

BRIEF REPORT

Association of cardiorespiratory fitness with the risk factors of cardiovascular disease: Evaluation using the Japan step test from the National Institute of Occupational Safety and Health

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Funding information

Industrial Disease Clinical Research Grant from the Japanese Ministry of Health, Labour and Welfare, Grant/Award Number: 180902-01 and 150903-01; Ministry of Health, Labour and Welfare

Abstract

Objective: Cardiorespiratory fitness (CRF) is an important factor for evaluating cardiovascular disease (CVD) risk. We recently developed a novel method (National Institute of Occupational Safety and Health, Japan step test [JST]) for evaluating CRF in workers; its criterion validity has been investigated. However, its association with health risk must be confirmed before its application in the workplace. Therefore, we aimed to determine the association of JST-evaluated CRF with the prevalence of CVD risk among Japanese workers.

Methods: For CRF evaluation, working adults completed the JST, which comprised a 3-minute stepping exercise and a 2-minute recovery period. Data on CVD risk factors and clinical history were collected through medical certification within 1 year from the date of the JST measurements. Participants were divided into three groups for multiple logistic regression analyses based on the JST values (low, moderate, and high). Odds ratios (ORs) for the prevalence of CVD risk were calculated.

Results: We recruited 885 working adults (46.4% women). The prevalence of CVD risk in the total population was 18.6%. When compared to the reference group (low CRF), the ORs for CVD risk prevalence after adjustments for lifestyle factors (smoking status, alcohol consumption status, and exercise habits) were 0.42 (95% confidence interval [CI], 0.28–0.63) and 0.29 (95% CI, 0.18–0.45) for the moderate and high groups, respectively.

Conclusion: An inverse association was noted between the JST-evaluated CRF and CVD risk prevalence. JST may be helpful for identifying workers at risk for CVD development.

KEYWORDS

cardiovascular disease, exercise test, occupational health, risk factors

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1 | INTRODUCTION

Cardiorespiratory fitness (CRF) is recognized as a vital component of health and longevity.^{1,2} It is also associated with the risk of developing cardiovascular disease (CVD) and is a powerful marker of cardiovascular health.¹ Recent scientific statements from the American Heart Association emphasize the importance of evaluating CRF.³ However, it has been pointed out that CRF is the only important risk factor for CVD that is not routinely assessed in health checkups,³ which may be attributed to the complexity of the methods used for CRF evaluation. It is well known that the gold standard approach for assessing CRF is the maximal oxygen consumption (VO_{2max}) measured by cardiopulmonary exercise tests. However, this approach requires specialized equipment and trained examiners, which render it expensive and less accessible. Several field-based simple CRF evaluation methods, such as the 12-minute running test⁴ and the 6-minute walk test, have been developed to address the above challenges.⁵ However, these methods are not intended for use in occupational health. Furthermore, it is difficult to apply them to the working population because they are often performed in conjunction with a sports event, thereby requiring the use of a gym or sports field. Thus, a validated CRF evaluation method that can be used in the workplace is required.

To solve the aforementioned problem, we developed the National Institute of Occupational Safety and Health, Japan step test (JST); it is a time-efficient, safe, and simple evaluation method that can be used in the workplace.⁶ This validated CRF evaluation algorithm uses clinicodemographic variables and a combination of heart rate (HR) values during a total test time of 5 minutes; it has shown a stronger correlation with measured VO_{2max} .⁶ It has been suggested that field-based CRF tests should meet several criteria, including reliability, criterion validity, safety, longitudinal validity, and relationship with health outcomes.⁷ From the above, before utilizing the JST in an epidemiological survey for workers' health management, there is a need to confirm the association of CRF with health risk. Therefore, in the present study, we aimed to determine the association between CRF (as evaluated by the JST) and the prevalence of CVD risk among Japanese workers.

2 | METHODS

2.1 | Participants

This cross-sectional study included Japanese workers and was performed from 2017 to 2020. The inclusion criteria for this study were as follows: (1) participant age between

30 and 60 years; (2) residence in the capital area of Japan; (3) full-time employment, i.e., working for more than 6 h a day and for at least 4 days a week; and (4) having received a medical certification within 1 year. The participants were recruited through a website advertisement. Participants were excluded if there were lacking results in medical certification even when obtained within 1 year before the measurement of JST data, such as the data required for the measurement of the CVD risk factors, were inadequate. The objectives and design of this study were fully explained to all the participants before they provided written informed consent. This study was conducted in accordance with the guidelines proposed in the Declaration of Helsinki, and the study protocol was reviewed and approved by the Ethical Committee of the National Institute of Occupational Safety and Health, Japan (ID H2920).

2.2 | Anthropometric measurements

Body weight and body fat percentage were measured using an InBody device (InBody 270; BioSpace) that incorporated weight scales and bioimpedance. Height was measured once to the nearest 0.1 cm using a wall-mounted stadiometer (to the nearest 0.1 cm). The body mass index (BMI) was calculated using the following formula: participant's weight (in kilograms) divided by the square of their height (in meters). Waist circumference was measured at the umbilicus while the participants were standing, and data were recorded in duplicates to the nearest 0.1 cm and averaged.

2.3 | Questionnaire-based information

A self-administered questionnaire was used, which contained questions on lifestyle, such as the smoking status (current smoker, ex-smoker, and non-smoker) and alcohol consumption status (non-consumption, 1–2 times per week, 3–5 times per week, and every day). Additionally, habitual exercise (defined by the Ministry of Health, Labour and Welfare as continual exercise lasting for at least 30 minutes per day and twice a week for ≥ 1 year) was assessed using the Worker's Living Activity-time Questionnaire.⁸

2.4 | Evaluation of cardiorespiratory fitness

Variables for the components of the CRF algorithm included age, sex, BMI, and the HR index collected by the JST. Details and validity of the JST have been reported

previously.⁶ Briefly, the JST comprises a 3-minute stepping exercise phase and a 2-minute recovery phase, with a total test time of 5 min. During the exercise phases, the participant is required to step up and down a 30-cm high step, with the tempo increasing every minute (stage 1, 60 bpm; stage 2, 80 bpm; and stage 3, 100 bpm) and the HR recorded every minute. At the end of the exercise phases, the participant rests in the sitting position, and the HRs at recovery (recovery stages 1 and 2) are recorded. In this study, HR was measured using an electrocardiogram monitor (LifeScope; Nihon Kohden Corp.) or a wrist-worn HR monitor (Polar® A370, Polar). The ranges were 69.5–129.1 beats for the electrocardiogram monitor and 76.0–122.8 beats for the wrist-worn HR monitor. The HR records collected during the test were used for calculating the HR index as follows:

$$(\text{HR at exercise stage 3} - \text{HR at exercise stage 1}) + (\text{HR at recovery stage 1} - \text{HR at recovery stage 2}).$$

Finally, the following algorithms were used to assess each participant's CRF: $67.20 - (0.25 \times \text{age}) + (5.63 \times \text{sex} [\text{female} = 0; \text{male} = 1]) - (0.55 \times \text{BMI}) - (0.20 \times \text{HR index})$. The results of assessments with these algorithms were highly correlated with the oxygen uptake ($r = 0.73$, $p < .01$).⁶

2.5 | Risk factors for cardiovascular disease

Data on the participants' CVD risk factor values (i.e., systolic blood pressure, diastolic blood pressure, high-density lipoprotein [HDL] cholesterol, triglycerides, fasting glucose, and HbA1c) and clinical history (hypertension, dyslipidemia, and diabetes) were collected through medical certification obtained within 1 year before the date of the JST measurements. The definition of CVD risk was derived from the Japanese definition of the metabolic syndrome,⁹ and the prevalence of CVD risk was defined by the fulfillment of two or more of the following criteria: (1) waist circumference ≥ 85 cm for men and ≥ 90 cm for women; (2) systolic blood pressure ≥ 130 mmHg, diastolic blood pressure ≥ 85 mmHg, or the use of medications for hypertension; (3) triglycerides ≥ 150 mg/dl, HDL cholesterol < 40 mg/dl, or the use of medications for dyslipidemia; and (4) fasting glucose ≥ 110 mg/dl or the use of glucose-lowering medications (insulin or oral agents).

2.6 | Statistical analyses

CRF tertiles were categorized to minimize the impact of age and sex.¹⁰ Initially, participants were categorized into two groups according to their sexes (namely male and

female); each sex group was further divided into three age-based categories, namely the ≤ 39 -, 40–49-, and ≥ 50 -year groups. Subsequently, we combined the respective CRF tertiles from all the age- and sex-based categories to form the CRF categories for all participants. An analysis of covariance was performed to test the differences in CVD risk factors between the CRF groups, with age, smoking status, alcohol consumption, and exercise habits as covariates. Continuous data are presented as mean \pm standard deviation, while categorical data are presented as n (%) and were compared using the Chi-squared test.

Multiple logistic regression analyses were performed to estimate the association between CRF and the prevalence of the CVD risk. The models were adjusted for the smoking status (0: ex-smoker and non-smoker, 1: smoker), alcohol consumption status (0: non-consumption; 1: 1–2 times per week, 3–5 times per week, and over six times per week), and exercise habits (0: no, 1: yes). All results are expressed as odds ratios (ORs), with the precision of estimates given in 95% confidence intervals (CIs).

In the analyses, $p < .05$ was considered to indicate statistical significance. All statistical analyses were performed using SAS, version 9.4 (SAS Institute Japan, Tokyo, Japan).

3 | RESULTS

A total of 1101 participants were recruited. Among these, 74 and 3 were excluded owing to inadequate HR data and insufficient medical certification results, respectively. Thus, 885 participants were included in the final analyses. The participants' characteristics and an intergroup comparison of the measurement values are presented in Table 1. Of the total participants included, 46.4% were women and 18.6% were categorized as having a CVD risk. There were significant differences between the groups ($p < .01$), except in terms of the age, current smoker status, and alcohol consumption status. The proportions of the participants' industrial occupation sectors were as follows: 0.4%, agriculture and forestry; 5.2%, construction; 14.5%, manufacturing; 7.1%, information and communications; 3.9%, transport and postal activities; 6.4%, wholesale and retail trade; 9.6%, finance and insurance; 2.1%, real estate and goods rental and leasing; 7.1%, scientific research, professional, and technical services; 1.4%, accommodation, eating, and drinking services; 2.3%, living-related and personal services; 5.8%, education and learning support; 10.7%, medical, health care, and welfare; 2.2%, compound services; 13.6%, services, N.E.C; and 7.7%, government.

Table 2 shows the ORs (95% CI) for the prevalence of the CVD risk in each CRF tertile. When compared with the reference group (low CRF), the significant ORs for the prevalence of CVD risk after adjustment for lifestyle

TABLE 1 Characteristics of the participants by tertiles of the cardiorespiratory fitness estimated by the JST ($n = 885$)

	Low ($n = 293$)	Moderate ($n = 297$)	High ($n = 295$)	<i>p</i> for ANCOVA
Sex (male/female)	157/136	159/138	158/137	1.00
Age, years ^a	46.6 ± 7.7	45.9 ± 8.0	44.9 ± 8.0	.03
BMI, kg/m ²	25.3 ± 3.8	22.7 ± 2.8	21.1 ± 2.5	<.01
Waist circumference, cm	87.8 ± 11.0	79.2 ± 8.0	75.4 ± 7.6	<.01
Percentage of body fat, %	29.4 ± 6.9	25.2 ± 6.2	22.3 ± 6.2	<.01
Prevalent hypertension risk, <i>n</i> (%) ^b	87 (9.8)	46 (5.2)	32 (3.6)	<.01
Systolic blood pressure, mmHg	118.8 ± 15.2	115.0 ± 14.4	113.0 ± 14.6	<.01
Diastolic blood pressure, mmHg	74.0 ± 11.6	71.3 ± 11.3	69.7 ± 11.9	<.01
Prevalent dyslipidemia risk, <i>n</i> (%) ^c	71 (8.0)	47 (5.3)	37 (4.2)	<.01
HDL cholesterol, mg/dl	60.2 ± 15.0	66.5 ± 15.6	69.3 ± 16.1	<.01
Triglycerides, mg/dl	113.6 ± 81.3	100.0 ± 83.0	80.2 ± 53.6	<.01
Prevalent diabetes risk, <i>n</i> (%) ^d	24 (2.7)	16 (1.8)	17 (1.9)	.32
Fasting glucose, mg/dl	94.5 ± 18.1	91.7 ± 12.8	91.4 ± 12.2	.04
Prevalent CVD, <i>n</i> (%)	87 (9.8)	46 (5.2)	32 (3.6)	<.01
Current smokers, <i>n</i> (%)	36 (4.1)	37 (4.2)	35 (4.0)	.97
Alcohol consumers, <i>n</i> (%)	136 (15.5)	156 (17.8)	142 (16.2)	.25
Exercise habits, <i>n</i> (%)	130 (14.7)	143 (16.2)	146 (16.5)	.43
Estimated CRF, METs	9.8 ± 1.3	11.1 ± 1.1	12.1 ± 1.1	<.01

Note: Values are presented as *n* (%) or mean ± standard deviation.

Significant differences between the groups noted using ANCOVA, with age, smoking status, alcohol consumption, and exercise habits as covariates ($p < 0.05$).

Abbreviations: JST, Japan step test; ANCOVA, analysis of covariance; BMI, body mass index; HDL, high-density lipoprotein; CVD, cardiovascular disease; estimated CRF, estimated cardiorespiratory fitness; MET, metabolic equivalent.

^aUsed ANCOVA with smoking status, alcohol consumption, and exercise habits as covariates ($p < 0.05$).

^bDefined as a systolic blood pressure ≥ 130 mmHg, a diastolic blood pressure ≥ 85 mmHg, and/or medications for hypertension.

^cDefined as triglycerides ≥ 150 mg/dl, HDL cholesterol < 40 mg/dl, or the use of medications for dyslipidemia.

^dDefined as fasting glucose ≥ 110 mg/dl and/or medications for diabetes.

TABLE 2 Odds ratios for the prevalence of cardiovascular risk and estimated cardiorespiratory fitness ($n = 885$)

	Prevalence of CVD risk		Model 1 [†]
	Yes	No	OR (95% CI)
Low	87	206	1.00 (reference)
Moderate	46	251	0.42 (0.28–0.63)
High	32	263	0.29 (0.18–0.45)

Note: Values are presented as odds ratio and 95% CI.

Model 1[†]: Adjusted for smoking status (0: ex-smoker and non-smoker; 1: smoker), alcohol consumption status (0: non-consumption; 1: 1–2 times per week, 3–5 times per week, and over six times per week), and engagement in exercise habits (0: no, 1: yes). A.

Abbreviations: CI, confidence interval; CVD, cardiovascular diseases; CRF, cardiorespiratory fitness.

factors (smoking status, alcohol consumption status, and engagement in exercise habits) were found to be 0.42 (95% CI, 0.28–0.63) in the moderate group and 0.29 (95% CI, 0.18–0.45) in the high group, respectively. We conducted

a sensitivity analysis for each component of the JST (i.e., age, sex, BMI, and the HR index) and the CVD prevalence; age, sex, and BMI were significantly associated with the CVD risk, but the HR index was not.

4 | DISCUSSION

The main finding of this study was that the CRF evaluated by a novel assessment method, the JST, was significantly and inversely associated with the prevalence of CVD risk among Japanese workers.

Numerous previous studies^{1,2,11,12} have reported the association of CRF, measured using a treadmill or cycle ergometer, with the CVD risk. These studies revealed that a low CRF was associated with increased prevalence of CVD and its risk factors. However, CRF is not routinely assessed in the workplace as well as in clinical practice, and simple and safe procedures for gathering occupational health information on CRF in association with the health risks are needed for the working population.

Several field-based tests, which address the previously mentioned limitations, have been developed as simple CRF evaluation methods.⁷ Particularly, step tests for evaluating CRF without expensive equipment are based on either HR changes during the recovery phase after the step exercise or HR changes during the exercise phase and soon after. Although the validity of some previous step tests has been investigated,⁷ data regarding the association of the CRF assessed by these tests and the health risk in working individuals remain limited. A previous study on 81 male steelworkers showed that the CRF evaluated by the Chester step test¹³ was associated with CVD risk factors. In this previous study, the participants were categorized by the CRF level; the absolute 10-year risk of CVD was significantly higher in the “Average” CRF group ($9.0 \pm 5.4\%$) than in the “Excellent” ($5.2 \pm 2.8\%$) or “Good” ($5.6 \pm 3.4\%$) CRF groups. This trend of results is consistent with our main findings, which indicated that a moderate-to-high CRF was associated with a significantly higher decrease in the prevalence of CVD risk. Another previous study¹⁴ involving a large community sample evaluated the relationships between CRF and the risk factors for coronary heart disease. In a previous study that utilized the Pawtucket heart health step test, the blood pressure, BMI, and HDL cholesterol were correlated with the estimated CRF ($r = 0.24\text{--}0.65$, $p < .01$). Consistent with our results, these results have provided new insights into the utility of step test-estimated CRF for identifying health risk factors. Conversely, there are other field-based CRF tests, such as the 20-m shuttle run or the 6-minute walk test; however, these are often performed in a sports field and are mostly limited to children or older people. Given these findings, the results of the present study suggest that the JST meets the minimum equipment and space requirements and provides a more straightforward alternative approach for evaluating CRF among workers.

In Japan, as an initiative for worker health management, the Total Health Promotion Plan (THP) is being implemented based on the Industrial Safety and Health Act revised in 1988 in response to the World Health Organization Ottawa Charter.¹⁵ The THP includes an annual medical check, and it optionally includes CRF as an indicator of physical fitness. However, the assessment is limited by the size of the company and the presence of industrial physicians, which make the approach expensive and complicated. Given this scenario, the JST is a time-efficient and simple CRF evaluation method and it may offer the best approach for workers' health management. Additionally, evaluating CRF using the JST has pragmatic importance and provides values that enhance CVD risk prediction, when using direct CRF measures is not feasible.

This study has strengths and limitations. A main strength of the study was our inclusion of a large worker population (from across 16 industrial sectors) and our attempt to develop a more practical application of CRF in the workplace. However, there are several limitations. First, although we considered the common CVD risk factors obtained from medical certification, the lack of information on other measures of health check, socio-economic status, and lifestyle limited the study analyses and may have influenced the results. Second, CVD risk factor values were collected through medical certification obtained within 1 year before the JST measurement in this study. However, a time lag related to the inter-individual validity of the measurements may have occurred between the measurement of CVD risk factors and its application to CRF evaluation. Third, although the JST is more advantageous than other CRF evaluation methods for workers, it underestimates the $VO_{2\max}$ of participants with high fitness levels and overestimates the $VO_{2\max}$ of those with low fitness levels. Therefore, further research is required to improve the validity of the JST.

5 | CONCLUSIONS

In this study, higher CRF levels (as evaluated by the JST) were associated with lower prevalence of CVD risk factors in Japanese workers. Our results suggest that in the existing occupational health industry, the JST may be leveraged to identify the prevalence of CVD risk factors in employees. To verify the generalizability of our findings, further studies including a wider range of occupations are needed. Moreover, a longitudinal study is required in the future to examine the potential associations between the JST-assisted CRF measurement and the risk of CVD development.

AUTHORS' CONTRIBUTIONS

R.S. and M.T. conceived the research question and controlled data collection; R.S. and F.M. analyzed and interpreted the data; R.S. wrote the manuscript; and M.T. assisted in the conception and critical review for intellectual content. All authors read and approved the final manuscript.

ACKNOWLEDGMENTS

We are thankful to Ms. Kondou for providing assistance with data processing. This study was funded by the Industrial Disease Clinical Research Grant from the Japanese Ministry of Health, Labour and Welfare (150903-01 and 180902-01).

CONFLICT OF INTEREST

The authors declare no conflict of interests for this article. The authors also declare that the study results are presented clearly; honestly; and without fabrication, falsification, or inappropriate data manipulation.

DATA AVAILABILITY STATEMENT

Data were not deposited in publicly available repositories owing to ethical restrictions and participant confidentiality concerns. However, on reasonable request, derived data supporting the findings of this study are available with approval from the principal investigator (Dr. Rina So or Tomoaki Matsuo) and the company that provided the data.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

The Ethics Committee of the National Institute of Occupational Safety and Health, Japan, reviewed and approved the study protocol (ID H2744). All participants provided written informed consent for participation in the study.

CONSENT FOR PUBLICATION

Not applicable.

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How to cite this article: So R, Murai F, Matsuo T. Association of cardiorespiratory fitness with the risk factors of cardiovascular disease: Evaluation using the Japan step test from the National Institute of Occupational Safety and Health. *J Occup Health*. 2022;64:e12353. doi: [10.1002/1348-9585.12353](https://doi.org/10.1002/1348-9585.12353)