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Role of the physical fitness test in risk prediction of diabetes among municipal in-service personnel in Guangxi

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Abstract

To explore the relationship between risk prediction of diabetes mellitus (DM) and different physical fitness parameters in municipal in-service personnel in Guangxi.

This was a cross-sectional study conducted in China from July 2015 to December 2016. We enrolled in-service adults (20–65 year of age) from public institutions. All subjects underwent National Physical Fitness Test (NPFT) and EZSCAN screening.

The 5668 subjects were 42.9±12.3 years; 2984 (52.6%) were male; 3998 (70.5%), 1579 (27.9%) and 85 (1.6%) were Han, Zhuang, and other ethnicities, respectively. The multivariable analysis showed that systolic blood pressure (odds ratio [OR]=1.013, 95% confidence interval [CI]: 1.003–1.022, $P=.01$), Harvard step test index (OR=0.958, 95% CI: 0.941–0.976, $P<.001$), bend-ahead in sitting (OR=0.945, 95% CI: 0.926–0.963, $P<.001$), hand grip strength (OR=0.981, 95% CI: 0.966–0.997, $P=.02$), vertical jump height (OR=0.969, 95% CI: 0.944–0.996, $P=.02$), time of single-leg standing with eyes closed (OR=0.981, 95% CI: 0.968–0.995, $P=.007$), choice reaction time (OR=2.103, 95% CI: 1.261–3.507, $P=.004$), and body composition minerals (OR=1.649, 95% CI: 1.261–1.813, $P<.001$) were independently associated with DM. The resulting equation for the prediction of DM had an area under the receiver operating characteristic curve of 0.808, indicating good predictive ability.

NPFT and EZSCAN could help predict the risk of diabetes and give early warnings to undertake preventive actions such as changing diet and performing physical activity.

Abbreviations: AUC = area under the receiver-operating characteristics curve, BAIS = bend-ahead in sitting, BP = blood pressure, BCM = body composition mineral, CI = confidence interval, CRT = choice reaction time, DM = diabetes mellitus, FPG = fasting plasma glucose, HGS = hand grip strength, HSTI = Harvard step test index, Ht = height, MOPA = moderate occupational physical activity, NPFT = National Physical Fitness Test, OR = odds ratio, P[DC] = probability of diabetic complication, P[IGT] = probability of impaired glucose tolerance, P[IR] = probability of insulin resistance, ROC = receiver-operating characteristics, TSEC = time of single-leg standing with eyes closed, VJHT = vertical jump height.

Keywords: body composition, diabetes, national physical fitness test, physical fitness, physical function, risk

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1. Introduction

Nowadays, non-communicable diseases are the most significant cause of death.[1] Unhealthy lifestyle could significantly change the body composition and increase the incidence of obesity, pathologic glycemia, diabetes mellitus (DM), cardio- and cerebrovascular events, fractures, and other non-communicable diseases.[2,3] Following its recent economic development, China adopted a more Westernized lifestyle, and this change led to increases in the incidence and prevalence of type 2 DM.[4,5] A previous study revealed that there are about 177 million adults with hypertension and 303 million smokers in China.[6] In addition, because of dietary changes and reduced physical activity, the prevalence of obesity in Chinese adults and children increased dramatically, and obesity is a well-known risk factor for DM.[6] Mortality caused by diseases related to unhealthy lifestyle habits in Chinese first-tier cities had nearly climbed to 50%, bringing a heavy burden on the society and families. In China, urban areas are mainly composed of people working in companies and government institutions, and they play an important role in the economic development of China. Studies showed that the prevalence of DM in China is more important in urban than rural areas.[5]

The American diabetes association (ADA) recommends mass screening in the general population for the early detection and treatment of DM instead of having to manage complications and treatments.[7] The American Society of Endocrinology and the American Society of Clinical Endocrinology jointly stated that in the early stage of DM, high blood glucose damage is already present; therefore, early detection and management of pre-DM is important.[8] Studies have shown that EZSCAN screening can reveal early-stage diabetes, which allows for the implementation of early treatments and healthier lifestyle habits, including diet and physical activity.[9–12] In addition, EZSCAN screening shows better reliability and validity for the diagnosis of diabetes than fasting blood glucose. Hence, EZSCAN has been adopted as a screening tool for DM in many cities in China.[13]

Controlling the diet and increasing physical activity are the main lifestyle interventions in high-risk populations to reduce the incidence of DM and related morbidity and mortality.[14] Physical inactivity is a major threat to health; hence, increasing physical activity should improve life expectancy.[15] Individualized exercise prescription is an effective measure to prevent and treat DM.[14] The very early recognition and treatment of DM risk have an important effect on preventing DM, especially in countries with poor economic conditions.[16] The risk of DM was not influenced by gender or ethnic groups, but was influenced by occupational labor intensity.[16] van Dijk et al found that blood glucose levels can be controlled using simple exercise.[17–19] Offering enhanced support for exercise to patients with DM led to improvements in exercise and glycemic controls.[20] The National Physical Fitness Test (NPFT) is a free-of-charge examination that is offered to the general population in China.[21] It is a non-invasive test aiming at revealing the physical status, physical function, and physical fitness of the subject.

So far, data and studies about the relationship between physical fitness and risk of DM in civil servants in Guangxi are still lacking. Guangxi is an autonomous region in Southeast China with nearly 50 million inhabitants. Therefore, this cross-sectional study aimed to explore the relationship between physical fitness parameters and risk prediction of diabetes in municipal in-service personnel in Guangxi.

2. Materials and methods

2.1. Ethical statement

This study was approved by the Medical Ethic Committee of Jiangbin Hospital (Guangxi Zhuang Autonomous Region, China). Informed consent was obtained from all participants.

2.2. Study design and subjects

This was a cross-sectional study of in-service municipal civil servants from Guangxi who underwent NPFT and EZSCAN screening between January 2015 and December 2016. From each of the 34 municipal districts in Guangxi, 3 large-scale institutions were randomly selected (lottery method). From each unit, 70 in-service civil servants were asked to participate voluntarily in the study. Large-scale institutions referred to government agencies, government-owned corporations (rail transport, electric power, etc.), and hospitals, with no less than 300 employees.

The inclusion criteria were:

1) working at government agencies, institutions, and state-owned corporations in the 1 of the 34 municipal districts of Guangxi Zhuang Autonomous Region (China);
2) lived in the area for >3 years; and
3) 20 to 65 years of age.

The exclusion criteria were:

1) severe heart, pulmonary, liver, or kidney disease;
2) history of disability, limb movement disorders, limited movement due to osteoarthritis, or bone and joint disease preventing the subject from participating in the physical fitness test;
3) pregnant women;
4) malignant tumor; or
5) travels outside Guangxi for >3 months per year.

2.3. Body composition test

The body composition test was performed in the morning, after an overnight fast, and on the day of the physical examination. Body height (Ht) was measured using a tape fixed to the wall (Jianmin Corporation, Beijing, China). Body weight (BW), body composition protein (BCP), body composition mineral (BCM), skeletal muscle mass (SMM), and lean body weight (LBW) were measured with an InBody370 system (Biospace, Seoul, Korea).

2.4. Blood pressure

Blood pressure (BP) was measured in the right arm and in the standard sitting position, using an Omron BP monitor. The measurement was repeated twice after a 15-minute rest. If the 2 values were similar, the first measurement was used. If the 2 values were different, the number of measurement would be increased, and the highest value among comparable results would be selected.

2.5. Physical fitness tests

The physical fitness tests were conducted by skilled and experienced examiners from the Physical Fitness Surveillance and Health Management Association and Guangxi Jiangbin Hospital (Guangxi Zhuang Autonomous Region, China). All equipment (Jianmin Corporation, Beijing, China) met the national standards. All subjects were tested for: vital capacity (VC, mL), choice reaction time (CRT, s), hand grip strength (HGS, kg), time of single-leg standing with eyes closed (TSEC, s), push-ups (PU, times/min), sit-ups (SU, times/min), vertical jump height (VJHT, cm), Harvard step test index (HSTI), and bend-ahead in sitting (BAIS, cm). All tests were performed in a standardized manner.[22]

2.6. Diabetes risk detection program

The EZSCAN device (Impeto Medical, Paris, France) measures electrochemical skin conductance using 6 nickel electrodes placed on the skin rich in sweat glands such as the hands, feet, and forehead. In the present study, the electrodes were placed on the hands and feet. Test results indicate the reaction time between the chloride ions in the sweat and the nickel electrodes of the device after direct current stimulation at an incremental voltage of $\leq$4 V. The EZSCAN value ranges from 0% to 100%, calculated by the device according to the electrochemical skin conductance of hands, feet, and forehead, and according to demographic data such as sex, age, height, weight, and systolic BP.[11] A higher EZSCAN value indicates a higher risk of sudomotor dysfunction.[12] The test parameters also include: probability of impaired glucose tolerance (P[IGT]), which is the risk of impaired glucose tolerance (the smaller the value, the lower the risk); probability of insulin resistance (P[IR]), which is the risk of insulin resistance (the smaller the value, the lower the risk); and probability of diabetic complication (P[Dc]), which is the risk of diabetic complications (the smaller the value, the lower the risk).

2.7. Grouping

All subjects were stratified into 3 ethnic groups: Han, Zhuang, and other ethnic groups. In addition, the subjects were grouped as low occupational physical activity (LOPA), moderate occupational physical activity (MOPA), and high occupational physical activity (HOPA) according to the "National Labor Force Scale of the People's Republic of China".

2.8. Quality control

For quality control of physical and body composition tests, all assessors and investigators participated in standardized training and had to pass the examination. For pre-investigation quality control, all personnel participated in the pre-investigation preparatory meeting. In the pre-investigation process, it was required to find and rectify improper operation and erroneous behaviors timely. Every time the test was ended, the problems that occurred were promptly corrected and supplemented. It was important to improve the investigative capabilities of the assessors and investigators. For on-site quality control, each testing item was conducted by 2 assessors to achieve mutual supervision and timely discovery and correction of improper operation. For quality control in data summarization: assessors were given training before data entry. During data entry, the data was divided according to the testing item. The double-entry method was applied, the 2 entries done by 2 different investigators, in order to ensure correct data entry and establish a complete and reliable database. For quality control in database maintenance, all investigators received training by professional biostatistics experts. The parameters of the database were strictly classified according to the nature of the data to clarify observation results and variables, which was performed by 2 investigators to ensure the accuracy of variables.

2.9. Statistical analysis

Categorical variables are expressed as percentages and were analyzed using the chi-square test. The Kolmogorov-Smirnov test was used to evaluate continuous data for normal distribution. Normally distributed data are expressed as mean ± standard deviation. Otherwise, they are expressed as median (P25, P75). All data were tested by homogeneity of variance test. If they met variance homogeneity, they were analyzed using one-way analysis of variance (ANOVA). Otherwise, they were analyzed using the Welch test. Multivariable analysis was performed using the stepwise logistic regression method. All variables with $P < .05$ in the univariable analyses were substituted into the equation, of which only the parameters found statistically significant were kept. Omnibus tests were used to validate the equations. The diagnostic accuracies were determined by calculating the area under the receiver-operating characteristics (ROC) curve (AUC). All data were analyzed using SPSS 21.0 (IBM, Armonk, NY). Two-sided P values <.05 were considered statistically significant.

3. Results

3.1. Characteristics of the subjects

Table 1 presents the characteristics of the subjects. Among the 5668 subjects, 52.6% were male. There was no difference in sex between the normal group and DM group ($P = .113$). DM subjects were older than non-DM subjects ($P < .001$). More subjects were with MOPA in the DM group ($P < .001$).

3.2. Results of the EZSCAN and NPFT

As shown in Table 2, compared with the normal group, DM subjects had lower P[IGT] ($P < .001$), higher P[IR] ($P < .001$), higher P[DC] ($P < .001$), higher weight ($P < .001$), smaller chest circumference ($P = .01$), larger waist circumference ($P < .001$), larger hip circumference ($P < .001$), larger subscapular skin fold thickness ($P < .001$), smaller vital capacity ($P = .002$), smaller HSTI ($P < .001$), higher systolic BP ($P < .001$), higher CRT ($P < .001$), smaller HGS ($P = .04$), lower BAIS ($P < .001$), lower VJHT ($P = .007$), and lower TSEC ($P = .001$).

3.3. Multivariable analysis

Table 3 shows that systolic BP (odds ratio [OR] = 1.013, 95% confidence interval [CI]: 1.003–1.022, $P = .01$), HSTI (OR = 0.958, 95% CI: 0.941–0.976, $P < .001$), BAIS (OR = 0.945, 95% CI: 0.926–0.963, $P < .001$), HGS (OR = 0.981, 95% CI: 0.966–

Table 1

Baseline characteristics of the study subjects.

Characteristics	All (n = 5668)	Normal (n = 3390)	Diabetes (n = 2278)	P
Age (yr), n (%)				<.001
20–44	2996 (52.9)	1957 (57.7)	1039 (45.6)	
45–54	1521 (26.8)	788 (23.2)	733 (32.2)	
55–65	1151 (20.3)	645 (19.0)	506 (22.2)	
Male, n (%)	2984 (52.6)	1755 (51.8)	1229 (54.0)	.113
Ethnicity, n (%)				<.001
Han	3998 (70.5)	2386 (70.4)	1379 (60.5)	
Zhuang	1579 (27.9)	927 (27.3)	652 (28.6)	
Others	85 (1.5)	71 (2.1)	14 (0.6)	
Occupational physical activity, n (%)				<.001
Low	2219 (37.4)	1445 (42.6)	774 (34.0)	
Moderate	2348 (42.2)	1237 (36.5)	1111 (48.8)	
High	1101 (19.4)	708 (20.9)	393 (17.3)	

Table 2

Results of the EZSCAN and National Physical Fitness Test.

Characteristics	Normal (n=3390)	Diabetes (n=2278)	P
P[IGT], %	36.4±4.5	32.2±21.7	<.001
P[IR], %	34.4±9.8	50.3±11.5	<.001
P[DC], %	0	10.4±16.2	<.001
Height, cm	160.9±8.1	160.5±8.9	.470
Weight, kg	58.1±9.2	61.3±11.7	<.001
Chest circumference, cm	85.2±11.0	82.4±20.6	.010
Waist circumference, cm	78.1±8.5	81.3±10.2	<.001
Hip circumference, cm	92.2±5.6	93.8±6.6	<.001
Skin fold thickness, mm			
Triceps	6.6±2.4	6.7±2.2	.452
Subscapular	12.3±3.9	13.7±4.9	<.001
Vital capacity, mL	2489±819	2313±800	.002
Harvard step test index	62.1±10.8	58.8±9.4	<.001
Blood pressure, mmHg			
Diastolic	121±16	127±20	.068
Systolic	75±11	78±13	<.001
Choice reaction time, s	0.6±0.3	0.7±0.4	<.001
Hand gripping strength, kg	31.4±11.5	29.7±11.8	.040
Back muscle strength, kg	84.9±35.1	86.0±36.9	.758
Bend-ahead in sitting, cm	8.6±8.5	5.0±8.2	<.001
Vertical jump height, cm	28.9±11.0	26.0±8.9	.007
Push-ups (male) (times/min)	26.9±13.5	23.3±13.1	.067
Sit-ups (female) (times/min)	19.7±8.8	18.6±9.4	.390
Time of single-leg standing with eyes closed, s	18.4±21.1	12.2±16.7	.001

P[IGT]=probability of impaired glucose tolerance; P[IR]=probability of insulin resistance; P[DC]=probability of diabetic complication.

Table 3

Multivariable analysis for the risk of diabetes mellitus.

Variables	P	OR	95% CI Lower	95% CI Upper
Systolic blood pressure	.011	1.013	1.003	1.022
Harvard step test index	<.001	0.958	0.941	0.976
Bend-ahead in sitting	<.001	0.945	0.926	0.963
Hand gripping strength	.019	0.981	0.966	0.997
Vertical jump height	.023	0.969	0.944	0.996
Time of single-leg standing with eyes closed	.007	0.981	0.968	0.995
Choice reaction time	.004	2.103	1.261	3.507
Body composition minerals	<.001	1.649	1.500	1.813

OR=odds ratio; CI=confidence interval.

0.997, $P=.02$), VJHT (OR=0.969, 95% CI: 0.944–0.996, $P=.02$), TSEC (OR=0.981, 95% CI: 0.968–0.995, $P=.007$), CRT (OR=2.103, 95% CI: 1.261–3.507, $P=.004$), and BCM (OR=1.649, 95% CI: 1.261–1.813, $P<.001$) were independently associated with DM.

3.4. ROC analysis

As shown in Table 4 and Figure 1, the AUC of the multivariable model was 0.808 (95% CI: 0.776–0.840; $P<.01$). The predictive ability of the equation was good. The predictive probability formula was:

$$Pro = \frac{e(0.013SBP - 0.043HSTI - 0.057BAIS - 0.019HGS - 0.031VJHT - 0.019TSEC + 0.743CRT + 0.500BCM - 2.691)}{1 + e(0.013SBP - 0.043HSTI - 0.057BAIS - 0.019HGS - 0.031VJHT - 0.019TSEC + 0.743CRT + 0.500BCM - 2.691)}$$

The optimization test of the model was carried out using the Hosmer–Lemeshow test and the difference between the prediction results and the actual values was not statistically significant ($P = .388$), indicating that the model fits well. In summary, the physical function parameters and body fitness parameters were appropriate to predict for the risk of developing DM, after adjusting for the risk factors associated with DM.

4. Discussion

Data are lacking about the relationship between physical fitness and the risk of DM among civil servants in Guangxi, which is an

Table 4

The precautionary value of the physical test parameters for diabetes risk.

			95% CI	
Area	**Std. Error**	***P***	**Lower**	**Upper**
0.808	0.016	<.001	0.776	0.84

autonomous region in Southeast China with nearly 50 million inhabitants. Therefore, the present cross-sectional study aimed to explore the relationship between physical fitness parameters and risk prediction of diabetes among municipal in-service personnel in Guangxi. The results suggest that among civil servants in Guangxi, the NPFT parameters were appropriate to predict the risk of developing DM, after adjusting for the risk factors associated with DM. NPFT and EZSCAN could help predict the risk of diabetes and give early warnings in order to undertake preventive actions such as changing diet and performing physical activity. The present study focused on civil servants because they represent the majority of urban dwellers and because the prevalence of DM is higher in urban areas in China.[5] As Guangxi is an important province with 50 million inhabitants in coastal Southeastern China, its urban population could have a fair representativeness of the urban people of China.

Previous studies consistently reported that physical activity, either recreational or occupational, is associated with a lower risk of metabolic disturbances associated with DM.[14,16–20] In China, the NPFT has been developed as an initiative to assess physical fitness during routine health examinations. It is free-of-charge and offered to anyone willing to assess its physical condition. Of course, it can also be used as an incentive to improve one's physical condition and hence lower the risk of metabolic complications. In the present study, the multivariable analysis

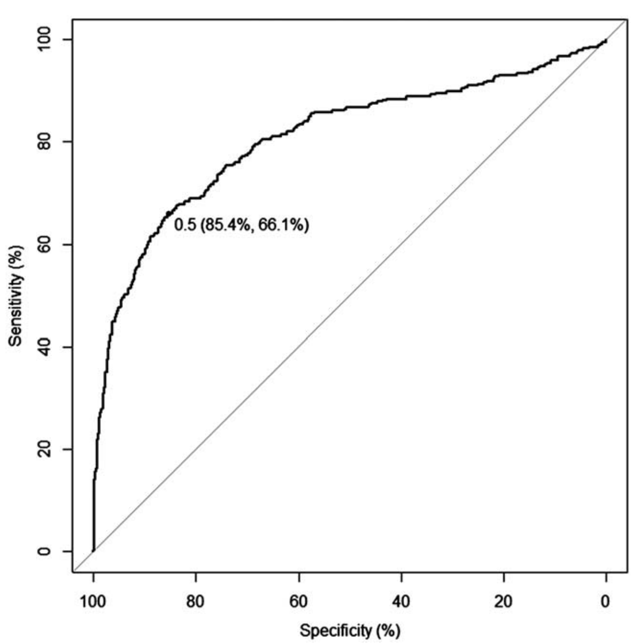

Figure 1. The precautionary value of the physical test parameters for diabetes risk (ROC curve). ROC=receiver-operating characteristics.

showed that components of the NPFT (including HSTI, BAIS, HGS, VJHT, TSEC, and CRT) were independently associated with DM, indicating that the simple NPFT could be a reliable tool to assess the risk of DM among civil servants in Guangxi. In addition, the present study provides useful epidemiological data about the general physical condition of civil servants in Guangxi. These data could be used as reference for future epidemiological studies in China.

It has been reported that BCM is associated with fasting plasma glucose (FPG) and triglycerides.[23,24] As FPG is considered as one of the indexes for insulin resistance assessment, BCM could be used as a surrogate in the determination of the risk of DM. In the present study, BCM was independently associated with DM. High BP is a component of the metabolic syndrome, which is associated with an increased risk of DM.[25,26] Elevated BP could thus be an indicator of an increased risk of DM, as suggested by the present study.

In the present study, ethnicity was associated with DM in the univariable analysis, but not in the multivariable analysis. Guangxi is composed of about 62% Han and 32% Zhuang,[27] which is similar to the percentages observed in the present study. Despite the fact that these ethnic groups have different traditional dietary and lifestyle habits, these results suggest that these differences could be marginal in the context of Westernization of the habits in China and of its association with the increase in DM incidence and prevalence.[4,5] Additional study is necessary to examine whether this trend is also observed in the other ethnic groups in China. Of course, differences may exist in areas where specific ethnic groups live isolated vs. large cities where different ethnic groups live together.

In the present study, the EZSCAN parameters were associated with DM, as shown by previous studies in China and Western populations.[9–12] Of course, the EZSCAN parameters could not be entered into the multivariable analysis because of this well-known association. The present study suggests that the equation developed in the present study could be a surrogate to the EZSCAN technology. This equation was developed using parameters that are routinely assessed during health check-ups in China and could provide a more useful approach in the context that the EZSCAN technology is not available everywhere. Nevertheless, where available, the EZSCAN provides an easy, non-invasive, and fast assessment of the risk of diabetes.[9–12]

The present study is not without limitations. The study population was limited to a single province and to a single social class. In addition, no blood test was performed, preventing the observation of correlations among the traditional markers of diabetes, EZSCAN parameters, and the risk equation developed here. The aim of the present study was to examine physical fitness parameters with the risk of DM. Blood tests also help predict the risk of DM, but they require specific settings for blood sampling and analysis. The 2 could eventually be used in combination. Additional study is necessary to validate these results.

5. Conclusions

Among civil servants in Guangxi, the NPFT parameters were appropriate to predict the risk of developing DM, after adjusting for the risk factors associated with DM. NPFT and EZSCAN could help predict the risk of diabetes and give early warnings in order to undertake preventive actions such as changing diet and performing physical activity.

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