CLINICAL SCIENCE

Prevalence of metabolic syndrome and related factors in Taiwanese high-tech industry workers

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OBJECTIVES: In light of the increasing number of high-tech industry workers and the differences in their working conditions compared to those of the general population, the health status of these workers merits serious attention. This study aimed to explore the prevalence of metabolic syndrome and its correlates among Taiwanese high-tech industry workers.

METHODS: This cross-sectional study included 4,666 workers who participated in labor health examinations at a hospital in southern Taiwan in 2008. Participants with metabolic syndrome were defined using the criteria proposed by the Taiwan National Department of Health in 2007. Factors associated with metabolic syndrome were determined using multiple logistic regression analysis.

RESULTS: The overall prevalence of metabolic syndrome was 8.2%, and the prevalence was higher in men than in women (14.0% *vs.* 2.3%, $p<0.01$). Male gender, advanced age, elevated white blood count, and elevated levels of blood biochemistry markers, such as alanine aminotransferase and uric acid, can independently predict metabolic syndrome.

CONCLUSIONS: The prevalence of metabolic syndrome among high-tech industry workers is lower than in the general population. Our study's findings may facilitate early health assessments and the provision of proper workplace health promotion programs to reduce the risks faced by high-risk workers.

KEYWORDS: High-tech industry; Metabolic syndrome; Workplace health promotion.

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INTRODUCTION

As a result of economic growth and associated socio-demographic shifts, changes in lifestyle and diet have led to an elevated risk with respect to chronic diseases, especially cardiovascular disease. According to the World Health Organization (WHO), cardiovascular disease is the leading cause of death worldwide, claiming 17.5 million victims yearly.[1] This high mortality rate creates an enormous financial burden. In the European Union, the yearly direct and indirect economic cost of cardiovascular disease is as high as 169 billion EUR.[2] In contrast, after reviewing the top ten causes of mortality in Taiwan, we found that chronic diseases had replaced infectious diseases as the main cause of death. For example, according to statistics reports from the Taiwan National Department of Health in 2008,[3] the mortality attributed to metabolic abnormalities (29.5%), including cerebrovascular disease, heart disease, diabetes mellitus, hypertension, and pyelonephritis, had surpassed cancer mortality (27.3%), revealing that metabolic abnormalities have become a major health challenge.

Given its threat to the well-being of humans, a syndrome related to insulin resistance abnormalities was first proposed by Reaven in 1988.[4] Subsequently, in 1998, the WHO introduced the first internationally recognized term for metabolic abnormalities, metabolic syndrome (MS), which is characterized by a core set of disorders, including glucose intolerance, central obesity, dyslipidemia, and hypertension co-occurring within an individual.[5] Although there is still some debate as to the precise definition of MS, its prevalence around the world has been estimated at approximately 7% to 58% according to the Adult Treatment Panel III definition, and these figures were still rising when the criteria were specified by the WHO.[6]

Recently, investigators have reported on the challenge that MS poses for human health. For example, MS is not only an indication of the likelihood of developing coronary heart disease or type II diabetes but is also associated with a threefold greater risk of cardiovascular death, as compared to those without the disorder.[5] Additionally, MS is related to cerebral atrophy, which may trigger depression and cognitive impairment.[7,8] Most recently, studies on the

correlation between malignancy and MS have shown that patients with MS have a 1.6-fold higher risk of death from cancer than those without MS.[9] Therefore, clarifying the factors related to MS and to identify high-risk cases early may be of utmost importance for public health.

Workers are an important part of any institution. Since the promulgation of the Ottawa Charter for Health Promotion by the WHO in 1986, global support for workplace health promotion has encouraged employers to hold health promotion activities to ensure employee health.[10] With increasing competition in the global market and the rapid development of technology, all countries (including Taiwan) seek to foster growth in high-tech industries. Facilitated by support from the government, high-tech products comprised 71.2% of all exports from Taiwan in 2006 with a value of US$159.5 billion.[11] Taiwan is a pivotal site for high-tech industry development in the world, but increasing demand for high-tech products may increase the already heavy workload for workers in this industry. Therefore, the health status of high-tech industry workers requires immediate attention. Many previous studies have focused on musculoskeletal discomfort,[12] workplace stress,[13] skin disease,[14] and lumbar pain,[15] among other issues, but there is a relative paucity of data pertaining to metabolic abnormalities in the workplace. Most importantly, the medical expenses related to MS are considerable and thus cannot be overlooked. Goetzel et al.[16] found that obesity poses a burden of US$644 per worker on companies, due to medical expenses and loss of productivity. Moreover, this cost rises to US$3,719 with the occurrence of MS,[17] which may have a major impact on the fiscal performance of the company. Therefore, our study aimed to understand the prevalence of MS and related factors in high-tech industry workers, which should facilitate the development of strategies for promoting appropriate workplace health.

METHODS

Research design and participants

This study was cross-sectional. The subjects were workers from a company in the integrated circuit industry; the company contracted a hospital in Taiwan for health examination services in 2008. A total of 4,666 workers providing informed consent were included in this study, and the study was reviewed and approved by the Institutional Review Board of the target hospital.

Data characteristics and diagnostic criteria

Analytical data were obtained from the health examination database. These data included gender, age, height, body weight, blood pressure, waist circumference, and blood biochemistry markers (i.e., white blood cell count (WBC), hemoglobin concentration, fasting blood glucose levels, high-density lipoprotein cholesterol (HDL-C), triglycerides, uric acid (UA), creatinine, aspartate aminotransferase (AST), and alanine aminotransferase (ALT)). The body mass index (BMI) was calculated by dividing weight (in kg) by height (in m^2). Systolic and diastolic blood pressures were measured using an automatic sphygmomanometer (UDEX-IIa, UEDA Corp., Tokyo, Japan) and recorded in the seated position after participants had rested for at least 5 min. Waist circumference was measured with a heavy-duty inelastic plastic fiber tape measure to the nearest 0.5 cm, while the subject stood balanced on both feet with the feet touching each other and both arms hanging freely. Hemoglobin concentration, ALT, AST, triglycerides, fasting blood glucose, UA, WBC, and HDL-C were evaluated by automatic bio-assays (Olympus AU-640, Tokyo, Japan).

MS was defined as the presence of three or more of the following five criteria proposed by the Taiwan National Health Department:[18] (1) fasting blood glucose $\geq$100 mg/dl or self-reported diabetes mellitus; (2) blood pressure $\geq$130/85 mmHg or self-reported hypertension; (3) HDL-C cholesterol $<$40 mg/dl in men or $<$50 mg/dl in women; (4) triglycerides $\geq$150 mg/dl; and (5) waist circumference $\geq$90 cm in men or $\geq$80 cm in women.

Statistical analysis

Descriptive and inferential analyses were conducted in accordance with the study's aims and the nature of the variables. For descriptive analysis, subjects were grouped according to the presence of MS. Differences in various factors between groups are expressed with averages, standard deviations (SDs), and percentages. Besides gender, which is shown as a percentage, other variables with continuous distributions are expressed as averages with SD. For inferential analysis, *t*-tests and chi-square tests were used to explore the relationship between analytical variables and MS. Multiple logistic regression analysis with the simultaneous entry method was further used to determine risk factors and their adjusted odds ratios (AORs). All analyses were conducted with Statistical Package for Social Sciences (SPSS) version 15.0 software (SPSS, Inc., Chicago, IL), and $p<0.05$ was considered significant.

RESULTS

The 4,666 high-tech industry workers enrolled in this study included 2,344 men and 2,322 women. Among subjects, the overall prevalence of MS was 8.2% (382/4,666) with 14.0% (328/2,344) in men and 2.3% (54/2,322) in women, revealing a higher MS prevalence in men ($p<0.01$). Based on the 2007 population census published by the Department of Health,[19] the age-standardized prevalence was 5.9%, which was also higher in men than in women (10.1% *vs.* 1.7%, $p<0.01$). Additionally, men also showed higher BMIs, WBCs, liver enzyme levels, creatinine, UA, and hemoglobin, as compared to women ($p<0.01$). Subjects with MS averaged 33.5 years in age, as opposed to 30.2 years for those without MS. On average, workers with MS had significantly higher BMIs and abnormal blood samples, as compared to those without MS (Table 1).

Our analysis also showed that the most common metabolic abnormalities among men and women with MS was higher waist circumference, which was followed by irregular blood pressure and hypertriglyceridemia; these disorders had prevalences of 82.0%, 81.4%, and 73.2% in males and 98.2%, 88.9%, and 64.8% in females, respectively (Table 2).

Multivariate analysis revealed that men had an AOR of 3.94 (95% confidence interval (CI) = 2.29−6.78) for developing MS, as compared to women. A one-year increase in age was associated with a 6% (95% CI = 1.04-1.09) increase in the risk of MS. An increase in BMI of one raised the AOR for MS by 2% (95% CI = 1.01−1.02). Regarding blood biochemistry markers, an increase of one unit of ALT increased the AOR for MS by 30% (95% CI = 1.26−1.35). An increase of one unit of UA or WBC was associated with an increase of

Table 1 - Characteristics of study participants.

Variables	MS cases (n = 382)		Non-MS cases (n = 4284)		*p*-value
	Mean (SD)	n (%)	Mean (SD)	n (%)	
Gender					
Male		328 (13.99)		2016 (86.01)	<0.01
Female		54 (2.33)		2268 (97.67)	
Age	33.52 (5.76)		30.17(5.36)		<0.01
BMI	28.50 (3.68)		22.97(3.75)		<0.01
Liver Enzymes					
AST (IU/L)	29.84 (20.04)		19.39 (8.39)		<0.01
ALT (IU/L)	49.99 (34.89)		22.29 (18.05)		<0.01
Creatinine (mg/dl)	1.12 (0.17)		0.99 (0.33)		<0.01
UA (mg/dl)	7.10 (1.48)		5.63 (1.45)		<0.01
WBC (10^3 cells/μl)	7.93 (1.95)		7.13 (1.87)		<0.01
Hemoglobin (g/dl)	15.05 (1.40)		14.00 (1.52)		<0.01

14% (95% CI = 1.03−1.27) and 12% (95% CI = 1.04−1.19), respectively, in the risk of being diagnosed with MS (Table 3).

DISCUSSION

The overall MS prevalence was 8.2% (14.0% in men and 2.3% in women). Because the average age of the subjects, who ranged in age from 31 to 40 years, was younger than in most other epidemiological studies, it is difficult to directly compare our results with MS prevalence reported elsewhere. However, as compared to the prevalence in similarly aged men and women (10.1%−25.8% and 2.1%−19.7%, respectively[20-22]), the MS prevalence among high-tech industry workers was lower than in the general population. This difference may be attributed to the healthy worker effect: these workers not only must demonstrate a better-than-average health status to qualify for work but also are screened by health examinations before being allowed to enter the high-tech industry.

We found that the most common manifestations of MS in both men and women were high waist circumference followed by high blood pressure and hypertriglyceridemia. However, Pan[23] found that blood pressure, triglyceride, and HDL-C disorders were the most common metabolic abnormalities among male and female adults in Taiwan. Another study of 1,562 Taiwanese teenagers indicated that triglycerides, HDL-C, and waist circumference were the most common abnormal indicators in male adolescents, as compared to HDL-C, blood pressure, and waist circumference in female adolescents.[24] Findings based on the same ethnic group, therefore, may vary due to age discrepancies with respect to the leading types of metabolic abnormalities (one third of Pan's subjects were aged 45 years or above). Despite several studies showing a significant correlation between age and predisposition for MS,[21-22] further research is needed to elucidate whether the leading metabolic abnormalities vary with age.

Men were at a 3.47-fold greater risk of MS than women, which is in line with previous studies.[22] Two reasons may account for this phenomenon. First, men are less aware of self-care than women. For instance, not only do fewer women smoke and drink, but they are more prone to seek medical counsel or an examination in the event of physical discomfort. Thus, the risks for chronic diseases, such as hypertension and diabetes, are usually lower in women than in men.[25] Second, this study was mostly conducted on younger subjects, and younger women may benefit from higher estrogen levels, which decrease serum low-density lipoprotein-cholesterol (LDL-C) and curb coronary thrombosis and atherosclerosis by regulating vascular smooth muscle and endothelial cells.

Our findings also show that age was positively correlated with the risk of MS, which is in line with previous studies.[20-21] It can be inferred that, with age, blood vessels gradually lose elasticity and gain resistance, slowing blood flow. Moreover, with poor circulation, fat is prone to accumulate in the abdomen and release free fatty acids into the serum, leading to higher insulin resistance, elevated serum triglyceride levels, increased small dense LDL-C levels, and, consequently, a greater risk of MS.[26] This study also showed that a higher BMI was associated with a greater AOR for developing MS, which confirms a previous report.[21] BMI can be used to assess body

Table 2 - Sex-specific prevalence of individual metabolic abnormalities among MS cases.

Metabolic abnormality	Male (n = 328)		Female (n = 54)	
	%	95% CI	%	95% CI
High triglycerides	73.17	68.37–77.97	64.81	52.07–77.55
High fasting glucose	49.09	43.68–54.50	55.56	42.31–68.81
Abdominal obesity	82.01	77.85–86.17	98.15	94.56–101.74
Low HDL–C	39.63	34.34–44.92	0	0
High blood pressure	81.40	77.17–85.61	88.89	80.51–97.27

Table 3 - Factors associated with MS according to multiple logistic regression analysis.

Variables	Crude OR (95% CI)	Adjusted OR (95% CI)
Gender		
Male	6.83 (5.09–9.12)	3.94 (2.29–6.78)**
Female	1	1
Age	1.11 (1.08–1.12)	1.06 (1.04–1.09)**
BMI	1.04 (1.03–1.04)	1.02 (1.01–1.02)*
Liver enzymes		
AST (IU/L)	1.06 (1.05–1.07)	1.00 (0.96–1.01)
ALT (IU/L)	1.36 (1.32–1.39)	1.30 (1.26–1.35)**
Creatinine (mg/dl)	4.62 (2.83–7.58)	0.73 (0.30–1.76)
UA (mg/dl)	1.87 (1.74–2.01)	1.14 (1.03–1.27)**
WBC (10^3 cells/μl)	1.21 (1.16–1.27)	1.12 (1.04–1.19)**
Hemoglobin (g/dl)	1.71 (1.57–1.86)	1.00 (0.88–1.13)

*$p<0.05$;
**$p<0.01$.

fat content, which serves as an indicator of obesity. In cases of obesity, adipose cells release free fatty acids and tumor necrosis factor-α (TNF-α), which blocks phosphatidylinositide-3-kinase-dependent signal transduction pathways and reduces glucose uptake in the liver and skeletal muscles.[6,27] To compensate, pancreatic β cells are induced to secrete excessive insulin, leading to hyperglycemia or type II diabetes.

We discovered that ALT can better assess the risk of MS than AST, which is in line with both cross-sectional and cohort studies.[28-29] This finding stems from the storage of ALT in hepatic cells; therefore, ALT is a more effective marker for detecting pathogenic hepatic fatty changes caused by obesity, as compared to AST.[29] Two reasons may explain the positive relationship between ALT and the risk of MS. First, abnormally elevated ALT is often found in people under tremendous workplace pressure or extreme fatigue.[30] High psychological pressure may activate the sympathetic system to raise arterial blood pressure and reduce renal blood flow.[31] Consequently, the patient develops vasculitic reactions and elevated serum UA levels, increasing the risk of MS. Second, elevated ALT can also indicate abnormal liver function caused by fatty liver.[28] Once a patient has developed fatty liver, fat accumulation has usually already occurred in the muscle and other organs, such as the pancreas. As these tissues release free fatty acids that inhibit the insulin-based regulation of the uptake and utilization of glucose, metabolic abnormalities subsequently emerge.[27]

This study found a positive correlation between WBC and the risk of MS, which was in line with previous literature reports.[32-33] A higher WBC may be related to bacterial infection or vasculitis caused by hyperglycemia and dyslipidemia. In an inflammatory state, vascular endothelial cells secrete proinflammatory cytokines, such as interleukin-6 or TNF-α, which can activate and attract massive numbers of white blood cells to the damaged region within the lumen of the vessel.[33] Following infiltration into the tunica media, white blood cells absorb oxidized LDL-C and become foam cells, which may greatly increase the risk of thromboembolism. Additionally, Rho kinase secreted by white blood cells can serve as another potential pathogenic mechanism. Liu et al.[32] have found that Rho kinase can block insulin signaling by stimulating the phosphorylation of insulin receptor substrate-1. This action prevents the translocation of glucose to the cell membrane by glucose transporter 4, thereby leading to insulin resistance.

Our study revealed that workers with MS have a higher risk of elevated UA, which is in accordance with a previous report.[34] The mechanism involved may be related to the ability of high levels of UA to inhibit the production of nitric oxide (NO) by endothelial cells. NO can serve as an inhibitor of thrombosis and inflammatory reactions, further preventing the growth and transfer of vascular smooth muscle cells.[35] As for hemoglobin levels, we discovered that hemoglobin was of borderline significance. Because the specific biological mechanisms by which hemoglobin levels increase the risk of MS remain unclear, further study is needed to clarify the effect of hemoglobin levels on MS, especially among diverse participants.

The results from this study should be interpreted with the following limitations in mind. First, subjects were drawn from a single company in southern Taiwan, and, therefore, the inferences drawn from the results are not completely generalizable. More diverse samples collected by a nationwide survey or random sampling should be considered in future research. Second, as a cross-sectional study, we cannot infer causality from our findings. A longitudinal study design is needed to investigate any causal relationships among the factors included in this study. Third, data on potential factors, such as smoking, alcohol, education, exercise habits, family history, and worksite pressure were not collected in this study; lack of information about these factors may have caused some inferential error. Future studies are needed to understand the impact of the abovementioned confounding variables on MS. Moreover, issues related to the medical costs induced by MS also warrant further evaluation. Despite these methodological concerns, to our knowledge, this was the first evidence-based study to estimate the prevalence of MS in Taiwanese high-tech industry workers. It also involved an analysis of corresponding health check-up data, which can be useful in assessing the risk factors for MS because the data were obtained from standardized laboratory tests.

CONCLUSION

This study explored the prevalence of MS and related factors among high-tech industry workers. We found that factors contributing to a high risk of MS included being male and older, as well as having a higher BMI, increased ALT, elevated UA, and higher WBC. If our study is replicated in other occupational settings, the results may have significant economic and public-health implications for other shift-work occupational groups, such as the military, medical service personnel, and police officers. We believe that our findings support the need to improve workplace health promotion in the high-tech industry. For example, appropriate on-site diet and exercise programs aimed at high-tech industry workers should be implemented. In addition, occupational managers should actively offer in-service education concerning MS prevention to workers and monitor their physical and mental health, especially in high-risk cases. In summary, the identification of at-risk workers and disease management programs addressing MS-related factors are of great importance in employer-based interventions.

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