup was healthier than other subgroups at beginning of the experiment in terms of the baseline MetS-component measures. Table 2 also shows that the five-year occurrence rates of MetS were significantly higher in the moderate- and severe-WG subgroups.

Since the baseline measurements were significantly different between the two genders, Table 3 presents the baseline data for the MetS-components according to the severity of weight gain for both genders. For the early-middle-aged females, the subjects showing severe-WG were younger than those in other WG groups. Although the majority of baseline characteristics were similar, females who gained a moderate or severe amount of weight tended to snack between meals and before sleeping (Table 3). In our male adults, the severe WG group was the youngest and had better MetS-component baseline data than the other subgroups. Males who gained a moderate or severe amount of weight were inclined to snack before sleeping.

Table 4 presents the changes of MetS-component factors and the occurrence of MetS among four WG

subgroups for each gender. For our early-middle-aged females, the changes in the factors for central obesity and in Low-HDL levels were significantly less favorable in workers who gained moderate or severe amounts of weight and the development of MetS was found to be significantly higher in these subgroups than in others. For the male adults in our study, the moderate- and severe-WG subgroups showed significantly more unfavorable changes in nearly all MetS-components and had higher rates of MetS within five years than mild-WG and control subgroups.

After controlling for the confounding factors of initial age, MetS-components and lifestyle factors, a multivariate analysis was conducted and the results are shown in Table 5. The risk of developing MetS in subjects with moderate- and severe-WG was 3.0-times [95% confidence interval (CI), 1.8-5.1] and 5.4-times (95% CI, 3.0-9.7) greater than with the control group. For female workers with moderate- and severe-WG, the risk of developing MetS was 3.6-times (95% CI, 1.03-12.4) and 5.5-times (95% CI, 1.4-21.4) higher than the control group. Females who had been smokers had an increased risk (6.7 times higher, 95% CI, 1.2-36.7) of developing MetS than those who had never smoked. The risk of developing MetS in male adults with moderate- and severe-WG was 3.0-times [95% confidence interval (CI), 1.6-5.5] and 5.2-times (95% CI, 2.6-10.2) greater than the control group.

DISCUSSION

In this five-year interval follow up, approximately half of healthy middle-aged adults had a WG of over 5%,

Table 3 Summary of baseline characteristics of variables for female and male adults according to the severity of weight gain

Female <i>N</i> = 388				
Baseline data	WG within 5 years			
	Control %WG ≤ 1%	Mild 1% < %WG ≤ 5%	Moderate 5% < %WG ≤ 10%	Severe %WG > 10%
	<i>n</i> = 105	<i>n</i> = 100	<i>n</i> = 99	<i>n</i> = 84
Measurements; mean (standard deviation)				
Age (year)	33.6 (8.7)	33.0 (7.4)	33.1 (8.1)	31.1 (7.0)
Body weight (kg)	55.3 (7.3)	53.0 (7.5)	53.5 (8.3)	55.3 (8.8)
Body mass index (kg/m ²) ^b	23.9 (2.7)	23.8 (2.8)	23.3 (3.0)	22.6 (2.8)
Waist (cm)	68.8 (5.9)	67.8 (6.4)	68.1 (7.9)	69.5 (7.2)
Systolic blood pressure (mmHg)	112.2 (13.8)	109.7 (12.1)	113.2 (14.6)	110.6 (12.9)
Diastolic blood pressure (mmHg)	68.9 (9.0)	67.7 (8.8)	69.8 (9.6)	67.7 (8.1)
Fasting blood glucose (mg/dL)	94.0 (9.1)	94.7 (8.6)	94.2 (7.0)	91.9 (7.4)
Triglycerides (mg/dL)	79.4 (38.3)	73.4 (33.6)	74.0 (33.1)	73.2 (51.9)
HDL cholesterol (mg/dL)	53.2 (11.6)	57.1 (12.9)	56.4 (14.4)	55.6 (10.2)
Prevalent rates (%)				
Lifestyle factors				
Physical exercise; ≥ 3 times a week	25.70%	26.00%	23.20%	27.40%
Habitual drinker	1.00%	0.00%	0.00%	0.00%
Having snacks before sleeping (≥ third a week)	28.60%	26.00%	44.40%	27.40%
Having snacks between meals (≥ third a week)	59.00%	55.00%	74.70%	54.80%
Ever been a smoker (yes <i>vs</i> no)	6.70%	3.00%	4.00%	7.10%
Male <i>N</i> = 996				
Baseline data	WG within 5 years			
	Control %WG ≤ 1%	Mild 1% < %WG ≤ 5%	Moderate 5% < %WG ≤ 10%	Severe %WG > 10%
	<i>n</i> = 236	<i>n</i> = 237	<i>n</i> = 288	<i>n</i> = 235
Measurements; mean (standard deviation)				
Age (year) ^b	33.4 (5.7)	33.5 (6.0)	32.2 (5.7)	29.2 (5.0)
Body weight (kg) ^b	68.5 (9.0)	68.6 (10.1)	67.1 (9.6)	65.6 (9.5)
Body mass index (kg/m ²)	22.2 (2.8)	21.6 (2.8)	21.8 (3.5)	22.4 (3.1)
Waist (cm) ^b	79.3 (7.0)	79.2 (7.5)	78.4 (7.9)	76.3 (7.5)
Systolic blood pressure (mmHg) ^b	121.8 (13.8)	119.2 (14.3)	118.2 (14.9)	117.6 (13.0)
Diastolic blood pressure (mmHg) ^b	75.2 (8.9)	73.4 (8.9)	72.0 (9.8)	71.1 (7.6)
Fasting blood glucose (mg/dL)	96.6 (17.1)	94.4 (7.6)	93.8 (7.5)	93.2 (22.3)
Triglycerides (mg/dL) ^b	131.5 (137.6)	119.1 (70.2)	107.3 (59.5)	95.9 (51.1)
HDL cholesterol (mg/dL) ^a	47.4 (10.3)	47.9 (11.5)	48.8 (11.3)	50.1 (10.5)
Prevalent rates (%)				
Lifestyle factors				
Physical exercise; ≥ 3 times a week	39.00%	32.90%	34.00%	32.80%
Habitual drinker	8.50%	10.10%	11.50%	9.40%
Having snacks before sleeping (≥ third a week) ^a	36.40%	40.10%	44.10%	48.90%
Having snacks between meals (≥ third a week)	41.10%	38.80%	37.50%	46.80%
Ever been a smoker (yes <i>vs</i> no)	41.90%	40.90%	43.10%	44.70%

^a*P* < 0.05, ^b*P* < 0.01, An ANOVA was conducted, adjusting for age, using a Tukey's test. A trend test was conducted for categorical variables; WG: weight gain; HDL: high density lipoprotein cholesterol.

and a quarter of the overall sample had a WG of more than 10%. Major clinical manifestations in adults, such as cardiovascular complications and diabetes, have been associated with excess WG^[10,15]. In a preventive sense, our analyses show that the development of MetS, a precursor of diabetes^[16,17], is significantly quantitatively associated with a five-year WG exceeding 5% in healthy early-middle-aged adults of both genders (Table 5).

Waist circumference is an important factor for MetS. It is likely that weight gain contributes to increases in waist circumference. However, for the general population, the body weight measurement is less rigorous than waist measurement which has a specific anatomic definitions^[18] and, therefore, present study investigated changes in

weight. Nevertheless, we treated waist circumference as a confounder in the multivariate analysis (Table 5) because it has a decisive influence on the development of metabolic syndrome. On the other hand, occupational and lifestyle factors naturally affect dietary behaviors and thus affect body weight changes^[19] and other factors of atherosclerosis which are important in MetS development, including total cholesterol, low density lipoprotein cholesterol, uric acid and insulin. Our present study focused on body weight changes, and although we controlled some occupational, lifestyle and baseline metabolic factors (not shown in tables), the detailed impact of these factors needs to be clarified by other investigations.

Findings from both our study (Table 4) and other

Table 4 Summary of five-year changes in metabolic syndrome-components for female and male adults and the occurrence rates of metabolic syndrome according to the severity of weight gain

Female <i>N</i> = 388				
Follow-up changes (%)	WG within 5 years			
	Control %WG ≤ 1%	Mild 1% < %WG ≤ 5%	Moderate 5% < %WG ≤ 10%	Severe %WG > 10%
	<i>n</i> = 105	<i>n</i> = 100	<i>n</i> = 99	<i>n</i> = 84
△Central obesity ^b	8.50%	16.00%	22.60%	32.80%
△High blood pressure	22.90%	28.70%	28.50%	37.00%
△Hyperglycemia	-3.40%	-4.20%	-3.10%	1.30%
△Hypertriglyceridemia ^b	-0.40%	8.00%	15.60%	24.30%
△Low-HDL cholesterol ^b	-14.40%	-17.70%	-5.90%	-6.00%
MetS Development within 5 years ^b	5.70%	3.00%	14.10%	13.10%
Male <i>N</i> = 996				
Follow-up changes (%)	WG within 5 years			
	Control %WG ≤ 1%	Mild 1% < %WG ≤ 5%	Moderate 5% < %WG ≤ 10%	Severe %WG > 10%
	<i>n</i> = 236	<i>n</i> = 237	<i>n</i> = 288	<i>n</i> = 235
△Central obesity ^b	10.00%	3.00%	21.20%	40.50%
△High blood pressure ^a	21.00%	20.00%	21.20%	19.00%
△Hyperglycemia	-8.00%	-11.00%	-5.10%	-2.40%
△Hypertriglyceridemia ^b	2.00%	2.00%	8.10%	11.90%
△Low-HDL cholesterol ^b	-34.00%	-24.00%	-24.20%	-7.10%
MetS development within 5 years	10.60%	12.20%	16.30%	17.00%

^a*P* < 0.05; ^b*P* < 0.01; An ANOVA was conducted, adjusting for age, using Tukey's test. △: Differences between 2007 and 2002; minus indicates decreasing trend within follow-up; WG: weight gain; HDL: high density lipoprotein cholesterol.

Table 5 The adjusted risks for development of metabolic syndrome

WG severities	Odd ratio	95% CI
Total population		
Mild WG (1% < %WG < 5%)	1.2	0.70 - 2.2
Moderate WG (5% < %WG < 10%) ^b	3.0	1.80 - 5.1
Severe WG (%WG > 10%) ^b	5.4	3.00 - 9.7
Female		
Mild WG (1% < %WG < 5%)	0.9	0.20 - 4.5
Moderate WG (5% < %WG < 10%) ^a	3.6	1.03 - 12.4
Severe WG (%WG > 10%) ^b	5.5	1.40 - 21.4
Male		
Mild WG (1% < %WG < 5%)	1.4	0.70 - 2.7
Moderate WG (5% < %WG < 10%) ^b	3/0	1.60 - 5.5
Severe WG (%WG > 10%) ^b	5.2	2.60 - 10.2

^a*P* < 0.05; ^b*P* < 0.01; Adjusted variables were age, metabolic syndrome components and lifestyle and occupational factors; WG: weight gain.

follow-up observations^[20] indicate that the adults without excess WG have stable or improved serum levels of HDL and glucose, while the adults gaining excess weight over several years have dramatically greater changes in triglyceride levels than other groups. HDL levels demonstrated improving trends in our middle aged sample population. This dissimilar to earlier findings in an elderly population^[21], but similar to what was shown in other follow-up observations for healthy Asian adults^[22]. Discussing these findings in an earlier article^[12], we suggested that our relative young healthy workers might not yet have reached their HDL concentration plateau so had the potential to increase their HDL concentration within our

follow-up. Significantly, moderate or severe weight gainers had much lower capacity for increasing their HDL levels than those free from significant weight gain (Table 4). In addition, as presented in Tables 3 and 4, although the severe-WG subgroups were the youngest (mean aged 31 years) at the outset, after five years they showed the worst changes in all MetS-components and the highest MetS occurrence rate among the workers examined. We found that the glucose and lipid metabolism capabilities in our young workers with excessive WG became significantly worse than in older subjects without excessive WG. This phenomenon supports, in terms of nutritional metabolism, the hypothesis that rapidly becoming obese can speed up the aging process in adults^[23]. Experts have suggested that public health efforts need to tackle rapid WG in adolescents^[24] and our findings indicate that these efforts should be extended to early-middle-aged workers. Since “yo-yo” effects^[25] have appeared in many trials for weight reduction, body weight monitoring and preventing excess WG is an important strategy for maintaining healthy lipid and sugar metabolism in early-middle-aged workers. Weight gain of more than 5% within a five-year period should be avoided in order to prevent the development of MetS. On the other hand, limited weight gain was previously found not to be a risk factor for diabetes^[15] and in the present analysis, five-year mild-WG (< 5% WG) appeared to be tolerable in terms of progression to MetS (Table 5).

For both genders, there were differences in dietary habits among our four WG subgroups: the moderate- and severe- weight gainers were significantly more likely to snack between meals or before sleep (Table 3). The major

weight-related behaviors in late-adolescence are snacking and late-night eating^[26]. Furthermore, a study on twins showed that night-time eating was significantly more common in obese subjects than in subjects with normal weight^[27]. Because awareness of weight control is itself beneficial for the prevention of MetS^[28] and our workers who gained excessive weight tended to snack in addition to regular meals, education and reminders of healthy dietary behaviors for employees are essential for MetS management in workplaces. Dietary behavior is an important but complex issue in surveys concerning MetS development^[29,30]. However, there is a lack of precise data regarding caloric intake and dietary contents in the current analysis, and this might explain why our multivariate analysis involving dietary behaviors did not reach a statistical significance for MetS outcome. Future surveys for MetS in workplaces should focus on the details of dietary behaviors among employees.

The present observational approach demonstrated a significant association between severity of weight gain and MetS outcome. However, there are several research limitations should be addressed. Because *National Health Insurance* in Taiwan provides convenient medical care for subjects with MetS traits, it was difficult to avoid confounding protective effects from the correction efforts for MetS components^[31] during the period of our follow up. At the same time, our conclusions were drawn from the relatively healthy employees by excluding the data of the workers who fulfilled the MetS criteria at baseline and, thus “healthy-worker effects^[32]” might be involved. Given the conditions mentioned above, it is possible that we might have underestimated the risk for MetS outcome. Finally, our findings were obtained from a five-year interval approach and thus the possible impacts on MetS outcomes of body weight changes over a shorter time period require further study. In conclusion, for early-middle-aged healthy adults with a five-year weight gain over 5%, severity of weight gain is quantitatively associated with the risk for metabolic syndrome development. We suggest prioritizing the optimization of body weight and modifications in dietary behaviors for the prevention of metabolic syndrome among early-middle-aged workers.

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COMMENTS

Background

Measuring body weight is noninvasive, inexpensive and reliable both in terms of clinical and self-health monitoring. Analyses from the general population have revealed excessive weight gain (WG) as an important risk factor for developing metabolic syndrome (MetS), which is becoming an important concern in workplaces for its impacts on both health conditions and productivity of employees. Excessive WG is common in the early-middle-aged population

who account for the majority of the workforce. However, there was a lack of a comprehensive follow-up survey for examining the quantitative association between WG severity and the risk for MetS development in the early-middle-aged worker population.

Research frontiers

Improving our knowledge of the impacts of WG on MetS development is helpful to health promotion in workplaces. Periodic routine health checkups are compulsorily for employees at many worksites in Taiwan, thus we had an opportunity to conduct a workplace-based follow-up observation of MetS development. We used this approach to evaluate the impacts of excessive WG on MetS development among early-middle-aged employees.

Innovations and breakthroughs

In comparison to the control group, mild-WG adults had an insignificant risk for MetS development, while adults having moderate-WG had a 3.0-fold increased risk for progression to MetS [95% confidence interval (CI), 1.8-5.1], and this risk was increased 5.4-fold (95% CI, 3.0-9.7) in subjects having severe-WG. For females having moderate- and severe-WG, the risk for developing MetS was 3.6 (95% CI, 1.03-12.4) and 5.5 (95% CI, 1.4-21.4), respectively. For males having moderate- and severe-WG, the odds ratio for MetS outcome was respectively 3.0 (95% CI, 1.6-5.5) and 5.2 (95% CI, 2.6-10.2).

Applications

For early-middle-aged healthy adults with a five-year weight gain over 5%, severity of weight gain is related to the risk for developing metabolic syndrome. We suggest prioritizing body weight optimization and modifications in dietary behaviors for the prevention of metabolic syndrome among early-middle-aged workers.

Terminology

A designation of Metabolic Syndrome was made if three or more of the following five criteria were fulfilled: central obesity (waist circumference > 90 cm for males and > 80 cm for females based on Taiwanese criteria); High blood pressure (systolic blood pressure \geq 130 mmHg or diastolic blood pressure \geq 85 mmHg); hyperglycemia (fasting sugar \geq 100 mg/dL); hypertriglyceridemia (triglycerides \geq 150 mg/dL); and low-HDL-cholesterolemia (high density lipoprotein cholesterol (HDL) < 40 mg/dL for males, < 50 for females).

Peer reviews

The major finding of the study is that weight gain, especially in the higher centiles is more likely to be associated with the development of the metabolic syndrome. Overall, this is a timely paper that could lead to public health measures encouraging exercise and care in the calorie consumption of workers in large plants. The benefits to the involved individuals, the companies they work for and society at large could be significant.

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