Original Contribution

Adiposity, Its Related Biologic Risk Factors, and Suicide: A Cohort Study of 542,088 Taiwanese Adults

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Recent studies in Western nations have shown inverse associations between body mass index (BMI, measured as weight (kg)/height (m)²) and suicide. However, it is uncertain whether the association is similar in non-Western settings, and the biologic pathways underlying the association are unclear. The authors investigated these issues in a cohort of 542,088 Taiwanese people 20 years of age or older who participated in a health check-up program (1994–2008); there were 573 suicides over a mean 8.1 years of follow up. There was a J-shaped association between BMI and suicide risk (P for the quadratic term = 0.033) but limited evidence of a linear association (adjusted hazard ratio per 1-standard-deviation increase = 0.95 (95% confidence interval: 0.85, 1.06)); compared with individuals whose BMI was 18.5–22.9, adjusted hazard ratios for those with a BMI <18.5 or ≥21 were 1.56 (95% confidence interval: 1.07, 2.28) and 3.62 (95% confidence interval: 1.59, 8.22), respectively. A high waist-to-hip ratio was associated with an increased risk of suicide. There was some evidence for a reverse J-shaped association of systolic blood pressure and high density lipoprotein cholesterol with suicide and an association of higher triglyceride level with increased suicide risk; these associations did not appear to mediate the associations of BMI and waist-to-hip ratio with suicide.

An emerging body of research indicates that body mass index (BMI, measured as weight (kg)/height (m)²), a measure of adiposity, is inversely associated with suicide risk. Greater BMI was found to be related to a stepwise decreased risk of completed suicide in several large cohorts from Western nations, including the United Kingdom (1), Sweden (2), Norway (3, 4), and the United States (5–8). Similar associations with attempted suicide have also been reported (9, 10). These associations are found across the whole range of BMI and persist after controlling for potential confounding factors, such as socioeconomic position, smoking, and alcohol use. Such findings are intriguing because obesity has been associated with stigma (11) and increased risk of depression (12), and depression is a well-established risk factor for suicide (13). With the exception of one recent Chinese study (14), analysis of the adiposity-suicide relation has generally been restricted to Western settings.

Biologic mechanisms underlying the association between low BMI and suicide might involve metabolic consequences of adiposity, such as insulin resistance, a syndrome that is associated with a high BMI and raised levels of insulin and fatty acids. Increased blood levels of fatty acids might raise levels of circulating tryptophan, which may in turn increase brain serotonin (15), an important neurotransmitter associated with reduced impulsivity and suicidality (16). Suicide risk has been found to decrease with increasing numbers of markers of insulin resistance, such as high BMI, high systolic blood pressure, and low high density lipoprotein cholesterol.
(HDL-C) level in one Finnish study (17). It has also been postulated that the lower circulating cholesterol levels that result from a lower BMI could reduce cerebral serotonin levels (18) and thus predispose people to suicidal behaviors (19). Although a number of studies have shown an association between suicide risk and a low blood cholesterol level, the findings have been inconsistent (20).

To assess whether the association between adiposity and suicide is similar in non-Western settings and to determine the possible biologic pathways underlying the association, we investigated the risk of suicide in relation to a range of adiposity measures (BMI, waist circumference, and waist-to-hip ratio) and related physiologic or biochemical changes (systolic blood pressure and levels of fasting glucose, cholesterol, and triglycerides) in a large sample of Taiwanese adults.

**MATERIALS AND METHODS**

**Participants**

The study cohort consisted of 542,088 Taiwanese adults 20 years of age or older who participated in a large health check-up program run by a private company (MJ Health Management Institution, Taipei, Taiwan) from 1994 to 2008. Program participants underwent a series of physical examinations and biochemical tests conducted using standardized procedures, as described elsewhere (21). Figure 1 is a flow chart of the participants included in the study. The final numbers of the subsamples for whom we had complete information on potential confounders and who were included in the multivariable analyses for 1) BMI, 2) waist circumference and waist-to-hip ratio, 3) systolic blood pressure, fasting glucose, total cholesterol and triglyceride, and 4) HDL-C and low density lipoprotein cholesterol (LDL-C) were 408,075 (75.3% of the total cohort), 345,357 (63.7%), 406,610 (75.0%), and 377,056 (69.6%), respectively.

**Measurements of adiposity and related biologic factors**

Participants were measured when they were barefoot and wearing light-weight clothes. Weight (to the nearest 0.1 kg) and height (to the nearest mm) were measured using an auto-anthropometer (KN-5000A, Nakamura, Tokyo, Japan). Waist circumference (to the nearest mm) was measured at the midpoint between the lower end of the rib cage and the crest of the ilium. Hip circumference (to the nearest mm) was measured at the midpoint between the lower end of the rib cage and the crest of the ilium. Hip circumference (to the nearest mm) was measured around the pelvis at the point of maximal protrusion of the buttocks. Blood pressure in the right arm was measured twice at 10-minute intervals, with the participants seated after a 5-minute rest, using a computerized auto-mercury sphygmomanometer (CH-5000, Citizen, Tokyo, Japan); the mean of the 2 measurements was used for the analysis. Fasting (overnight) blood was collected for the measurement of glucose, total cholesterol, HDL-C, LDL-C, and triglyceride levels using the Hitachi 7150 auto-analyzer (Hitachi Ltd., Tokyo, Japan). Study participants provided written consent after reading a complete description of the use of data collected from the health check-up for research. The study was approved by the National Health Research Institutes, Taipei, Taiwan, and the MJ Health Management Institution.
Table 1. Characteristics of the Participants for Whom We Had Sociodemographic and Health-related Information, by Body Mass Index (n = 408,075), MJ Health Check-up Program, Taiwan, 1994–2008

| Characteristic               | Body Mass Index<sup>a</sup> |
|------------------------------|-----------------------------|
|                              | <18.5          | 18.5–22.9          | 23.0–24.9          | 25.0–26.9          |
|                              | Mean (SD) No. | Mean (SD) No.     | Mean (SD) No.     | Mean (SD) No.     |
| Men                          |               |                   |                   |                   |
| Age, years                   | 36.8 (14.7)   | 38.7 (13.7)       | 41.5 (13.3)       | 42.7 (13.1)       |
| Systolic blood pressure, mm Hg<sup>b</sup> | 114.9 (15.3) | 119.5 (15.9) | 123.2 (16.5)  | 126.1 (17.1)  |
| Fasting glucose, mg/dL<sup>b</sup> | 95.0 (19.6)  | 98.1 (21.5)  | 101.0 (22.2)  | 103.3 (24.3)  |
| Total cholesterol, mg/dL<sup>b</sup> | 177.5 (34.1)  | 188.5 (35.8) | 198.2 (36.4)  | 202.5 (37.2)  |
| HDL cholesterol, mg/dL<sup>b</sup> | 55.0 (14.5)  | 49.5 (13.2)  | 45.6 (12.1)  | 43.7 (11.4)  |
| LDL cholesterol, mg/dL<sup>b</sup> | 107.0 (30.5)  | 118.5 (32.0) | 125.9 (32.1)  | 128.3 (32.6)  |
| Triglycerides, mg/dL<sup>b</sup> | 79.9 (49.8)  | 106.1 (81.1) | 141.0 (111.3) | 164.7 (138.5) |
| Married                      | 4,263 52.9    | 46,461 62.3      | 37,363 73.8      | 28,146 77.8     |
| College education or higher  | 2,496 31.0    | 27,711 37.1      | 18,967 37.5      | 12,722 35.2     |
| Current smoker               | 3,746 46.5    | 30,016 40.2      | 19,694 38.9      | 14,493 40.0     |
| Regular alcohol user         | 707 8.8       | 7,483 10.0       | 5,539 10.9       | 4,285 11.8      |
| Physically inactive          | 4,488 55.7    | 34,091 45.7      | 22,251 43.9      | 16,289 45.0     |
| History of diabetes          | 154 1.9       | 2,453 3.3        | 2,488 4.9        | 2,509 6.9       |
| History of cancer            | 77 1.0        | 472 0.6          | 252 0.5          | 203 0.6         |
| Use of psychotropic drugs    | 58 1.0        | 397 0.7          | 217 0.6          | 151 0.6         |
| Women                        | 27,239        | 107,774          | 31,437           | 19,413          |
| Age, years                   | 31.2 (9.3)    | 37.4 (12.0)      | 45.9 (13.6)      | 48.8 (13.5)     |
| Systolic blood pressure, mm Hg<sup>b</sup> | 107.1 (13.4) | 112.0 (16.6) | 122.3 (21.1) | 127.6 (21.9) |
| Fasting glucose, mg/dL<sup>b</sup> | 90.8 (11.4)  | 94.1 (17.0) | 100.2 (24.7) | 103.3 (28.3) |
| Total cholesterol, mg/dL<sup>b</sup> | 178.3 (31.7) | 187.1 (34.9) | 199.8 (39.0) | 204.8 (39.5) |
| HDL cholesterol, mg/dL<sup>b</sup> | 63.8 (15.3)  | 59.0 (15.1) | 54.0 (14.5) | 51.7 (13.9) |
| LDL cholesterol, mg/dL<sup>b</sup> | 101.2 (28.1) | 112.0 (31.0) | 123.6 (33.9) | 127.7 (34.5) |
| Triglycerides, mg/dL<sup>b</sup> | 66.1 (28.5)  | 82.7 (54.0) | 116.2 (91.2) | 132.7 (97.7) |
| Married                      | 12,107 44.4   | 67,021 62.2      | 22,650 72.0      | 14,171 73.0     |
| College education or higher  | 10,712 39.3   | 33,685 31.3      | 5,428 17.3       | 2,443 12.6      |
| Current smoker               | 2,712 10.0    | 7,377 6.8        | 1,628 5.2        | 892 4.6         |
| Regular alcohol user         | 475 1.7       | 1,814 1.7        | 545 1.7          | 341 1.8         |
| Physically inactive          | 18,593 68.3   | 63,093 58.5      | 16,619 52.9      | 10,333 53.2     |
| History of diabetes          | 179 0.7       | 2,216 2.1        | 1,926 6.1        | 1,663 8.6       |
| History of cancer            | 198 0.7       | 1,455 1.4        | 677 2.2          | 492 2.5         |
| Use of psychotropic drugs    | 139 0.6       | 614 0.7          | 255 1.1          | 150 1.1         |

Abbreviations: HDL, high density lipoprotein; LDL, low density lipoprotein; SD, standard deviation.
<sup>a</sup> Weight (kg)/height (m)<sup>2</sup>.
<sup>b</sup> In the subsample of participants for whom we had information on biochemical tests (200,915 men and 205,695 women except for HDL cholesterol and LDL cholesterol (n = 184,282 men and 192,774 women)).
<sup>c</sup> In the subsample of participants for whom we had information on the use of psychotropic drugs (150,515 men and 155,326 women).

Ascertainment of suicide deaths

Suicide deaths that occurred from the date of recruitment to December 31, 2008, were identified through linkage with Taiwan’s national cause-of-death register, using the International Classification of Diseases, Ninth Revision, codes E950–E959. Previous research indicates that, in keeping with findings seen in Western nations, many Taiwanese deaths coded as undetermined intent (E980–E989), accidental pesticide poisoning (E863), and accidental suffocation (E913) are likely to be misclassified suicides (22). We therefore included these deaths in our definition of suicide. In a sensitivity analysis, we included only certified suicides that were coded as E950–E959.
Sex-specific z scores for adiposity measures (BMI, waist circumstance, and waist-to-hip ratio), systolic blood pressure, and biochemical levels (fasting glucose, total cholesterol, HDL-C, LDL-C, and triglycerides) were calculated as the number of standard deviations above (positive values) or below (negative values) the mean. BMI was also categorized into 7 groups according to the World Health Organization criteria (23), with additional cut-off points proposed for Asian populations (24) (underweight: < 18.5; normal weight: 18.5–22.9 and 25.0–29.9; overweight: 25.0–29.9; grade I obesity: 30.0–34.9; and grade II and III obesity: ≥35), and other risk factors were categorized into quintiles. Cox proportional hazards models were used to investigate the association of adiposity and associated risk factors with suicide. Time of entry was the date of recruitment; time of exit was December 31, 2008, or the date of death if earlier. The proportional hazards assumption was assessed by plotting Schoenfeld residuals versus time and examining their correlation.

### Body Mass Index

| BMI Category | Mean (SD) | No. | % | Mean (SD) | No. | % | Mean (SD) | No. | % | Mean (SD) | No. | % |
|--------------|----------|-----|---|----------|-----|---|----------|-----|---|----------|-----|---|
| 27.0–29.9    | 23,449   | 7,612 | 1,101 | 40.5 (13.5) | 201,650 | 69.5 |
| 30.0–34.9    | 129.0 (17.2) | 39.5 (12.4) | 35.0 (10.6) | 136.7 (17.7) | 132.3 (17.5) | 108.9 (28.6) | 100.9 (23.3) | 203.9 (37.3) | 195.7 (37.3) | 206.1 (39.3) | 624 (53.4) | 46.0 |
| ≥35.0        | 105.3 (25.9) | 107.8 (29.7) | 105.3 (25.9) | 106.9 (31.8) | 110.1 (34.7) | 112.6 (35.4) | 96.8 (21.7) | 207.4 (39.5) | 208.1 (39.1) | 207.5 (40.9) | 191.6 (37.3) | 46.0 |
| All Participants | 128.7 (33.1) | 127.2 (33.1) | 125.9 (31.5) | 123.2 (32.7) | 120,120 | 69.5 |
|              | 187.0 (153.2) | 206.4 (190.2) | 204.5 (172.3) | 138.1 (120.3) | 21,000 | 5.3 |

### Statistical analysis

Sex-specific z scores for adiposity measures (BMI, waist circumstance, and waist-to-hip ratio), systolic blood pressure, and biochemical levels (fasting glucose, total cholesterol, HDL-C, LDL-C, and triglycerides) were calculated as the number of standard deviations above (positive values) or below (negative values) the mean. BMI was also categorized into 7 groups according to the World Health Organization criteria (23), with additional cut-off points proposed for Asian populations (24) (underweight: < 18.5; normal weight: 18.5–22.9 and 23.0–24.9; overweight: 25.0–26.9 and 27.0–29.9; grade I obesity: 30.0–34.9; and grade II and III obesity: ≥35), and other risk factors were categorized into quintiles. Cox proportional hazards models were used to investigate the association of adiposity and associated risk factors with suicide. Time of entry was the date of recruitment; time of exit was December 31, 2008, or the date of death if earlier. The proportional hazards assumption was assessed by plotting Schoenfeld residuals versus time and examining their correlation.
Table 2. Hazard Ratio for Suicide by Body Mass Index According to World Health Organization Classification, Waist Circumference, and Waist-to-Hip Ratio, MJ Health Check-up Program, Taiwan, 1994–2008

| Covariate                        | Total Cohort | Subsample With Confounder Information |
|----------------------------------|--------------|----------------------------------------|
|                                  | No. of       | No. of                                 | Multivariable |
|                                  | Participants | Suicides | Adjusted for Sex and Age | HR 95% CI | Participants | Suicides | Adjusted for Sex and Age | HR 95% CI | Adjustment | P Value | No. of Participants | No. of Suicides | Adjusted for Sex and Age | HR 95% CI |
| Body mass index<sup>b</sup>      |              |          |                                  |           |              |          |                                  |           |            |          |              |               |                                  |            |
| <18.5                            | 542,088      | 408,075  |                                  |           | 408,075      |          |                                  |           |            |          |              |               |                                  |            |
| 18.5–22.9                        | 239,050      | 229      | 1.00                              | Referent  | 182,378      | 139      | 1.00                              | Referent  | 1.00       | 1.18     | 0.89        | 1.55        | 0.89              | 1.55        | 1.07       | 2.28      |
| 23.0–24.9                        | 110,022      | 127      | 0.99                              | 0.80, 1.24 | 82,068       | 86       | 1.14                              | 0.87, 1.51 | 1.18       | 0.89     | 1.55        | 0.89        | 1.55              | 0.89        | 1.55       | 1.07      |
| 25.0–26.9                        | 75,733       | 90       | 0.97                              | 0.76, 1.25 | 55,604       | 48       | 0.90                              | 0.65, 1.26 | 0.91       | 0.65     | 1.28        | 0.65        | 1.28              | 0.65        | 1.28       | 1.07      |
| 27.0–29.9                        | 51,406       | 55       | 0.88                              | 0.66, 1.19 | 37,317       | 31       | 0.88                              | 0.59, 1.31 | 0.87       | 0.58     | 1.29        | 0.58        | 1.29              | 0.58        | 1.29       | 1.07      |
| 30.0–34.9                        | 18,581       | 19       | 0.94                              | 0.59, 1.50 | 13,379       | 11       | 0.97                              | 0.52, 1.79 | 0.91       | 0.49     | 1.70        | 0.49        | 1.70              | 0.49        | 1.70       | 1.18      |
| ≥35.0                            | 2,751        | 6        | 2.42                              | 1.08, 5.43 | 2,028        | 6        | 4.15                              | 1.83, 9.39 | 3.62       | 1.59     | 8.22        | 1.59        | 8.22              | 1.59        | 8.22       | 1.30      |

Per 1-standard-deviation increase (sex-specific)  
0.94 0.86, 1.02 0.14<sup>c</sup>  
0.95 0.85, 1.06 0.35<sup>c</sup>  
0.95 0.85, 1.06 0.35<sup>c</sup>  

P for quadratic term 0.033<sup>d</sup>  
0.013<sup>d</sup>  
0.050<sup>d</sup>  

Quintile of waist circumference<sup>e</sup>  
392,886  
1 70,637 61 1.00 Referent  
63,448 50 1.00 Referent  
2 67,721 43 1.58 1.07, 2.35  
60,294 35 1.33 0.88, 2.02  
3 81,761 46 1.24 0.82, 1.89  
72,199 44 1.05 0.67, 1.63  
4 81,580 62 1.24 0.84, 1.82  
71,015 49 1.06 0.71, 1.60  
5 91,187 93 1.42 0.99, 2.04  
78,401 83 1.37 0.94, 2.00  

Per 1-standard-deviation increase (sex-specific)  
1.02 0.91, 1.15 0.74<sup>c</sup>  
1.09 0.96, 1.23 0.20<sup>c</sup>  
1.08 0.95, 1.22 0.25<sup>c</sup>  

P for quadratic term 0.063<sup>d</sup>  
0.11<sup>d</sup>  
0.24<sup>d</sup>  

Quintile of waist-to-hip ratio<sup>f</sup>  
392,886  
1 56,203 32 1.00 Referent  
50,634 27 1.00 Referent  
2 76,484 45 1.03 0.65, 1.63  
68,407 38 1.03 0.63, 1.70  
3 77,819 46 1.24 0.64, 1.62  
68,757 39 1.02 0.62, 1.69  
4 88,478 77 1.34 0.86, 2.07  
77,307 67 1.43 0.89, 2.30  
5 93,902 104 1.40 0.89, 2.18  
80,252 91 1.55 0.96, 2.51  

Per 1-standard-deviation increase (sex-specific)  
1.04 1.01, 1.07 0.022<sup>d</sup>  
1.04 1.01, 1.07 0.013<sup>d</sup>  
1.04 1.00, 1.07 0.045<sup>d</sup>  

P for quadratic term 0.018<sup>f</sup>  
0.008<sup>f</sup>  
0.041<sup>f</sup>  

Abbreviations: CI, confidence interval; HR, hazard ratio.  
<sup>a</sup> Adjusted for sex, age, educational level, marital status, smoking, frequency of alcohol use, physical activity level, diabetes history, and cancer history.  
<sup>b</sup> Weight (kg)/height (m)<sup>2</sup>. The quintiles for men were <21.1, 21.1–22.9, 23.0–24.7, 24.8–26.6, and ≥26.7 and the quintiles for women were <19.3, 19.3–21.3, 21.4–23.2, 23.3–25.4, and ≥25.5.  
<sup>c</sup> P value for the linear associations between adiposity measures (body mass index, waist circumference, and waist-to-hip ratio) and suicide (i.e., tests of linear trends), derived by including these adiposity measures as continuous variables (i.e., using their z scores) in the models.  
<sup>d</sup> P value of likelihood ratio test comparing the goodness-of-fit of models with and without the quadratic term of the continuous z score. A small P value indicates a quadratic relation.  
<sup>e</sup> The quintiles of waist circumference for men were <74.8, 74.8–78.9, 79.0–83.9, 84.0–88.9, and ≥89.0 cm and the quintiles for women were <64.0, 64.0–67.9, 68.0–71.9, 72.0–77.9, and ≥78.0 cm.  
<sup>f</sup> The quintiles of waist-to-hip ratio for men were <0.80, 0.80–0.83, 0.84–0.86, 0.87–0.90, and ≥0.91 and the quintiles for women were <0.71, 0.71–0.73, 0.74–0.76, 0.77–0.80, and ≥0.81.
Participant characteristics

In the total cohort of 542,088 participants, we identified 573 people who died from certified or possible suicides (455 (79.4%) certified suicides, 104 (18.2%) deaths of undetermined intent, 9 (1.6%) accidental deaths by pesticide poisoning, and 5 (0.9%) accidental deaths by suffocation) over an average 8.1-year follow-up period. The crude suicide rates were 16.2 and 10.4 per 100,000 person-years for men and women, respectively. The mean age at baseline was 41.2 years for men and 41.1 years for women.

At baseline, the mean BMI was 23.9 (standard deviation (SD), 3.4) for men and 22.1 (SD, 3.6) for women; corresponding figures for waist circumference and waist-to-hip ratio were 82.3 cm (SD, 9.2) and 0.86 cm (SD, 0.07) for men and 71.6 cm (SD, 8.9) and 0.77 cm (SD, 0.06) for women. Overweight and obesity were more common in men than in women. The proportions of men who were overweight, normal, overweight, and obese were 4.1%, 61.9%, 29.8%, and 4.3%, respectively; the corresponding figures for women were 12.0%, 66.7%, 17.7%, and 3.6%, respectively.

Compared with participants for whom we did not have information on sociodemographic and health-related factors, the 408,075 participants (356 certified or possible suicides) for whom we had these data were slightly younger (40.3 vs. 43.3 years of age) and more likely to be male (49.4% versus 42.2%). Characteristics of the 408,075 participants are shown in Table 1. Underweight subjects and very obese men were younger than persons in other BMI categories. Individuals with high BMIs were more likely to have lower educational levels (women) and diabetes than were persons with lower BMIs. The proportions of individuals who were current smokers, unmarried, or physically inactive were highest at both the high and low extremes of the BMI distributions. The prevalence of current smoking was high in male participants (40.6%) but low in female participants (6.7%). High BMI was associated with higher blood pressure and higher levels of fasting glucose, total cholesterol, LDL-C, and triglycerides but lower levels of HDL-C.

RESULTS

Participant characteristics

In sex- and age-adjusted models based on data for the total cohort, there was little evidence of a linear association between BMI z score and suicide risk (per 1-SD increase, hazard ratio (HR) = 0.94, 95% confidence interval (CI): 0.86, 1.02) (Table 2). There was evidence of a quadratic relation (P for likelihood ratio test = 0.033) that was in keeping with the finding of an increased risk of suicide in both underweight and extremely obese subjects (Table 2). There was no evidence of sex or age differences in associations between BMI and suicide (both P values for interaction > 0.10); in age-adjusted models, the hazard ratios for suicide per 1-standard-deviation increase in BMI were 0.98 (95% CI: 0.87, 1.10) for men and 0.88 (95% CI: 0.77, 1.03) for women.

Associations were very similar in the subsample of participants for whom we had information on confounders (Table 2). In separate sex- and age-adjusted analyses, both current smoking (HR = 2.16, 95% CI: 1.69, 2.76) and regular drinking (HR = 1.78, 95% CI: 1.30, 2.43) were associated with an increased risk of suicide, but there was no strong evidence of interactions between these variables and BMI in relation to suicide risk (both P values for interaction > 0.10). Fully adjusted analyses stratified by smoking or drinking status showed somewhat weak evidence of an inverse association between BMI and suicide in smokers (HR = 0.87, 95% CI: 0.73, 1.04) but not in nonsmokers or former smokers (HR = 1.01, 95% CI: 0.87, 1.17); there was no strong evidence for a linear association in regular drinkers (HR = 0.94, 95% CI: 0.69, 1.27) or nondrinkers, occasional drinkers, or former drinkers (HR = 0.94, 95% CI: 0.84, 1.06).

In the subsample of participants for whom we had information on psychotropic drug use, sex- and age-adjusted analyses showed a strong association between this variable and suicide risk (HR = 13.79, 95% CI: 8.43, 22.55); after further controlling for the use of psychotropic drugs, there was still limited evidence of a linear association between BMI and suicide (HR = 0.92, 95% CI: 0.78, 1.07). Results were similar when we excluded all suicides that occurred in the first 2 years after baseline measurements and when we restricted analyses to certified suicides only (data not shown).

Waist circumference, waist-to-hip ratio, and suicide

Waist circumference was not associated with risk of suicide; there was no evidence of an association in the total sample or the subsample of participants for whom we had full information on sociodemographic and health-related factors. To assess their potential confounders was obtained from the baseline questionnaires completed by participants. Severe mental illness and use of psychotropic drugs is associated with both suicide risk and weight loss/gain or metabolic abnormalities (e.g., high lipid levels) (25). To assess their possible impact on the associations between our exposures and suicide, we conducted 2 sensitivity analyses. First, in the subset of participants for whom we had data on medication use, we controlled for the use of psychotropic drugs in multivariable models. Second, in keeping with previous studies (2, 3), we excluded all suicides that occurred in the first 2 years of follow-up, as BMI in these participants was more likely to have been influenced by any preexisting severe mental illness at baseline. All analyses were conducted using SAS software, version 9.1 (SAS Institute, Inc., Cary, North Carolina).

BMI and suicide

In sex- and age-adjusted models based on data for the total cohort, there was little evidence of a linear association between BMI z score and suicide risk (per 1-SD increase, hazard ratio (HR) = 0.94, 95% confidence interval (CI): 0.86, 1.02) (Table 2). There was evidence of a quadratic relation (P for likelihood ratio test = 0.033) that was in keeping with the finding of an increased risk of suicide in both underweight and extremely obese subjects (Table 2). There was no evidence of sex or age differences in associations between BMI and suicide (both P values for interaction > 0.10); in age-adjusted models, the hazard ratios for suicide per 1-standard-deviation increase in BMI were 0.98 (95% CI: 0.87, 1.10) for men and 0.88 (95% CI: 0.77, 1.03) for women.

Associations were very similar in the subsample of participants for whom we had information on confounders (Table 2). In separate sex- and age-adjusted analyses, both current smoking (HR = 2.16, 95% CI: 1.69, 2.76) and regular drinking (HR = 1.78, 95% CI: 1.30, 2.43) were associated with an increased risk of suicide, but there was no strong evidence of interactions between these variables and BMI in relation to suicide risk (both P values for interaction > 0.10). Fully adjusted analyses stratified by smoking or drinking status showed somewhat weak evidence of an inverse association between BMI and suicide in smokers (HR = 0.87, 95% CI: 0.73, 1.04) but not in nonsmokers or former smokers (HR = 1.01, 95% CI: 0.87, 1.17); there was no strong evidence for a linear association in regular drinkers (HR = 0.94, 95% CI: 0.69, 1.27) or nondrinkers, occasional drinkers, or former drinkers (HR = 0.94, 95% CI: 0.84, 1.06).

In the subsample of participants for whom we had information on psychotropic drug use, sex- and age-adjusted analyses showed a strong association between this variable and suicide risk (HR = 13.79, 95% CI: 8.43, 22.55); after further controlling for the use of psychotropic drugs, there was still limited evidence of a linear association between BMI and suicide (HR = 0.92, 95% CI: 0.78, 1.07). Results were similar when we excluded all suicides that occurred in the first 2 years after baseline measurements and when we restricted analyses to certified suicides only (data not shown).

Waist circumference, waist-to-hip ratio, and suicide

Waist circumference was not associated with risk of suicide; there was no evidence of an association in the total sample or the subsample of participants for whom we had full information on sociodemographic and health-related factors.
Table 3. Hazard Ratio for Suicide, by Systolic Blood Pressure and Levels of Fasting Glucose, Total Cholesterol, Triglycerides, High Density Lipoprotein Cholesterol, and Low Density Lipoprotein Cholesterol, MJ Health Check-up Program, Taiwan, 1994–2008

| Covariate | Total Cohort | Subsample With Confounder Information |
|-----------|--------------|--------------------------------------|
|           | Number of Participants | Number of Suicides | Adjusted for Sex and Age | Number of Participants | Number of Suicides | Adjusted for Sex and Age | Multivariable Adjustment a |
|           | HR 95% CI | P Value | HR 95% CI | P Value | HR 95% CI | P Value |
| Quintile of systolic blood pressure | | | | | | | |
| Quintile 1 | 537,620 | 110,524 | 139 | 1.00 Referent | 84,218 | 87 | 1.00 Referent | 1.00 Referent |
| 2 | 108,582 | 109 | 0.85 0.66, 1.09 | 84,672 | 68 | 0.81 0.59, 1.12 | 0.84 0.61, 1.16 |
| 3 | 109,380 | 84 | 0.61 0.47, 0.80 | 84,689 | 56 | 0.63 0.45, 0.89 | 0.66 0.47, 0.92 |
| 4 | 99,384 | 89 | 0.65 0.50, 0.86 | 75,514 | 51 | 0.60 0.42, 0.85 | 0.62 0.43, 0.88 |
| 5 | 109,750 | 151 | 0.75 0.58, 0.98 | 77,517 | 94 | 0.81 0.59, 1.13 | 0.83 0.60, 1.16 |
| Per 1-standard-deviation increase (sex-specific) | | 0.95 0.87, 1.04 | 0.25 c | | 1.00 0.90, 1.12 | 0.96 c | 1.01 0.90, 1.13 | 0.87 c |
| P for quadratic term | | | 0.005 d | | | | 0.001 d | 0.002 d |
| Quintile of fasting glucose | | | | | | | |
| Quintile 1 | 537,620 | 116,391 | 151 | 1.00 Referent | 85,291 | 91 | 1.00 Referent | 1.00 Referent |
| 2 | 99,942 | 96 | 0.78 0.60, 1.00 | 76,377 | 57 | 0.71 0.51, 0.99 | 0.74 0.53, 1.03 |
| 3 | 115,161 | 118 | 0.82 0.64, 1.04 | 89,623 | 79 | 0.82 0.61, 1.11 | 0.87 0.64, 1.18 |
| 4 | 104,168 | 92 | 0.71 0.55, 0.93 | 80,151 | 62 | 0.72 0.52, 1.00 | 0.77 0.55, 1.06 |
| 5 | 101,958 | 115 | 0.78 0.60, 1.01 | 75,168 | 67 | 0.70 0.50, 0.98 | 0.73 0.52, 1.02 |
| Per 1-standard-deviation increase (sex-specific) | | 0.97 0.89, 1.05 | 0.46 c | | 0.90 0.79, 1.03 | 0.14 c | 0.90 0.80, 1.03 | 0.12 c |
| P for quadratic term | | | 0.42 d | | | | 0.41 d | 0.33 d |
| Quintile of total cholesterol | | | | | | | |
| Quintile 1 | 537,620 | 110,888 | 127 | 1.00 Referent | 78,603 | 69 | 1.00 Referent | 1.00 Referent |
| 2 | 105,503 | 111 | 0.92 0.71, 1.19 | 79,566 | 63 | 0.86 0.61, 1.21 | 0.88 0.62, 1.24 |
| 3 | 107,906 | 93 | 0.73 0.56, 0.96 | 82,890 | 66 | 0.82 0.59, 1.16 | 0.84 0.59, 1.18 |
| 4 | 108,063 | 129 | 0.98 0.76, 1.25 | 83,582 | 77 | 0.89 0.64, 1.25 | 0.91 0.65, 1.27 |
| 5 | 105,260 | 112 | 0.80 0.61, 1.04 | 81,969 | 81 | 0.85 0.60, 1.19 | 0.85 0.61, 1.19 |
| Per 1-standard-deviation increase (sex-specific) | | 0.97 0.89, 1.05 | 0.41 c | | 0.97 0.87, 1.08 | 0.59 c | 0.97 0.87, 1.08 | 0.54 c |
| P for quadratic term | | | 0.15 d | | | | 0.40 d | 0.54 d |
### Quintile of Triglycerides

| Quintile | Count | Sex 95% CI | HR (95% CI) | P for quadratic term |
|----------|-------|------------|-------------|----------------------|
| 1        | 107,842 | 91 | 1.00 Referent | 1.00 Referent |
| 2        | 109,128 | 104 | 1.03 0.78, 1.36 | 1.02 0.79, 1.60 | 0.77, 1.57 |
| 3        | 105,924 | 93 | 0.90 0.67, 1.20 | 1.01 0.70, 1.45 | 0.67, 1.40 |
| 4        | 107,122 | 128 | 1.17 0.89, 1.54 | 1.15 0.81, 1.65 | 0.76, 1.57 |
| 5        | 107,604 | 156 | 1.33 1.01, 1.74 | 1.44 1.02, 2.03 | 0.90, 1.81 |

Per 1-standard-deviation increase in triglycerides (sex-specific)

- **1.08 1.03, 1.13**
- **1.08 1.02, 1.15**
- **1.06 0.99, 1.13**

**P** value for quadratic term: 0.15<sup>d</sup>

### Quintile of HDL Cholesterol

| Quintile | Count | Sex 95% CI | HR (95% CI) | P for quadratic term |
|----------|-------|------------|-------------|----------------------|
| 1        | 89,880 | 120 | 1.00 Referent | 1.00 Referent |
| 2        | 86,642 | 89 | 0.97 0.74, 1.28 | 0.94 0.69, 1.27 | 0.72, 1.32 |
| 3        | 89,872 | 66 | 0.78 0.58, 1.06 | 0.72 0.51, 1.00 | 0.53, 1.05 |
| 4        | 86,902 | 69 | 0.93 0.69, 1.25 | 0.92 0.66, 1.27 | 0.70, 1.34 |
| 5        | 84,072 | 63 | 0.93 0.68, 1.26 | 0.88 0.63, 1.23 | 0.64, 1.27 |

Per 1-standard-deviation increase in HDL cholesterol (sex-specific)

- **0.97 0.88, 1.07**
- **0.94 0.84, 1.06**
- **0.96 0.86, 1.07**

**P** value for quadratic term: 0.039<sup>d</sup>

### Quintile of LDL Cholesterol

| Quintile | Count | Sex 95% CI | HR (95% CI) | P for quadratic term |
|----------|-------|------------|-------------|----------------------|
| 1        | 89,423 | 81 | 1.00 Referent | 1.00 Referent |
| 2        | 86,647 | 75 | 0.84 0.61, 1.15 | 0.91 0.65, 1.28 | 0.67, 1.32 |
| 3        | 88,313 | 69 | 0.69 0.50, 0.95 | 0.72 0.51, 1.03 | 0.53, 1.08 |
| 4        | 87,577 | 92 | 0.84 0.62, 1.14 | 0.86 0.61, 1.21 | 0.64, 1.26 |
| 5        | 85,440 | 90 | 0.74 0.54, 1.01 | 0.76 0.54, 1.08 | 0.56, 1.13 |

Per 1-standard-deviation increase in LDL cholesterol (sex-specific)

- **0.91 0.83, 1.01**
- **0.94 0.84, 1.05**
- **0.95 0.85, 1.06**

**P** value for quadratic term: 0.26<sup>d</sup>
variables (Table 2). A larger waist-to-hip ratio was associated with a higher suicide risk. In sex- and age-adjusted models based on the total cohort, the hazard ratio per 1-standard-deviation increase in waist-to-hip ratio was 1.04 (95% CI: 1.01, 1.07). This association did not differ by sex, age, smoking status, or drinking status (all P values for interaction > 0.10). When we examined the associations by quintile, there appeared to be a threshold effect, with suicide risk only clearly increasing in persons in the top 2 quintiles, and statistical evidence for a curvilinear association (P for likelihood ratio test comparing the model with a quadratic term with the model without = 0.018). Results were similar in the subset of participants for whom we had full information on confounders. The results remained unchanged in sensitivity analyses that were further adjusted for psychotropic drug use or that excluded all suicides that occurred in the first 2 years of follow-up, as well as in analyses based on certified suicides only (data not shown).

Biologic factors related to adiposity and suicide

There was no evidence of a linear association between suicide risk and systolic blood pressure (Table 3), although there was evidence of a quadratic relation (P for likelihood ratio test = 0.005), with increased risk toward the extremes of systolic blood pressure distributions (a reverse J-shaped association). Fasting glucose was not associated with suicide risk in the total sample after adjustment for sex and age; in the subsample of participants for whom we had information on confounders, there was weak evidence for an association between higher glucose levels and lower suicide risk (per 1-SD increase, fully adjusted HR = 0.90, 95% CI: 0.80, 1.03). In the total cohort, there was some evidence of a reduced suicide risk in participants in the middle quintile of the total cholesterol levels compared with persons in the lowest quintile; there was little evidence of a linear or quadratic relation between suicide risk and total cholesterol level in the subsample. There was some evidence for a quadratic relation between HDL-C and suicide (P for likelihood ratio test = 0.039 (total sample)), with increased suicide risk towards the 2 ends of the HDL-C distribution. There was limited evidence of an association between LDL-C and suicide risk.

In the sex- and age-adjusted model for the total sample, a higher triglyceride level was associated with greater suicide risk (per 1-SD increase, HR = 1.08, 95% CI: 1.03, 1.13). When the sample was restricted to participants for whom we had information on potential confounders, this association was similar in the sex- and age-adjusted model but was somewhat attenuated after adjustment for potential confounders (HR = 1.06, 95% CI: 0.99, 1.13). In a sensitivity analysis that was further controlled for psychotropic drug use, the association was similar (HR = 1.07, 95% CI: 0.98, 1.17). Individuals in the highest quintile of triglyceride level had a 28%–44% increased risk of suicide compared with persons in the lowest quintile.

When assessing the impact of controlling for systolic blood pressure, HDL-C level, and triglyceride level because of the evidence of their associations with suicide, we found similar associations between BMI/waist-to-hip ratio and suicide when controlling for each of the 3 biologic markers (data not shown).

DISCUSSION

In contrast to the linear inverse association between BMI and suicide seen in several Western cohorts (1–8), we found only limited evidence of such a relation in this Taiwanese study. Suicide risks were increased in both underweight and extremely obese individuals. There was also evidence of quadratic relations of systolic blood pressure and HDL-C with suicide. Higher waist-to-hip ratios and triglyceride levels were both associated with a higher risk of suicide, but lower levels of these 2 exposures were not related to greater suicide risk. The associations of systolic blood pressure, HDL-C, and triglycerides with suicide did not appear to mediate the associations of BMI and waist-to-hip ratio with suicide. We found limited evidence that waist circumference, fasting glucose level, total cholesterol level, or LDL-C level was associated with suicide.

Strengths and limitations

To the best of our knowledge, the present study is the first large cohort study in which the association of a range of adiposity measures and related biologic markers with risk of suicide was investigated in a non-Western setting. Anthropometric data were measured using standardized procedures as part of a comprehensive health check. The study has several limitations. First, the associations could have been confounded by unmeasured factors; for example, we had no detailed information on psychiatric morbidity (e.g., depression), although associations were similar in models that controlled for a proxy indicator of psychiatric disorders (i.e., psychotropic drug use). Second, adiposity and related biologic markers were measured once only at the baseline assessment. Repeated measures of these factors and psychiatric morbidity may have provided further information on their relations with suicide. Third, the cohort was derived from a privately run health check-up program. However, the prevalence rates of obesity and other characteristics, such as smoking, in this cohort were similar to those shown in a national survey in 2000–2001 (26, 27), although suicide rates in this cohort were slightly lower than those for Taiwan’s overall population (8.4 versus 11.9 per 100,000 (age-standardized rates)) (28).

Association of adiposity with suicide

We found an increased risk of suicide in both underweight and extremely obese individuals. A recent study of British male government employees also showed an increased suicide risk in obese men (BMI ≥30) (29), although evidence for an increased suicide risk in individuals with obesity/extreme obesity remains to be firmly established because there were few suicides in the obese in the British study (n = 6) or the very obese group in our study (n = 6). Unlike several large cohort studies in Western countries (1–8), we did not find that suicide risk decreased linearly from a low BMI to a high BMI, although the 95% confidence interval estimates of the association with BMI from our study overlapped those reported in previous research. In one Norwegian cohort, the hazard ratio for suicide was estimated to be
0.82 (95% CI: 0.68, 0.98) per 1-standard-deviation increase in BMI (3), whereas our estimate based on the total cohort was 0.94 (95% CI: 0.86, 1.02).

It is possible that the obesity-suicide association differs in Western and non-Western settings, although a recent cohort study of 170,000 Chinese adults found some evidence of an inverse association between BMI and suicide (14). If our study findings do signal a difference in associations in Asian versus Western settings, possible explanations include differing cultural attitudes toward body size and dietary differences. In traditional Chinese culture, thinness is associated with poverty, misfortune, and poor health, whereas a certain degree of “fullness” symbolizes prosperity and longevity (30); this contrasts with the Western pattern of attitudes towards body size. One dietary factor, polyunsaturated fatty acids (PUFAs), has been linked to a decreased risk of depression and suicidal ideation (31), and a recent study showed that the Taiwanese population had the highest percentage (percentage of total dietary energy intake) of PUFAs among 28 countries investigated (32). However, one US study found that the inverse association of BMI with suicide persisted after controlling for intake of dietary omega-3 fatty acids, an important type of PUFA (7).

Our finding that a higher waist-to-hip ratio was associated with a greater suicide risk differed from 1 previous US study that found weak evidence for a higher suicide risk in men with lower values of self-reported waist-to-hip ratios (7). In the absence of other studies of this association, it remains unclear what the true association between waist-to-hip ratio and suicide risk is.

**Association of biologic markers of adiposity with suicide**

In general, beyond studies of the associations between BMI or cholesterol and suicide, there have been few studies that investigated other markers of adiposity or adiposity-related mediators in relation to suicide risk. Of the range of potential mediators that we examined, only 3 were related to suicide risk (systolic blood pressure and HDL-C level with a reverse J-shaped association and triglyceride with a positive association), but controlling for these factors in multivariable models indicated that they did not mediate associations between adiposity and suicide. Findings from previous studies of the relation between blood pressure and suicide were inconsistent (17, 33–35). To our knowledge, no previous study has investigated the association between triglycerides and the risk of suicide; the few studies that have examined the association between triglycerides and suicide attempts have produced inconsistent findings (36–40). Our finding that fasting glucose was not associated with suicide risk was consistent with one previous study (33).

**Possible explanations for associations**

This association between being underweight and suicide risk might be confounded by psychopathology, such as anorexia nervosa, that is related to both low body weight and increased risk of suicide (41). As discussed earlier, it is also possible that physiologic changes associated with low body weight, including low levels of circulating fatty acids, might influence an individual’s neurotransmitter levels, and these may in turn affect impulsivity and suicide risk (17), but we found no evidence that lower levels of fasting glucose, cholesterol, or triglycerides were associated with increased risk. Indeed, higher triglyceride levels were associated with increased suicide risk. Increased abdominal fat, indicated by high waist-to-hip ratios, has been found to be associated with heightened cortisol levels in response to stress (42) and depressive symptoms (43), and it may lead to increased suicide risk. Alternatively, use of certain psychotropic drugs (e.g., some antipsychotics) may result in greater waist-to-hip ratios (44) and explain an association with suicide. However, our results remained unchanged when we controlled for psychotropic drug use.

As mentioned earlier, one biologic factor that may contribute to the association of high triglyceride with increased suicide risk is dietary PUFAs, which have been found to be associated with both reduced triglyceride levels (45) and reduced risk of suicidal ideation (31). Another possible underlying mechanism is hyperactivity of the hypothalamic-pituitary-adrenocortical axis; an increased circulating cortisol level has been linked to both hypertriglyceridemia (46) and depression (47), although its other related physiologic effects, such as hypercholesterolemia and hypertension, were not found to be associated with suicide risk in our study.

**Implications**

The present study indicates that associations of adiposity with suicide risk may differ between Asian and Western populations. A better understanding of the complex interactions among adiposity, its related biologic factors, and suicide may pave the way to new findings about the causes of suicide and, possibly, novel targets for intervention and drug development.

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REFERENCES

1. Gasse C, Derby LE, Vasilakis C, et al. Risk of suicide among users of calcium channel blockers: population based, nested case-control study. BMJ. 2000;320(7244):1251.

2. Magnusson PK, Rasmussen F, Lawlor DA, et al. Association of body mass index with suicide mortality: a prospective cohort study of more than one million men. Am J Epidemiol. 2006;163(1):1–8.

3. Bjerkedse O, Romundstad P, Evans J, et al. Association of adult body mass index and height with anxiety, depression, and suicide in the general population: the HUNT Study. Am J Epidemiol. 2008;167(2):193–202.

4. Gravseth HM, Mehlum L, Bjerkedal T, et al. Suicide in young Norwegians in a life course perspective: population-based cohort study. J Epidemiol Community Health. 2010;64(5):407–412.

5. Kaplan MS, Huguet N, McFarland BH, et al. Suicide among male veterans: a prospective population-based study. J Epidemiol Community Health. 2007;61(7):619–624.

6. Kaplan MS, McFarland BH, Huguet N. The relationship of body weight to suicide risk among men and women: results from the US National Health Interview Survey Linked Mortality File. J Nerv Ment Dis. 2007;195(11):948–951.

7. Mukamal KJ, Kawachi I, Miller M, et al. Body mass index and risk of suicide among men. Arch Intern Med. 2007;167(5):468–475.

8. Mukamal KJ, Rimm EB, Kawachi I, et al. Body mass index and risk of suicide among one million US adults. Epidemiology. 2010;21(1):82–86.

9. Osler M, Nybo Andersen AM, Nordentoft M. Impaired childhood development and suicidal behaviour in a cohort of Danish men born in 1953. J Epidemiol Community Health. 2008;62(1):23–28.

10. Batter GD, Whitley E, Kivimäki M, et al. Body mass index and attempted suicide: cohort study of 1,133,019 Swedish men. Am J Epidemiol. 2010;172(8):890–899.

11. Puhl R, Brownell KD. Bias, discrimination, and obesity. Obes Res. 2001;9(12):878–805.

12. Luppino FS, de Wit LM, Bouvy PF, et al. Overweight, obesity, and depression: a systematic review and meta-analysis of longitudinal studies. Arch Gen Psychiatry. 2010;67(3):220–229.

13. Hawton K, van Heeringen K. Suicide. Lancet. 2009;373(9672):1372–1381.

14. Rebholz CM, Gu D, Yang W, et al. Mortality from suicide and other external cause injuries in China: a prospective cohort study. BMC Public Health. 2011;11(1):56. (doi:10.1186/1471-2458-11-56).

15. Golomb BA, Mednick SA, Tenkanen L. Suicide: a weighty matter? [letter]. Arch Intern Med. 2007;167(17):1908.

16. Virkkunen M, Goldman D, Nielsen DA, et al. Low brain serotonin turnover rate (low CSF 5-HIAA) and impulsive violence. J Psychiatry Neurosci. 1995;20(4):271–275.

17. Golomb BA, Tenkanen L, Alikoski T, et al. Insulin sensitivity markers: predictors of accidents and suicides in Helsinki Heart Study screenees. J Clin Epidemiol. 2002;55(8):767–773.

18. Engelberg H. Low serum cholesterol and suicide. Lancet. 1992;339(8795):727–729.

19. Mann JJ. The neurobiology of suicide. Nat Med. 1998;4(1):25–30.

20. Lester D. Serum cholesterol levels and suicide: a meta-analysis. Suicide Life Threat Behav. 2002;32(3):333–346.

21. Wen CP, Cheng TY, Tsai MK, et al. All-cause mortality attributable to chronic kidney disease: a prospective cohort study based on 462 293 adults in Taiwan. Lancet. 2008;371(9631):2173–2182.

22. Chang SS, Sterne JA, Lu TH, et al. ‘Hidden’ suicides amongst deaths certified as undetermined intent, accident by pesticide poisoning and accident by suffocation in Taiwan. Soc Psychiatry Psychiatr Epidemiol. 2010;45(2):143–152.

23. World Health Organization. BMI Classification. Geneva, Switzerland: World Health Organization; 2006. (http://apps.who.int/bmi/index.jsp?introPage=intro_3.html). (Accessed August 11, 2010).

24. World Health Organization International Association for the Study of Obesity International Obesity Task Force. The Asia-Pacific Perspective: Redefining Obesity and its Treatment. Sydney, Australia: Health Communications Australia Pty Limited; 2000.

25. Schwartz TL, Nihalani N, Jindal S, et al. Psychiatric medication-induced obesity: a review. Obes Rev. 2004;5(2):115–121.

26. Chu NF. Prevalence of obesity in Taiwan. Obes Rev. 2005;6(4):271–274.

27. Wen CP, Levy DT, Cheng TY, et al. Smoking behaviour in Taiwan. 2001. Tob Control. 2005;14(suppl 1):i51–i55.

28. Taiwan Suicide Prevention Center. Trends in Suicide Rates in Taiwan, 1994–2009. Taipei, Taiwan: Taiwan Suicide Prevention Center; 2010. (http://www.tspc.doh.gov.tw/tspc/portal/know/index.jsp?type=2). (Accessed January 25, 2011).

29. Elvovamio M, Shipley MJ, Ferrie JE, et al. Obesity, unexplained weight loss and suicide: the original Whitehall Study. J Affect Disord. 2009;116(3):218–221.

30. Lee S, Leung T, Lee AM, et al. Body dissatisfaction among Chinese undergraduates and its implications for eating disorders in Hong Kong. Int J Eat Disord. 1996;20(1):77–84.

31. Tanskanen A, Hibbeln JR, Hinikka J, et al. Fish consumption, depression, and suicidality in a general population. Arch Gen Psychiatry. 2001;58(5):512–513.

32. Elmadfa I, Kornsteiner M. Dietary fat intake—a global perspective. Ann Nutr Metab. 2009;54(suppl 1):8–14.

33. Iribarren C, Reed DM, Wergowske G, et al. Serum cholesterol level and mortality due to suicide and trauma in the Honolulu Heart Program. Arch Intern Med. 1995;155(7):695–700.

34. Giltay EJ, Zitman FG, Menotti A, et al. Respiratory function and other biological risk factors for completed suicide: 40 years of follow-up of European cohorts of the Seven Countries Study. J Affect Disord. 2010;120(1-3):249–253.

35. Terry PD, Abramson JL, Neaton JD. Blood pressure and risk of death from external causes among men screened for the Multiple Risk Factor Intervention Trial. Am J Epidemiol. 2007;165(3):294–301.

36. Lee HJ, Kim YK. Serum lipid levels and suicide attempts. Acta Psychiatr Scand. 2003;108(3):215–221.

37. Brunner J, Bronisch T, Pfister H, et al. High cholesterol, triglycerides, and body mass index in suicide attempters. Arch Suicide Res. 2006;10(1):1–9.
38. Deisenhammer EA, Kramer-Reinstadler K, Liensberger D, et al. No evidence for an association between serum cholesterol and the course of depression and suicidality. *Psychiatry Res*. 2004;121(3):253–261.
39.Marcinko D, Marcinko V, Karlovic D, et al. Serum lipid levels and suicidality among male patients with schizoaffective disorder. *Prog Neuropsychopharmacol Biol Psychiatry*. 2008;32(1):193–196.
40. Pompili M, Innamorati M, Lester D, et al. Nearly lethal resuscitated suicide attempters have no low serum levels of cholesterol and triglycerides. *Psychol Rep*. 2010;106(3):785–790.
41. Pompili M, Girardi P, Tatarelli G, et al. Suicide and attempted suicide in eating disorders, obesity and weight-image concern. *Eat Behav*. 2006;7(4):384–394.
42. Epel ES, McEwen B, Seeman T, et al. Stress and body shape: stress-induced cortisol secretion is consistently greater among women with central fat. *Psychosom Med*. 2000;62(5):623–632.
43. Rosmond R, Lapidus L, Márin P, et al. Mental distress, obesity and body fat distribution in middle-aged men. *Obes Res*. 1996;4(3):245–252.
44. Meyer JM. Antipsychotics and metabolics in the post-CATIE era. *Curr Top Behav Neurosci*. 2010;4:23–42.
45. Delarue J, LeFoll C, Corporeau C, et al. N-3 long chain polyunsaturated fatty acids: a nutritional tool to prevent insulin resistance associated to type 2 diabetes and obesity? *Reprod Nutr Dev*. 2004;44(3):289–299.
46. Anagnostis P, Athyros VG, Tziomalos K, et al. Clinical review: the pathogenetic role of cortisol in the metabolic syndrome: a hypothesis. *J Clin Endocrinol Metab*. 2009;94(8):2692–2701.
47. Pompili M, Serafini G, Innamorati M, et al. The hypothalamic-pituitary-adrenal axis and serotonin abnormalities: a selective overview for the implications of suicide prevention. *Eur Arch Psychiatry Clin Neurosci*. 2010;260(8):583–600.