Sex differences in relationships between metabolic syndrome components and factors associated with health-related quality of life in middle-aged adults living in the community: a cross-sectional study in Taiwan

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Abstract

Background: Metabolic syndrome (MetS) is a widespread condition with important effects on public health, in general. There is a lack of relevant research on possible sex differences in the relationship between MetS and health-related quality of life (HRQoL) and also the sex differences in factors associated with HRQoL. The aims of this study were to identify: 1) whether women exhibit greater negative impacts on physical domain HRQoL from MetS compared with men; 2) whether women exhibit greater mental domain impacts compared with men; and 3) whether factors associated with HRQoL scores are different for men and women.

Methods: This cross-sectional study was conducted in Taipei, Taiwan. Using random sampling, a total of 906 participants aged 35–55 years were recruited. MetS was defined according to the MetS criteria for the Taiwanese population, and HRQoL were assessed using physical component summary (PCS) and mental component summary (MCS) scores of the Short Form Health Survey (SF-36), Taiwan version. Demographics, physical activity, medical history, and blood tests as covariates were recorded and checked. The associations were assessed by multiple linear regression.

Results: After adjusting for covariates, women but not men with more components of MetS had significantly lower PCS scores ($\beta = -0.542$, $p = 0.036$). The number of components of MetS was not a significant factor in MCS score differences between the sexes. Furthermore, there were sex differences regarding age, education level, physical activity, and smoking status in association with PCS scores. For MCS scores, sex differences were found in education level, marital status, and habits of smoking and alcohol consumption.

Conclusions: There were sex differences in the relationships between metabolic syndrome components and factors associated with HRQoL among middle-aged adults living in the community in Taiwan. Further research should be conducted to investigate mechanisms of these sex differences.

Keywords: Health-related quality of life, Metabolic syndrome, Physical activity, Sex differences, SF-36
Background

The term metabolic syndrome (MetS) refers to a collection of conditions, including central obesity, elevated triglyceride, elevated blood pressure, fasting hyperglycemia, and low levels of high-density lipoprotein cholesterol (HDL-C). MetS is regarded as a major public health issue in many developed and developing countries [1]. Many studies have shown that MetS is associated with increased risks of diabetes, cardiovascular diseases, cerebrovascular diseases, poorer quality of life, and mortality [2–5]. According to the 1999–2000 National Health and Examination Survey (NHANES) in the United States, the age-adjusted prevalence of MetS was 27.0%, according to Adult Treatment Panel III (ATP III) criteria [6]. A systemic review conducted in 2013 showed that the weighted mean general prevalence of MetS in Brazil was 29.6% [7]. In mainland China, a meta-analysis of 35 studies that collectively analyzed data from 2000 to 2015 for 2,26,653 Chinese participants more than 15 years old found that the pooled prevalence of MetS was 24.5% [8].

In Taiwan, according to the 2005–2008 Nutrition and Health Survey in Taiwan [9], the prevalence of MetS among all people over 19 years of age was 28.5%; the prevalence in women was 31.5% and it was 25.5% in men, with prevalence generally increasing with age. According to a 2005 study, the overall prevalence of MetS in Japan was 5.3%, with rates of 4.4% among women and 6.2% among men. The low rate of MetS in Japan might be related to the fact that the Japanese population generally consumes a balanced diet, engages in brisk walking and regular exercise, and works 3 to 7 h a day [10]. The prevalence of MetS in Taiwan is therefore similar to rates in the United States, Brazil, and mainland China and are substantially higher than those in Japan. Furthermore, there is an increasing prevalence of MetS in the middle-aged population of Taiwan (i.e., those aged 30–65 years), especially men [11].

Health-related quality of life (HRQoL) is a broad, multidimensional concept that usually includes subjective evaluations of both positive and negative aspects of life [12]. Health has traditionally been measured narrowly and from a deficit perspective, often using measures of morbidity or mortality. Owing to advances in modern medicine and improved social welfare, however, average human life expectancy has increased. At the same time, people have gradually noted that health is no longer viewed as purely a matter of longevity but is now also seen as a multidimensional construct that includes physical, mental, and social domains [13]. As such, the ways in which health outcomes are measured should assess the health of a population not only with the aim of saving lives but also to improve quality of life among the population.

Previous studies on associations between MetS and HRQoL have found that participants who exhibit more components of MetS generally have a poorer quality of life [14, 15]. Regarding sex differences between the association of MetS components and HRQoL, there have been few studies that have considered differing HRQoL impacts among men and women. A previous study of the general population in Iran indicated that MS is associated with poor HRQoL in women but not in men, and that this association is formed mainly in relation to physical rather than mental health [14]. Another study in Korea found that MS has a significant negative impact on the HRQoL of middle-aged Korean women but no significant impact on that of middle-aged Korean men [16]. The negative impacts of MetS on women might be related to several factors, including the level of physical morbidity, the prevalence of chronic conditions, and the level of pain [16]. Another study in Japan examining relationships between HRQoL and clustering of MS diagnostic components in participants aged 19–69 years found that the number of components of MetS was negatively associated with the general health score of HRQoL but positively associated with the mental health score of HRQoL in both men and women [15].

Given that MetS is a widespread condition with important public health effects in general, and considering the lack of relevant research on possible sex differences in the relationship between MetS and HRQoL, and also sex differences in the factors associated with HRQoL, the aim of this study was to identify: 1) whether women exhibit greater negative impacts on physical domain HRQoL owing to MetS compared with men; 2) whether women exhibit greater mental domain impacts compared with men; and 3) whether factors associated with HRQoL scores differ between men and women.

Methods

Ethical statement

This study was approved by the institutional review board of Taipei Veterans General Hospital, Taipei, Taiwan. Informed consent was obtained from all individuals who participated in the study.

Study design, target population, and participants

This study was a cross-sectional study conducted in nine neighborhoods in the Shipai area of Taipei, Taiwan during 2009–2010. The inclusion criteria were as follows: (1) residents of Shipai who had lived in the area for at least 6 months, and (2) aged between 35 and 55 years. Potentially eligible participants were identified from the official government household registration system in December 2008 and January 2009. Those who fulfilled with the inclusion criteria were randomly sampled and were sent invitation letters. Individuals who agreed to participate were included after they had signed an informed consent form. Participants then underwent examination
Definitions of components of MetS

The five components of MetS considered in this study were chosen according to the criteria proposed by the Taiwan National Department of Health in 2007, as follows: (1) central obesity, defined as a waist circumference ≥90 cm for men and ≥80 cm for women; (2) elevated blood pressure, defined as systolic blood pressure ≥130 mmHg, diastolic blood pressure ≥85 mmHg, or receiving any specific treatment for hypertension; (3) elevated triglyceride, defined as triglyceride ≥150 mg/dL or receiving any specific treatment for this lipid abnormality; (4) low HDL-C, defined as HDL-C < 40 mg/dL for males, HDL-C < 50 mg/dL for females, or receiving any specific treatment for this lipid abnormality; and (5) fasting hyperglycemia, defined as fasting plasma glucose ≥100 mg/dL or previously diagnosed type 2 diabetes [17]. If a person had three or more of the above five components, then they were regarded as having MetS. Accordingly, the number of MetS components for each participant in this study was recorded and subjected to further analysis.

Measurement of HRQoL

The Short Form Health Survey (SF-36), Taiwan version, which was developed following International Quality of Life Assessment (IQOLA) project protocols [18,19], was used for evaluating HRQoL among participants in this study. This questionnaire was self-administered by participants with the help of trained research assistants at the research center of Taipei Veterans General Hospital. The SF-36 measures eight health domains that can be grouped into two categories under the physical component summary (PCS) and mental component summary (MCS), with overall PCS and MCS scores representing subjective physical health and mental health, respectively. The PCS comprises the four physical health domains of the SF-36: physical functioning (ten items), role limitations owing to physical problems (four items), bodily pain (two items), and general health (five items). The MCS comprises the other four domains, which are mental health domains: vitality (four items), social functioning (two items), role limitations owing to emotional problems (three items), and mental health (five items). Another single item evaluating perceived change in health is also included in the SF-36. Responses to these 36 items are scored according to the scoring instructions provided in the SF-36 Health Survey Manual and Interpretation Guide. For each domain, the score ranges from 0 to 100, with lower scores indicating more impaired HRQoL. Previous studies revealed that the SF-36 Taiwan version has good validity and reliability with a Cronbach's α of 0.8 [18,19]. The Cronbach's α of SF-36 in this study was 0.68.

Demographics, medical history, medications, and physical activity

For each participant, demographic characteristics including sex, age, educational level, marital status, personal habits of cigarette smoking and alcohol consumption, and medical history were recorded using participants' reports. Reported educational level was categorized as illiterate/elementary school, senior/junior high school, or university and above. Reported marital status was categorized as married or single/divorced/separated/widowed/other. Key aspects of participants' self-reported medical history, including diabetes mellitus, hypertension, and dyslipidemia, were recorded. The medications currently used, including antihypertensive agents, antidiabetic medication (insulin or oral agents), and lipid-lowering agents, were noted.

The International Physical Activity Questionnaire (IPAQ) Short-Form, Taiwan version, was used to measure physical activity in this study. Previous studies have reported good validity and reliability of this measurement in Taiwan [20]. This questionnaire was also self-administered by participants with the help of trained research assistants. The questionnaire consists of seven questions that measure the frequency and/or duration with which a person has engaged in vigorous physical activity, moderate physical activity, walking for at least 10 min at a time, or sitting, during the previous 7 days. The frequency and/or duration of each specific type of physical activity was computed by weighting its equivalent metabolic equivalent of task (MET), an energy expenditure indicator, to yield an IPAQ score in MET-
minutes. The sum of MET-minutes, in turn, represents the overall volume of activity. Vigorous physical activity refers to activities with a value of 8 METs that require intense physical effort and make the person breathe much harder than normal; moderate physical activities refer to activities with a value of 4 METs that require moderate physical effort and make the person breathe somewhat harder than normal; walking is calculated as having a value of 3.3 METs. Accordingly, participants were stratified into three levels of physical activity according to their overall volume and frequency of activity: low, moderate, and high. A high level of physical activity refers to: (1) doing vigorous physical activities for at least 3 days, adding up to at least 1500 MET-minutes/week or (2) doing a combination of vigorous physical activities, moderate physical activities, and/or walking for at least 7 days adding up to at least 3000 MET-minutes/week. A moderate level of physical activity refers to: (1) doing

Table 1 Demographic characteristics of participants

|                                | Total  |   | Men     |   | Women    |   | P value |
|--------------------------------|--------|---|---------|---|----------|---|---------|
|                                | n      | % |         |   |          |   |         |
| Sex                            |        |   |         |   |          |   |         |
| Men                            | 347    | 38.3 | –       | – | –        | – | –       |
| Women                          | 559    | 61.7 | –       | – | –        | – | –       |
| Age (mean ± SD)                | 46.9   | 5.5 | 46.9    | 5.7 | 46.9   | 5.5 | 0.884 |
| BMI (mean ± SD)                | 23.8   | 3.5 | 25.2    | 3.3 | 23      | 3.4 | < 0.001 |
| BMI < 18.5                     | 30     | 3.3 | 5       | 1.4 | 25      | 4.5 |         |
| 18.5–23.9                      | 492    | 54.3 | 129    | 37.2 | 363   | 64.9 |         |
| ≥ 24                           | 384    | 42.4 | 213    | 61.4 | 171   | 30.6 |         |
| Waist circumference (mean ± SD) | 83.4   | 9.9 | 884    | 8.7 | 80.3   | 9.3 | < 0.001 |
| < 80 cm                        | –      | –  | –       | – | 310      | 55.5 | –       |
| ≥ 80 cm                        | –      | –  | –       | – | 249      | 44.5 |         |
| < 90 cm                        | –      | –  | 217    | 62.2 | –    | –  |         |
| ≥ 90 cm                        | –      | –  | 130    | 37.5 | –    | –  |         |
| Education level                |        |   |         |   |          |   | 0.001   |
| Illiterate/Elementary school   | 16     | 1.8 | 3      | 0.9 | 13      | 2.3 |         |
| Senior / Junior high school    | 324    | 35.8 | 102   | 29.4 | 222   | 39.9 |         |
| University and above           | 563    | 62.1 | 242  | 69.7 | 321   | 57.7 |         |
| Marital status                 |        |   |         |   |          |   | 0.002   |
| Married                        | 764    | 84.3 | 309  | 89.6 | 455   | 82.0 |         |
| Single/Divorced/Separated/Widowed/others | 136   | 15   | 36   | 10.4 | 100   | 18.0 |         |
| Personal habits                |        |   |         |   |          |   |         |
| Smoking                        |        |   |         |   |          |   | < 0.001 |
| Non-smoker                     | 723    | 79.8 | 205  | 59.2 | 518   | 93.0 |         |
| Current smoker                 | 125    | 13.8 | 96    | 27.7 | 29    | 5.2  |         |
| Ex-smoker                      | 55     | 6.1  | 45    | 13.0 | 10    | 1.8  |         |
| Alcohol consumption            |        |   |         |   |          |   | < 0.001 |
| No                             | 765    | 84.4 | 240  | 69.2 | 525   | 94.3 |         |
| Yes                            | 139    | 15.3 | 107  | 30.8 | 32    | 5.7  |         |
| Physical activity (IPAQ score) |        |   |         |   |          |   | 0.866   |
| Low                            | 318    | 35.1 | 120  | 34.6 | 198   | 35.4 |         |
| Moderate                       | 403    | 44.5 | 153  | 44.1 | 250   | 44.7 |         |
| High                           | 185    | 20.4 | 74   | 21.3 | 111   | 19.9 |         |
vigorou physical activities for at least 20 min per day for
at least 3 days, (2) doing moderate physical activities or
walking for at least 30 min per day for at least 5 days, or
(3) doing a combination of vigorous physical activities,
moderate physical activities, or walking for at least 5 days
adding up to at least 600 MET-minutes/week. A low level
of physical activity refers to any level of activity not meet-
ing the above criteria for high and moderate levels.

**Anthropometry, blood pressure, and blood tests**
The body weight, height, body mass index (BMI), waist
circumference, and systolic and diastolic blood pressure
of each participant were measured and recorded. Height
and weight were evaluated using an automatic electronic
measuring device, and BMI was obtained via calculation.
Waist circumference was measured by the standard
method. Blood pressure was measured using a standard-
ized sphygmomanometer applied with the participant in
a seated position, after 30 min of rest.

Each participant fasted for at least 8 h before the co-
lection of blood samples. Blood tests including fasting
plasma glucose, triglycerides, and HDL-C were conducted
at the central laboratory of Taipei Veterans General Hos-
pital, which has obtained laboratory accreditation/certifi-
cation from the College of American Pathologists.

**Statistical analysis**
Statistical analyses were performed using Microsoft Excel
(2016) and IBM SPSS, version 20.0 (IBM Corporation,
Armonk, NY, USA). All analyses were stratified by sex.
Descriptive statistics are presented as means and standard
deviations for continuous variables, and as numbers and
percentage for categorical variables. The differences
between means were evaluated using a Student t-test
(continuous variables with 2 categories) or analysis of vari-
ance (ANOVA) (continuous variables with ≥3 categories);
the differences between categorical variables were evalu-
ated using the chi-square test. Comparisons of HRQoL
scores across physical activity groups were performed by
ANOVA. Multiple linear regression models were used to
determine the associations between covariates and PCS
and MCS quality of life scores for all male and female par-
ticipants. Covariates entered in the models included sex,
age, education level, marital status, number of MetS com-
ponents, physical activity level, and personal habits of
smoking and alcohol consumption. For education level,
we coded illiterate/elementary school as the reference
level whereas for physical activity, we coded low physical
activity as the reference level. A two-tailed p value < 0.05
was considered statistically significant.

**Results**
Table 2 shows the sex differences in the components of
MetS and SF-36 scores. Men had significantly higher
proportions of high blood pressure compared with
women (both systolic BP [47.8% vs. 21.6%, p < 0.001]
and diastolic BP [40.3% vs. 16.8%, p < 0.001]). A signifi-
cantly higher proportion of male participants demon-
strated abnormal triglyceride levels (34.3% vs. 14.9%, p <
0.001) and fasting hyperglycemia than female partici-
pants (24.8% vs. 15.4%, p < 0.001). A significantly higher
percentage of women had a large waist circumference (49.2%
v% vs. 40.9%, p = 0.015). In terms of SF-36 scores, female
participants had significantly lower scores than male ones
in physical functioning (52.4 ± 5.3 vs. 54.2 ± 4.4, p < 0.001),
role limitations owing to physical problems (51.3 ± 8.3 vs.
52.6 ± 7.7, p = 0.022), bodily pain (52.3 ± 8.1 vs. 53.9 ± 8.3,
p = 0.003), mental health (38 ± 4.5 vs. 39.3 ± 4.3, p < 0.001),
and PCS score (54.1 ± 6.9 vs. 55.7 ± 6.7, p < 0.001).

Table 3 presents the results of regression analyses of
the PCS scores. For all participants, men had significantly
higher PCS scores than women (β = 1.353, p = 0.012); par-
ticipants with more MetS components had significantly
lower PCS scores (β = −0.371, p = 0.043). Other significant
factors associated with higher PCS scores including higher
education level and higher physical activity level; current
smokers had significantly lower PCS scores, and ex-
smokers had higher PCS scores than non-smokers. For
the different sexes, male participants with an education
level of university/above had higher PCS scores than those
who were illiterate or had an elementary school education
(β = 17.02). Similarly, men with a high school education
had higher PCS scores than those who were illiterate or
only completed elementary school (β = 17.686). The table
also shows that male participants with moderate and
high physical activity had significantly higher PCS scores
than those with low physical activity (β = 2.203,
p = 0.005 and β = 3.370, p = 0.001, respectively). Inter-
estingly, ex-smoker status was positively correlated
with PCS scores whereas current smoker status was inversely
correlated (β = 2.521 and −1.721, respectively) in relation to
non-smoker status. Among women, older age and number
of components of MS were significantly associated with
lower PCS score (β = −0.114, p = 0.041 and β = −0.542, p =
0.036, respectively); however, education and physical activ-
ity levels were not significantly associated with PCS scores.

Table 4 presents the results of regression analyses of
the MCS scores. For all participants, sex and number of
MetS components were not significantly associated with
MCS scores. However, participants with a high school-
level education had significantly lower MCS scores than
those who were illiterate or only completed elementary
school (β = −2.590, p = 0.042). Participants who were
current smokers and consumed alcohol had significantly
lower MCS scores than non-smokers and non-drinkers
(β = −1.394, p = 0.009 and β = −1.173, p = 0.020, respec-
tively). As for the different sexes, male participants with a
high school education level had lower MCS scores than

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those who were illiterate or had an elementary school education ($\beta = -5.761$. In addition, married men had significantly higher MCS scores ($\beta = 2.837, p = 0.001$), and males who reported alcohol consumption had significantly lower MCS scores ($\beta = -1.293, p = 0.03$). Among female participants, current smoking was inversely correlated with MCS scores ($\beta = -2.322, p = 0.019$).

**Discussion**

In this study, after adjusting for covariates, we found that women but not men with more MetS components had significantly lower PCS scores. The results also showed significant sex differences in several dimensions, including education level, physical activity level, and smoking status for PCS scores; and education level, smoking status, and alcohol consumption for MCS scores.

Some studies have reported that declining physical HRQOL is accompanied by a greater number of MetS components in women but not in men [14, 21]. Katano et al. found that the number of MetS components was inversely associated with general health and positively associated with mental health in both sexes [15]. Although most previous studies have found that MS components are associated with worse HRQoL [15, 22], the reported associations between MetS components and HRQoL in the different sexes have been inconsistent.

A prospective study of middle-aged women in the United States showed that weight gain was associated

| Components of metabolic syndrome | Total | Men | Women | P value |
|---------------------------------|-------|-----|-------|---------|
| Systolic blood pressure ≥130    | 287   | 166 | 121   | < 0.001 |
| Diastolic blood pressure ≥85    | 234   | 140 | 94    | < 0.001 |
| Triglyceride ≥150               | 202   | 119 | 83    | < 0.001 |
| HDL-C < 40 for male & < 50 for female | 156 | 59 | 97 | 0.8922 |
| Fasting glucose ≥100           | 172   | 86  | 86    | 0.001   |
| Waist circumference ≥90 for male & ≥80 for female | 417 | 142 | 275 | 0.015   |
| History of diabetes mellitus   |       |     |       |         |
| No                              | 741   | 280 | 461   | 0.769   |
| Yes                             | 28    | 12  | 16    | 2.9     |
| Missing                         | 137   | 55  | 82    | 14.7    |
| History of hypertension         |       |     |       |         |
| No                              | 714   | 256 | 458   | 0.004   |
| Yes                             | 78    | 42  | 36    | 6.4     |
| Missing                         | 114   | 49  | 65    | 11.6    |
| History of dyslipidemia         |       |     |       |         |
| No                              | 757   | 271 | 486   | 0.001   |
| Yes                             | 110   | 62  | 48    | 8.6     |
| Missing                         | 39    | 14  | 25    | 4.5     |
| SF-36 (mean ± SD)               |       |     |       |         |
| Physical functioning            | 53.1  | 5.1 | 54.2  | 4.4     |
| Role physical                   | 51.8  | 8.4 | 52.6  | 7.7     |
| Bodily pain                     | 52.9  | 8.2 | 53.9  | 8.3     |
| General health                  | 47.3  | 9.2 | 47.8  | 9.6     |
| Vitality                        | 47.8  | 4.6 | 48.1  | 4.6     |
| Social functioning              | 31.6  | 4.2 | 31.9  | 4.2     |
| Role emotional                  | 50.4  | 9.8 | 50.6  | 9.7     |
| Mental health                   | 38.5  | 4.5 | 39.3  | 4.3     |
| Physical component summary (PCS)| 54.7  | 6.9 | 55.7  | 6.7     |
| Mental component summary (MCS)  | 38.0  | 5.0 | 38.1  | 5.0     |
### Table 3: Multiple linear regression model for correlates of SF-36 PCS score

| Covariates                              | Total |          | Males |          | Females |          |
|-----------------------------------------|-------|----------|-------|----------|---------|----------|
|                                         | Beta  | P value  | Beta  | P value  | Beta    | P value  |
| Demographics                            |       |          |       |          |         |          |
| Sex (male vs. female)                   | 1.353 | 0.012    | –     | –        | –       | –        |
| Age (year)                              | −0.081| 0.051    | −0.007| 0.912    | −0.114  | 0.041    |
| Education level                         |       |          |       |          |         |          |
| Illiterate/elementary school            |       |          | Reference | Reference | Reference |          |
| High school                             | 3.43  | 0.047    | 17.02 | < 0.001  | −0.035  | 0.986    |
| University and above                    | 4.724 | 0.006    | 17.686| < 0.001  | 1.588   | 0.418    |
| Marital status (married vs. others)     | −0.197| 0.757    | 0.591 | 0.607    | −0.382  | 0.62     |
| No. of component of metabolic syndrome  | −0.371| 0.043    | −0.116| 0.645    | −0.542  | 0.036    |
| Physical activity level                 |       |          |       |          |         |          |
| Low                                     |       |          | Reference | Reference | Reference |          |
| Moderate                                | 0.897 | 0.076    | 2.203 | 0.005    | 0.101   | 0.878    |
| High                                    | 2.09  | 0.001    | 3.37  | 0.001    | 1.22    | 0.137    |
| Personal habits                         |       |          |       |          |         |          |
| Smoking                                 |       |          |       |          |         |          |
| Current smoker vs. non-smoker           | −1.675| 0.02     | −1.721| 0.036    | −1.084  | 0.421    |
| Ex-smoker vs. non-smoker                | 2.451 | 0.014    | 2.521 | 0.019    | 2.393   | 0.276    |
| Alcohol consumption (yes vs. no)        | 1.163 | 0.087    | 0.483 | 0.536    | 2.442   | 0.055    |

### Table 4: Multiple linear regression model for correlates of SF-36 MCS score

| Covariates                              | Total |          | Males |          | Females |          |
|-----------------------------------------|-------|----------|-------|----------|---------|----------|
|                                         | Beta  | P value  | Beta  | P value  | Beta    | P value  |
| Demographics                            |       |          |       |          |         |          |
| Sex (male vs. female)                   | 0.702 | 0.079    | –     | –        | –       | –        |
| Age (year)                              | 0.056 | 0.069    | 0.073 | 0.124    | 0.028   | 0.49     |
| Education level                         |       |          |       |          |         |          |
| Illiterate/elementary school            |       |          | Reference | Reference | Reference |          |
| High school                             | −2.59 | 0.042    | −5.761| 0.043    | −1.727  | 0.231    |
| University and above                    | −2.315| 0.069    | −4.778| 0.091    | −1.901  | 0.183    |
| Marital status (married vs. others)     | 0.789 | 0.094    | 2.837 | 0.001    | −0.058  | 0.918    |
| No. of component of metabolic syndrome  | 0.121 | 0.369    | −0.023| 0.903    | 0.269   | 0.156    |
| Physical activity level                 |       |          |       |          |         |          |
| Low                                     |       |          | Reference | Reference | Reference |          |
| Moderate                                | −0.286| 0.444    | −0.611| 0.302    | −0.08   | 0.868    |
| High                                    | −0.769| 0.098    | −1.06 | 0.149    | −0.335  | 0.578    |
| Personal habits                         |       |          |       |          |         |          |
| Smoking                                 |       |          |       |          |         |          |
| Current smoker vs. non-smoker           | −1.394| 0.009    | −0.939| 0.132    | −2.322  | 0.019    |
| Ex-smoker vs. non-smoker                | 0.614 | 0.042    | 0.800 | 0.327    | 0.776   | 0.63     |
| Alcohol consumption (yes vs. no)        | −1.173| 0.02     | −1.293| 0.03     | −0.784  | 0.401    |
with decreased physical functioning and vitality, as well as increased body pain, regardless of baseline weight [23]. In other recent studies, obesity was usually documented as being associated with poor HRQoL, not only in the physical but also in the mental domain [24, 25]. In our study, a trend indicating that higher numbers of MetS components were accompanied by lower physical health scores was found in women but not in men, indicating other mechanisms that are associated with this sex difference might deserve further investigation.

Although recent studies have demonstrated that dietary modification and enhanced physical activity may delay or prevent the transition from impaired glucose tolerance to type 2 diabetes mellitus and provide an adequate lifestyle for obese people [26], physical activity is probably not the most influential factor in MetS, or MetS may be affected by many factors. When adjustments for other lifestyle factors were made, we found significant associations between physical activity levels and physical health scores among men who participated in our study. Specifically, men who had insufficient physical activity had worse PCS scores than those with both moderate and high levels of physical activity; this finding was in line with previous studies [27, 28]. People with impaired HRQoL may also be less likely to participate in physical activity. On the other hand, it is possible that physical activity can improve HRQoL. However, because this was a cross-sectional research study, we could not determine any cause–effect relationship.

Some studies have found that physical activity most directly affects HRQoL through its impact on psychological well-being or emotional function [29]. Results from the Alameda County Study also suggest that people with low physical activity levels have a higher risk for depression compared with those who have higher levels of physical activity, independent of the presence of chronic conditions [30]. In our study, there was no difference in mental health scores between the sexes. More studies might be required to determine possible mechanisms explaining the relationship between physical activity and mental health.

In our study, we noted that male current smokers had significantly lower PCS scores whereas female current smokers had lower MCS scores than non-smokers. In addition, we noted that males who had quit smoking had better PCS scores than non-smokers. As we know, cigarette smoking plays a substantial role in the pathogenesis of numerous chronic diseases such as cardiovascular, cancer, lung, and other diseases [31, 32]. Thus, quitting smoking is a healthy behavior that can elevate not only HRQoL but also improve the environment, allowing others to feel more comfortable. Regarding alcohol consumption, the results in our study were line with those of several previous studies that also found that consuming alcohol was associated with poor HRQoL [33–37], especially for males [38]. The relationship between alcohol consumption and HRQoL is complex. Possible mechanisms included alcohol-related medical conditions, mental disorders, social problems, accidents, and violence. Our results suggest that maintaining healthy behaviors can lead to better HRQoL.

The significant positive association between high education levels and PCS score and the negative association between education levels and MCS score were found in males but not females. Sex differences in the associations between education level and PCS and MCS scores might be complicated. People with higher education levels might have better health knowledge, which could be helpful in maintaining healthy behaviors, disease prevention, and seeking professional medical treatment [39–41], all of which positively influence physical health-related quality of life. For mental health-related quality of life score, the negative associations might be related to stress from various aspects of daily life such as family issues, work competition, and so on. Males who were married had significantly higher MCS scores, which might be related to having better family supports.

The results of this analysis have some limitations. The analysis was cross-sectional in nature, such that making determinations about cause and effect is impossible. Furthermore, the sample in our study was local and too small to be representative of the entire population of Taiwan. In addition, mechanisms of the sex differences found in the associations between HRQoL and MS are unclear; these might be both biological and psychosocial. It is possible that sex variations in health-related behaviors (e.g., physical activity, smoking, alcohol consumption) may have many different kinds of impact on HRQoL outcomes. There are also differences in symptom presentation and management between men and women that could affect their perceptions of HRQoL. Thus, the sex differences in HRQoL require further study. However, to our knowledge, there have been few previous studies on the association between HRQoL and MS in Asian countries, especially in Taiwan. Our study was the first of its type to consider a middle-aged population in Taiwan, and the findings should allow us to better understand the health burden of MS among Taiwanese adults. A clearer finding of sex differences related to the association between MS and HRQoL will offer more information, to improve HRQoL of the population in the future.

Conclusion
The results of this study showed that, after adjusting for covariates, women but not men with more MetS components had significantly lower PCS scores. The number of MetS components was not a significant factor of MCS scores between sexes. Furthermore, there
were sex differences regarding age, education level, physical activity, and smoking status in association with PCS scores. For MCS scores, sex differences were found in education level, marital status, and habits of smoking and alcohol consumption. Further research should be conducted to investigate mechanisms of these sex differences.

**Abbreviations**

BMI: Body mass Index; HRQoL: Health-related quality of life; IPAQ-Taiwan: International physical activity questionnaire Taiwan version; IQOL-A: International quality of life assessment; MCS: Mental component summary; MET: Metabolic equivalent of task; METS: Metabolic syndrome; PCS: Physical component summary; SF-36 Taiwan: Short form-36 Taiwan version.

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**Availability of data and materials**

The datasets generated during and/or analyzed during the current study are not publicly available because the local ethics committee requested to protect the participant privacy.

**Authors’ contributions**

CCL wrote the first draft of the paper, with contribution from SJH and HTC. The data analyses and interpretation were completed by CCL, HTC and SCC. HTC and SJH revised the manuscript and gave the final approval to submit the manuscript for publication. All authors contributed to study design and conduct of the study, and contributed to the final manuscript. All authors have read and approved the final manuscript.

**Ethics approval and consent to participate**

This study was approved by the institutional review board of Taipei Veterans General Hospital, Taipei, Taiwan (97-12-06A and 2017-01-0088CF). All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. Informed consent was obtained from all individual participants included in the study.

**Competing interests**

The authors declare that they have no competing interests.

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**Authors’ contributions**

CCL wrote the first draft of the paper, with contribution from SJH and HTC. The data analyses and interpretation were completed by CCL, HTC and SCC. HTC and SJH revised the manuscript and gave the final approval to submit the manuscript for publication. All authors contributed to study design and conduct of the study, and contributed to the final manuscript. All authors have read and approved the final manuscript.

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