Association between physical activity energy expenditure and cardiometabolic risk factor clustering among Chinese adults in 2015

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ABSTRACT

To understand the association between cardiometabolic risk factor (CMRF) clustering and physical activity (PA) levels, we included 86520 Chinese adults aged 18–64 years having at least one CMRF (hypertension, diabetes, dyslipidemia, or obesity) from the China Chronic Disease and Nutrition Surveillance survey in 2015, a nationally and provincially representative investigation with a multistage clustering sampling design. Self-reported PA information was collected with the Global Physical Activity Questionnaire through face-to-face interviews. In view of the obesity epidemic in CMRF patients, PA energy expenditure (PAEE) per kilogram body weight was used, and was defined into four categories: (i) inactivity: 0 kJ/kg/day; (ii) low activity: 0–5 kJ/kg/day; (iii) moderate activity: 6–11 kJ/kg/day; and (iv) vigorous activity: ≥ 12 kJ/kg/day. The estimated weighted prevalence (95% confidence interval [CI]) of having 1, 2, 3, and 4 CMRFs was 60.57% (59.48%–61.67%), 28.10% (27.40%–28.79%), 9.82% (9.22%–10.39%) and 1.50% (1.37%–1.64%), respectively. The rate (95%CI) of inactivity, low activity, moderate activity, and vigorous activity was 36.52% (35.29%–37.75%), 22.22% (21.37%–23.07%), 15.80% (15.38%–16.25%) and 27.28% (26.02%–28.53%), respectively. For those having 2, 3 and 4 CMRFs (compared to those having 1 CMRF), the adjusted odds ratio (95%CI) for moderate activity and vigorous activity were 0.91 (0.85–0.98) and 0.92 (0.85–0.99), 0.87 (0.80–0.95) and 0.84 (0.77–0.92), and 0.77 (0.67–0.89) and 0.85 (0.72–1.00), respectively. In conclusion, CMRF clustering was a pandemic among Chinese adults in 2015 and was inversely associated with PA level. PAEE (in kJ/kg/day) may be introduced into PA management practice, especially for populations with high body weight.

Introduction

According to the Global Burden of Disease Study, the burden of cardiometabolic risk factors (CMRFs) has remarkably increased worldwide, with faster growth in the prevalence of metabolic factors than that of behavior factors.1 High systolic blood pressure (SBP) is the leading risk factor for cardiovascular disease (CVD) and accounted for more than 10 million deaths from 2007 to 2019.1,2 High fasting plasma glucose and high body mass index (BMI) are other high-risk exposures.1 In China, the sharp increase in CMRFs (hypertension, diabetes, dyslipidemia, and obesity) and its clustering has become a public concern,3,4 as the prevalence of hypertension and prehypertension reached 23.2% and 41.3%, respectively, from 2012 to 2015; that of diabetes and prediabetes reached 10% and 35.7%, respectively, in 2013; that of obesity and overweight reached 16.4% and 34.3%, respectively, from 2015 to 2019; and that of dyslipidemia reached 34% during 2007–2010.6–9

Physical activity (PA) is beneficial for a single CMRF and has been recommended over the last few decades.10–12 Previous studies have identified a favorable and socioeconomically diverse association between PA energy expenditure (PAEE) (measured in metabolic equivalent task [MET]-min/week) and the prevalence of CMRF(s) among adults in China, but national representative analyses have been limited.13–18 Although body weight is one of the key factors for physical activity expenditure in a population characterized by an obesity epidemic (in China), studies on PAEE/kg body weight are very limited, which could have been providing only a partial understanding of its correlation with CMRFs. Using data from the China Chronic Disease and Nutrition Surveillance (CCDNS) in 2015, we aimed to determine the association between PAEE/kg and the prevalence of CMRFs in Chinese adults aged 18–64 years.
Material and methods

Study design and participants

The CCDNS is a periodic cross-sectional survey used to assess the national profile of chronic diseases and their related risk factors among the residents of 22 provinces, 4 municipalities, 5 autonomous regions, and Xinjiang Production and Construction Corps in mainland China. The Chinese Center for Disease Control and Prevention (China CDC; Beijing, China) has been organizing consecutive surveys every 3–5 years since 2004. The CCDNS scheme was designed to represent the entire population in mainland China, along with each province’s subpopulation from 2015.19 The CCDNS study uses a multistage, stratified, cluster-randomized, sampling design, and eligible participants are community-based Chinese residents aged ≥18 years who have been living in their current residence for ≥6 months in the 12 months prior to the survey. First, four townships or streets from each county or district were selected with proportionate to population size (PPS) methods. Second, three administrative villages or communities in each sampled township or street were also selected using PPS methods. Third, each administrative village or community was divided into several residential quarters – each with nearly 50 households – of which one quarter was randomly selected. Finally, one individual was chosen at random from each household of the selected residential quarter using Kish tables.20,21

The CCDNS 2015 was approved by the National Health and Family Planning Commission of China and the Ethical Committee of the National Center for Chronic and Non-Communicable Disease Control and Prevention, China CDC (approval number 201519-A). All participants provided written informed consent. The population included in the present analysis was aged 18–64 years and had at least one CMRF.

Assessment of PA

The Global Physical Activity Questionnaire was used to collect information on moderate and vigorous PA (MVPA) in the following domains: occupation, household, transportation, and leisure time. Information was collected through face-to-face interviews by trained investigators regarding ≥10-min specific activities and their intensity, time spent daily on them, and time spent weekly on them during a typical week.22–25 Met scores (MET-min/week) were generated from the raw data and analyzed according to the analysis guideline.24 Based on World Health Organisation Guidelines on Physical Activity and Sedentary Behavior, the PA level was defined into four categories by PAEE: (i) inactivity: PAEE = 0 kJ/kg/day; (ii) low activity: 0 kJ/kg/day < PAEE < 6 kJ/kg/day; (iii) moderate activity: 6 kJ/kg/day ≤ PAEE < 12 kJ/kg/day; and (iv) vigorous activity: PAEE ≥ 12 kJ/kg/day.25

We aimed to understand the association between MVPA and CMRF(s) to confirm the benefit of MVPA on cardiometabolic health. According to the well-accepted PA Compendium, the intensity of household activities is generally light.26 Due to the decreasing tendency in the intensity of work and household activities in China, we only included transportation and leisure-time MVPA in the analysis framework.

In the CCDNS, information on leisure-time sedentary behavior (LTSB) has been independently and repeatedly inquired about since 2010.28 Four open questions on four types of specific activities during leisure time were designed – (i) how many minutes per day do you spend watching television after work?; (ii) how many minutes per day do you spend reading after work?; (iii) how many minutes per day do you spend using the computer after work?; and (iv) how many minutes per day do you spend playing computer games after work? – and the leisure sedentary hours were calculated. According to consistent evidence in China and in other countries, LTSB ≥ 4 h/day was defined as LTSB-lifestyle in this analysis.29,30

Assessment of CMRFs

Four CMRFs were selected in this study: hypertension, diabetes, dyslipidemia, and obesity (measured by body mass index, BMI). CMRF clustering was defined as having ≥2 CMRFs.

Body measurements and blood pressure recordings were taken three times on the same day using a standardized methodology in the local clinical center. Blood pressure was measured with a standardized electronic sphygmomanometer. Hypertension (HTN) was defined as a self-reported history of a clinical diagnosis of HTN or as SBP ≥140 mmHg and/or diastolic blood pressure ≥ 90 mmHg.31 BMI was calculated as body weight (kg) divided by height (m) squared, and obesity was defined as a BMI ≥ 28 kg/m², according to standard Chinese criteria.32

Blood samples were collected for all participants after an overnight fast of ≥10 h. Blood glucose, lipid profile, and glycosylated hemoglobin (HbA1c) were measured with standard methods. Dyslipidemia was defined as a self-reported history of a clinical diagnosis of dyslipidemia or as having ≥1 of the higher lipid profile measurements (total cholesterol ≥ 6.2 mmol/L, triglycerides ≥ 4.1 mmol/L, high-density lipoprotein cholesterol < 1.0 mmol/L, or low-density lipoprotein cholesterol ≥ 2.3 mmol/L).33 Diabetes was defined as a self-reported history of a clinical diagnosis of diabetes or as having a high fasting glucose level (fasting plasma glucose level ≥ 7.0 mmol/L) or HbA1c ≥ 6.5%.34

Statistical methods

All statistical analyses were calculated by accounting for the complex sampling weight, stratification, and clusters.35 The prevalence of 1, 2, 3, and 4 CMRFs and of inactivity, low activity, moderate activity, and vigorous activity were determined for the overall study population and in subgroups classified by age, sex, education level, location, region, and LTSB-lifestyle status.

The Taylor series linearization method was used to estimate variance. The Rao-Scott chi-squared test was used to compare prevalence rates, and the Wald log-linear chi-square test was introduced for the trend feature. Multivariable logistic regression was used to examine the association between the odds of CMRF clustering and MVPA after adjusting for age, sex, education level, location, region, and LTSB-lifestyle status. Statistical significance was determined as a two-sided p < 0.05. All analyses were performed in SAS version 9.4 (SAS Institute Inc., Cary, USA).

Results

Prevalence of CMRF clustering

As presented in Table 1, 86520 participants aged 18–64 years and having CMRF in 2015 were included in this study. The estimated
weighted prevalence (95% confidence interval (CI)) of 1, 2, 3, and 4 CMRFs was 60.57% (59.48%–61.67%), 28.10% (27.40%–28.79%), 9.82% (9.22%–15.42%), and 1.50% (1.37%–1.63%), respectively. A significant difference was detected among different sexes, age groups, education levels, residences (urban and rural), and regions (p < 0.01), while not repeated between those with LTSB-lifestyle or not (p > 0.05). In addition, a higher percentage of men had 2 and 3 CMRFs than did women (p < 0.05). The number of CMRFs significantly increased with age (p < 0.001) and significantly decreased with education level (p < 0.001). A larger proportion of urban patients had 3 and 4 CMRFs than did rural patients (p < 0.01), with a higher percentage of 1 CMRF detected among those living in western regions than among those living in eastern or central regions (p < 0.05).

Prevalence of PA levels

In 2015, 34.52% (32.69%–36.35%), 22.22% (21.37%–23.37%), 15.98% (15.38%–16.58%), and 27.28% (26.02%–28.53%) of patients reported inactivity, low activity, moderate activity, and vigorous activity, respectively. A higher percentage of inactivity and low activity was found in men than in women (p < 0.05) respectively (Table 2).

Compared to the converse tendency in vigorous activity (p < 0.001), the overall percentage of inactivity and low activity significantly decreased with age (p < 0.001). With increased education level, the rate of inactivity significantly decreased (p < 0.01), while that of low activity (p < 0.01), moderate activity (p < 0.01) and vigorous activity (p < 0.01) significantly increased. Especially, a U-shape tendency appeared with less prevalence of vigorous activity among those having primary or junior high school than those having less or more education levels.

The inactivity rate in urban patients was significantly lower than that in rural patients (p < 0.01), with a higher prevalence of moderate activity (p < 0.01) and vigorous activity (p < 0.01) in urban than in rural locations. Concurrently, patients from the western region reported less inactivity (p < 0.05) and more vigorous activity than did those from other regions. Moreover, those with a habitual LTSB-lifestyle showed higher MVPA than did their counterparts (p < 0.05).

Association between PA levels and CMRFs

Table 3 shows the association between PA levels and CMRFs. Among the low activity group, with the number of CMRFs increasing, the rate of low activity significantly increased (p < 0.01) despite a non-significant difference in other PA level groups by the number of CMRFs (p > 0.05). After controlling for other factors, an inverse linear relationship between PA levels and CMRF clustering was identified, as an increased number of CMRFs was associated with a lower odds ratio (OR) of MVPA. The adjusted ORs (95%CI) of having 2, 3 and 4 CMRFs (with those having 1 CMRF as reference) for the moderate activity and group and the vigorous activity group was 0.91 (0.85–0.98) and 0.92 (0.85–0.99), 0.87 (0.80–0.95) and 0.84 (0.77–0.92), and 0.77 (0.67–0.89) and 0.85 (0.72–1.00), respectively (Table 4).

Discussion

Based on the nationally representative, large sample data from the CCDNS, this study detected a negative association between CMRFs (hypertension, diabetes, dyslipidemia, and obesity) and PA levels in patients aged 18–64 years in 2015. Compared to having 1 CMRF, having 2, 3, and 4 factors were associated with a 9%, 13%, and 23% decrease, respectively, for moderate activity and higher (≥ 6 kJ/kg/day), and with 8%, 16%, and 15% decrease, respectively, for vigorous activity (≥ 12 kJ/kg/day).

PAEE measurement

For convenience, PA recommendations are usually interpreted with PAEE in practice, and PAEE in units of MET-min is roughly equal to energy expenditure in kCal/60 kg body weight. As such, the

Table 1

| 1 risk factor | 2 risk factors | 3 risk factors | 4 risk factors | p     |
|--------------|---------------|---------------|---------------|-------|
| n (%)        | n (%)         | n (%)         | n (%)         |       |
| Total        | 49927 (60.57) | 25695 (28.10) | 9345 (9.82)   | 1553 (1.50) |
| Sex          |               |               |               | <0.01 |
| Male         | 24664 (59.14) | 12690 (28.77) | 4767 (10.52)  | 757 (1.58)  |
| Female       | 25263 (62.54) | 13005 (27.17) | 4578 (8.88)   | 796 (1.40)  |
| Age (years)  |               |               |               | <0.01 |
| 18–24        | 1581 (74.90)  | 400 (20.43)   | 75 (4.18)     | 8 (0.49)    |
| 25–34        | 5602 (68.22)  | 1872 (24.30)  | 490 (7.02)    | 46 (0.46)   |
| 35–44        | 9076 (61.35)  | 3804 (27.30)  | 1304 (9.92)   | 169 (1.42)  |
| 45–54        | 16588 (55.72) | 9044 (30.60)  | 5287 (11.62)  | 566 (1.06)  |
| 55–64        | 17080 (52.27) | 10575 (32.87) | 4189 (12.59)  | 762 (1.26)  |
| Education    |               |               |               | <0.01 |
| Less than primary school | 12676 (58.36) | 6544 (29.55) | 2287 (10.45) | 364 (1.64) |
| Primary school | 9764 (59.29)  | 5106 (29.82)  | 1686 (9.46)   | 289 (1.43)  |
| Junior high school | 16685 (60.32) | 8435 (27.77)  | 3321 (10.32)  | 559 (1.58)  |
| Senior high school | 7048 (60.17)  | 3872 (28.46)  | 1483 (9.98)   | 238 (1.39)  |
| College or higher | 3754 (60.61)  | 1738 (24.63)  | 568 (7.98)    | 103 (1.38)  |
| Location     |               |               |               | <0.01 |
| Urban        | 19609 (59.58) | 10945 (28.08) | 4390 (10.53)  | 822 (1.81)  |
| Rural        | 30318 (61.66) | 14750 (32.81) | 2817 (9.28)   | 731 (1.17)  |
| Region       |               |               |               | <0.01 |
| Eastern      | 18186 (59.32) | 10217 (28.49) | 4017 (10.60)  | 705 (1.59)  |
| Middle       | 14185 (58.81) | 7529 (28.83)  | 2816 (10.58)  | 484 (1.77)  |
| Western      | 17556 (64.93) | 7949 (26.50)  | 2512 (7.55)   | 364 (1.01)  |
| LTSB-lifestyle| No          | 35886 (60.13) | 18327 (28.24) | 6550 (10.19) |
|             | Yes          | 14041 (61.29) | 7368 (28.76)  | 2795 (9.24)  |

CMRF, cardiometabolic risk factor (hypertension, diabetes, dyslipidemia, or obesity); LTSB-lifestyle, leisure-time sedentary behavior ≥4 h/day; LTSB-lifestyle, leisure-time sedentary behavior ≥4 h/day; 95%CI, 95% confidence interval.
recommendation of 600 MET-min/week (about 600 kcal/week/60 kg) has been widely set as the target PA, especially with the increased spread of motion sensors. For the reason of a readily comprehensible concept about energy expenditure in the unit of kcal, 600 kcal per week has been usually set as a physical activity intervention target for adults in practice, overlooking the influence of extra body weight in CMRF management practice. Since bodyweight influences an individual’s energy expenditure, PAEE in units of MET-min may overestimate the activity level among those with increased body weight in practice.36 In such a situation, PAEE adjusted for body weight was introduced based on the recommendations has been usually set as the target PA, especially with the increased body weight in China to use nationally representative, large-scale data to translate PA into clinically meaningful outcomes.37

**Table 2**
Prevalence of physical activity levels among Chinese adults by selected demographic characteristics in 2015.

| Education                     | Total (n=29198) | Male (n=15479) | Female (n=13679) |
|-------------------------------|----------------|----------------|------------------|
| Inactivity                    | Low activity   | Moderate activity | Vigorous activity |
| Prevalence (% (95% CI))       | Prevalence (% (95% CI)) | Prevalence (% (95% CI)) | Prevalence (% (95% CI)) |
| Total                          | 34.52 (32.69–36.35) | 22.22 (21.37–23.37) | 13.693 (15.98–18.58) | 25604 (27.28–26.02–28.53) |
| Sex                            |                |                |                  |                |
| Male                           | 36.01 (34.14–37.89) | 22.67 (21.79–23.55) | 16.443 (14.65–16.74) | 11752 (25.97–24.71–27.23) |
| Female                         | 32.47 (30.48–34.47) | 21.60 (20.54–22.67) | 16.85 (15.09–16.71) | 13852 (29.07–27.60–32.54) |
| Age (years)                   |                |                |                  |                |
| 18–24                         | 35.38 (32.04–38.72) | 23.81 (20.33–27.29) | 15.46 (13.30–17.62) | 561 (25.35–21.96–28.74) |
| 25–34                         | 35.04 (32.38–37.61) | 24.00 (23.11–25.68) | 17.09 (15.84–18.33) | 1892 (23.48–21.62–25.34) |
| 35–44                         | 35.70 (33.24–38.16) | 23.18 (21.85–24.51) | 16.77 (15.12–17.62) | 3612 (24.75–23.16–26.34) |
| 45–54                         | 34.61 (32.71–36.51) | 22.04 (21.16–22.92) | 15.28 (14.83–16.13) | 8361 (28.07–26.39–29.75) |
| 55–64                         | 32.22 (30.41–34.02) | 18.83 (17.82–19.84) | 15.72 (15.05–16.38) | 11178 (33.24–31.76–34.71) |
| Education                     | Less than primary school (n=8091) | 39.76 (37.58–41.95) | 32.26 (31.78–13.49–15.64) | 6429 (27.12–25.51–28.73) |
| Region                        | Urban (n=9711) | 28.22 (26.24–26.32) | 14.25 (19.17–21.69) | 3226 (13.78–20.62–14.56) |
|                           | Rural (n=19447) | 41.38 (38.97–47.38) | 6314 (18.21–23.17–19.28) | 12370 (31.22–29.63–32.84) |
| Location                      | Eastern (n=11484) | 35.05 (32.39–37.77) | 21.98 (20.79–23.16) | 5207 (17.67–24.58–12.79) |
|                           | Middle (n=8668) | 36.49 (32.50–45.48) | 23.38 (21.53–25.24) | 4114 (16.25–15.11–18.71) |
|                           | Western (n=9006) | 31.12 (28.78–33.47) | 21.16 (19.75–22.57) | 4372 (16.01–15.00–17.33) |
| 1STB-lifestyle                | No (n=21309) | 36.42 (34.35–38.39) | 2270 (22.08–21.83–23.27) | 9699 (15.14–14.44–15.84) |
|                           | Yes (n=7849) | 31.49 (29.61–33.36) | 22.45 (21.40–23.49) | 3994 (17.33–16.19–18.47) |

**CMRF, cardiometabolic risk factor (hypertension, diabetes, dyslipidemia, or obesity); 1STB-lifestyle, leisure-time sedentary behavior ≥ 4 h/day; Physical activity levels: inactivity, 0 kJ/kg/day; low activity, 0–5 kJ/kg/day; moderate activity, 6–11 kJ/kg/day, vigorous activity, ≥ 12 kJ/kg/day; 95%CI, 95% confidence interval; 1STB-lifestyle, leisure-time sedentary behavior ≥ 4 h/day.**

**Table 3**
Prevalence of physical activity levels among Chinese adults by number of CMRFs in 2015.

| Number of CMRFs | Inactivity                    | Low activity   | Moderate activity | Vigorous activity |
|-----------------|-----------------------------|---------------|-------------------|------------------|
| n Prevalence (% (95%CI)) | n Prevalence (% (95%CI)) | n Prevalence (% (95%CI)) | n Prevalence (% (95%CI)) |
| 1               | 17223 (34.99 (33.23–36.75) | 9699 (20.95 (20.04–21.87) | 7949 (16.26 (15.50–17.54) | 14786 (27.80 (26.43–29.17))
| 2               | 8487 (34.05 (31.72–36.38) | 5487 (23.63 (22.25–25.22) | 4009 (15.47 (14.59–16.35) | 7712 (26.85 (25.35–28.34) |
| 3               | 2964 (33.41 (31.21–35.66) | 2210 (25.10 (23.60–26.60) | 1497 (16.14 (14.72–17.57) | 2674 (25.35 (24.21–27.28) |
| 4               | 484 (31.68 (27.20–36.17) | 399 (27.89 (24.86–37.92) | 238 (13.66 (10.78–16.54) | 432 (26.75 (23.04–39.48) |

**CMRF, cardiometabolic risk factor (hypertension, diabetes, dyslipidemia, or obesity); Physical activity levels: inactivity, 0 kJ/kg/day; low activity, 0–5 kJ/kg/day; moderate activity, 6–11 kJ/kg/day, vigorous activity, ≥ 12 kJ/kg/day; 95%CI, 95% confidence interval.**

In recent years, inverse associations between PA and CVD risk or deaths among Chinese adults were evident in several large-scale cohort studies in China. Compared to nonactive commuting, walking and cycling were associated with lower risks (10% and 19%, respectively) of ischemic heart disease, and cycling was associated with a lower risk (18%) of ischemic stroke in urban China.35 Meeting the recommendation reduced ≥ 25% of the risk of CVD incidence in the Prediction for Atherosclerotic Cardiovascular Disease Risk in China (China-PAR) project.16 Leisure-time activity resulted in a 14% risk reduction of CVD or all-cause mortality in Chinese adults in Shanghai city and Taiwan, respectively.29,40 Both PA level and CMRFs vary geographically and socioeconomically in China.41–44 A favorable dose-response relationship between PA and a single CMRF among Chinese adults was addressed in recent reports. Prospective studies in China showed that compared to the bottom fifth level, the top PA level was associated with close to a 50% risk reduction for type 2 diabetes in urban areas and close to a 16% reduction in ten diverse areas (five urban and five rural).13,18 Leisure-time activity was related to a 12%–25% lower risk of diabetes in adults with impaired fasting glucose.14 In addition, a higher PA reduced the odds of hypertension incidence by 12%–15%, and even 14 MET-h/day PA was associated with a 0.15-unit lower BMI, a 0.58-cm smaller waist circumference, and 0.48% less body fat.15,43
Regarding cardiovascular diseases’ modifiable risk factors (CVDMRF) and total PA, a cross-sectional study from two cities in China identified that meeting the PA recommendations was related to a 15% decrease in the OR for having ≥2 factors (dyslipidemia, hypertension, diabetes, cigarette smoking, and overweight) compared to inactivity. In our study, the prevalence of CVDMRF clustering was 40%, and the clustering of 3 and 4 CVMRFs was noted to be 9.82% and 1.50%, respectively. Variations in population and geographical distribution were detected with a lower prevalence of ≥2 factor clustering in females, those with a low education level, and rural or western patients (compared to their counterparts at the same time). About 40% of patients reported MVPA in the transportation and leisure-time domains. Females, the elderly group, those with a high education level, and those living in urban or western areas were more likely to meet the PA recommendations. This nationally and provincially representative large-scale investigation may convincingly add evidence of the comprehensive distribution characteristics. Furthermore, identifying the continuously unsatisfactory behavior factors during the past decade (e.g., PA level) adds to the relatively urgent need for attention to CMRFs in China.

Table 4

| Items                              | Vigorous activity | Moderate activity |
|------------------------------------|------------------|------------------|
| Number of risk factors             |                  |                  |
| 1                                  | 1.00             | 1.00             |
| 2                                  | 0.92 (0.85-0.99) | 0.91 (0.85-0.98) |
| 3                                  | 0.84 (0.77-0.92) | 0.87 (0.80-0.95) |
| 4                                  | 0.85 (0.72-1.00) | 0.77 (0.67-0.89) |
| LTSB-lifestyle                     |                  |                  |
| No                                 | 1.00             | 1.00             |
| Yes                                | 1.12 (1.05-1.19) | 1.12 (1.04-1.21) |
| Sex                                |                  |                  |
| Male                               | 1.00             | 1.00             |
| Female                             | 1.20 (1.13-1.27) | 1.29 (1.23-1.36) |
| Age group, year                    |                  |                  |
| 18–24                              | 1.00             | 1.00             |
| 25–34                              | 0.92 (0.75-1.13) | 1.02 (0.84-1.24) |
| 35–44                              | 1.09 (0.91-1.32) | 1.19 (0.98-1.44) |
| 45–54                              | 1.40 (1.15-1.70) | 1.42 (1.18-1.70) |
| 55–64                              | 1.87 (1.57-2.23) | 1.90 (1.60-2.24) |
| Education                          |                  |                  |
| Less than primary school           | 1.00             | 1.00             |
| Primary school                     | 1.00 (0.97-1.15) | 1.07 (0.99-1.17) |
| Junior high school                 | 1.06 (0.97-1.15) | 1.13 (1.03-1.23) |
| Senior high school                 | 1.45 (1.30-1.61) | 1.72 (1.55-1.91) |
| College or higher                  | 1.63 (1.37-1.94) | 2.01 (1.71-2.36) |
| Location                           |                  |                  |
| Urban                              | 1.00             | 1.00             |
| Rural                              | 0.71 (0.64-0.79) | 0.66 (0.60-0.73) |
| Region                             |                  |                  |
| Eastern                            | 1.00             | 1.00             |
| Middle                             | 0.91 (0.80-1.03) | 0.99 (0.88-1.11) |
| Western                            | 1.41 (1.25-1.59) | 1.43 (1.28-1.60) |

OR, odds ratio (95% confidence interval of the odds ratio); 95%CI, 95% confidence interval; CVRF, cardiometabolic risk factor (hypertension, diabetes, dyslipidemia, or obesity); moderate activity, physical activity energy expenditure ≥6 kJ/kg/day; vigorous activity, physical activity energy expenditure ≥12 kJ/kg/day; LTSB-lifestyle, leisure-time sedentary behavior ≥4 h/day.

In summary, CMRF clustering was a pandemic in 2015 among Chinese adults aged 18–64 years having CMRF(s) and was inversely associated with PAEE (kJ/kg/day). Adjusted for body weight, PAEE ≥6 kJ/kg/day and ≥12 kJ/kg/day are equivalent to the recommended moderate (≥ 600 MET-min/week) and vigorous (1200 ≥ MET-min/week) regarding the epidemic of CMRFs. In our study, the prevalence of CMRF clustering was 40%, and the clustering of 3 and 4 CMRFs was noted in 9.82% and 1.50%, respectively. Variations in population and geographical distribution were detected with a lower prevalence of ≥2 factor clustering in females, those with a low education level, and rural or western patients (compared to their counterparts at the same time). About 40% of patients reported MVPA in the transportation and leisure-time domains. Females, the elderly group, those with a high education level, and those living in urban or western areas were more likely to meet the PA recommendations. This nationally and provincially representative large-scale investigation may convincingly add evidence of the comprehensive distribution characteristics. Furthermore, identifying the continuously unsatisfactory behavior factors during the past decade (e.g., PA level) adds to the relatively urgent need for attention to CMRFs in China.

**Implications**

The prevention and control of CVD in China have been challenging. In 2017, the General Office of the State Council of the People’s Republic of China issued the Medium-to-Long Term Plan of China for the Prevention and Treatment of Chronic Diseases (2017–2025). This marked a milestone in the prevention and treatment of chronic diseases in China with reported expectations of a 15% reduction in CVD mortality and 140 million more active adults by 2025. Subsequently, the Guideline on the Assessment and Management of Cardiovascular Risk in China was released in 2019 and targeted risk factor assessment and management, as well as therapeutic lifestyle changes like improving PA among those at high risk for developing CVD. Because the design of the CCDNS survey is nationally and provincially representative, our analysis may help in assessing and managing CMRFs for the primary prevention of CVD among adults at both these levels. Future analysis among subgroup populations in China may provide more practical results in typical areas.

**Limitations**

Our study had some limitations. First, although CMRFs were derived with objective measures (e.g., anthropometry, blood pressure, lipids, blood glucose and HbA1c) or were self-reported based on validated instruments (e.g., PA, socioeconomic status), some misclassification might have occurred. Second, as with all cross-sectional investigations, the causal association between PA and CMRF clustering could only be inferred; however, the study provided correlations and clues for potential cohort studies. Third, as with many current population studies, the self-reported method of PA information used in the CCDNS might have been subject to reporting bias, especially compared to the objectively quantified PA with motion sensors, which have been increasingly popular in practice. Fourth, only four routinely accessible and authorized metabolic risk factors were measured in the CCDNS, while other metabolic factors (e.g., serum uric acid) might have also influenced the magnitude of their association with PAEE.

**Conclusions**

In summary, CMRF clustering was a pandemic in 2015 among Chinese adults aged 18–64 years having CMRF(s) and was inversely associated with PAEE (kJ/kg/day). Adjusted for body weight, PAEE ≥6 kJ/kg/day and ≥12 kJ/kg/day are equivalent to the recommended moderate (≥ 600 MET-min/week) and vigorous (1200 ≥ MET-min/week) regarding the epidemic of CMRFs.
activity. In populations characterized by an obesity epidemic, ≥ 6 kJ/kg/day or ≥12 kJ/kg/day may be practically used to evaluate PA levels or set physical activity intervention targets.

Conflict of interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Submission statement

The work described in this study is presented clearly, honestly, and without fabrication, falsification, or inappropriate data manipulation. The manuscript has not been published, is not under consideration for publication elsewhere, and will not be published elsewhere including electronically in the same form, in English or in any other language, without the written consent of the copyright-holder. The publication of this manuscript has been approved by all authors.

Authors’ contributions

Chen X reviewed the literature, analyzed the data, and drafted the manuscript. Wang L, Zhang M, and Wu J designed the study and supervised and coordinated the data collection. Huang Z and Zhang W established and collated the database. All authors approved the final version of the manuscript.

Ethical approval statement

The CCDNS 2015 was approved by the National Health and Family Planning Commission of China and the Ethical Committee of the National Center for Chronic and Non-Communicable Disease Control and Prevention, China CDC (approval number 201519-A). All participants provided written informed consent.

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