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Original Article

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%–15.42%) and 1.50% (1.37%–1.63%), respectively. The rate (95%*CI*) of inactivity, low activity, moderate activity, and vigorous activity was 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%), 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,[3–5] 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.

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List of abbreviations

BMI	Body mass index
CCDNS	China Chronic Disease and Nutrition Surveillance
CMRF	Cardiometabolic risk factor
CI	Confidence interval
LTSB	Leisure-time sedentary behavior
CVD	Cardiovascular disease
CVDMRF	Cardiovascular diseases' modifiable risk factors
HTN	Hypertension
LTSB	Leisure-time sedentary behavior
MVPA	Moderate and vigorous physical activity
OR	Odds ratio
PA	Physical activity
PAEE	PA energy expenditure
PAR	Prediction for atherosclerotic cardiovascular disease risk
PPS	Proportionate to population size
SBP	Systolic blood pressure

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.[19-21] 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.[22,23] Met scores (MET-min/week) were generated from the raw data and analyzed according to the analysis guideline.[24] Based on *World Health Organization 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,[27] 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/m^2, 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, residencies (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
Prevalence of CMRF clustering among Chinese adults by selected demographic characteristics in 2015.

	1 risk factor		2 risk factors		3 risk factors		4 risk factors		*p*
	n	% (95%*CI*)	*n*	% (95%*CI*)	*n*	% (95%*CI*)	*n*	% (95%*CI*)	
Total	49927	60.57 (59.48–61.67)	25695	28.10 (27.40–28.79)	9345	9.82 (9.22–15.42)	1553	1.50 (1.37–1.63)	<0.01
Sex									
Male	24664	59.14 (57.66–61.61)	12690	28.77 (27.81–29.74)	4767	10.52 (9.72–11.31)	757	1.58 (1.41–1.74)	<0.01
Female	25263	62.54 (61.62–63.47)	13005	27.17 (26.49–27.86)	4578	8.88 (8.37–9.38)	796	1.40 (1.24–1.56)	
Age (years)									<0.01
18–24	1581	74.90 (72.17–77.63)	400	20.43 (17.93–22.92)	75	4.18 (2.70–5.66)	8	0.49 (0.00–1.12)	
25–34	5602	68.22 (66.47–69.96)	1872	24.30 (23.13–25.47)	490	7.02 (5.85–8.18)	46	0.46 (0.28–8.64)	
35–44	9076	61.35 (59.57–63.13)	3804	27.30 (26.06–28.55)	1304	9.92 (8.89–16.95)	169	1.42 (1.13–1.71)	
45–54	16588	55.72 (54.69–56.75)	9044	30.60 (29.78–31.41)	3287	11.62 (11.01–12.24)	568	2.06 (1.83–2.29)	
55–64	17080	52.27 (51.18–53.36)	10575	32.87 (31.98–33.77)	4189	12.59 (11.96–13.23)	762	2.26 (1.99–2.53)	
Education									<0.01
Less than primary school	12676	58.36 (56.93–59.79)	6544	29.55 (28.45–33.64)	2287	10.45 (9.52–11.38)	364	1.64 (1.39–1.88)	
Primary school	9764	59.29 (57.47–61.11)	5106	29.82 (28.22–31.42)	1686	9.46 (8.65–17.27)	289	1.43 (1.14–1.71)	
Junior high school	16685	60.32 (58.98–61.67)	8435	27.77 (26.92–28.62)	3321	10.32 (9.56–11.48)	559	1.58 (1.39–1.77)	
Senior high school	7048	60.17 (58.42–61.92)	3872	28.46 (27.18–29.74)	1483	9.98 (8.81–11.16)	238	1.39 (1.13–1.65)	
College or higher	3754	66.01 (63.84–68.19)	1738	24.63 (22.98–26.28)	568	7.98 (6.42–9.54)	103	1.38 (0.82–1.93)	
Location									<0.01
Urban	19609	59.58 (57.82–61.34)	10945	28.08 (27.04–29.13)	4390	10.53 (9.53–11.52)	822	1.81 (1.58–2.83)	
Rural	30318	61.66 (60.54–62.77)	14750	28.11 (27.24–28.98)	4955	9.06 (8.56–9.56)	731	1.17 (1.05–1.29)	
Region									<0.01
Eastern	18186	59.32 (57.46–61.19)	10217	28.49 (27.35–29.63)	4017	10.60 (9.50–11.69)	705	1.59 (1.43–1.75)	
Middle	14185	58.81 (56.65–61.98)	7529	28.83 (27.43–39.22)	2816	10.58 (9.50–11.66)	484	1.77 (1.46–2.18)	
Western	17556	64.93 (63.75–66.18)	7949	26.50 (25.63–27.38)	2512	7.55 (6.94–8.17)	364	1.01 (0.84–1.19)	
LTSB-lifestyle									>0.05
No	35886	60.13(59.04–61.21)	18327	28.24(27.54–28.95)	6550	10.19(9.52–17.86)	1071	1.44(1.31–1.57)	
Yes	14041	61.29 (59.77–62.87)	7368	27.87 (26.68–29.25)	2795	9.24 (8.48–9.99)	482	1.61 (1.35–1.87)	

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.

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

	Inactivity		Low activity		Moderate activity		Vigorous activity		*p*
	n	Prevalence (% (95% *CI*))	*n*	Prevalence (% (95% *CI*))	*n*	Prevalence (% (95% *CI*))	*n*	Prevalence (% (95% *CI*))	
Total	29158	34.52 (32.69–36.35)	18065	22.22 (21.37–23.37)	13693	15.98 (15.38–16.58)	25604	27.28 (26.02–28.53)	<0.01
Sex									
Male	15479	36.01 (34.14–37.89)	9204	22.67 (21.79–23.55)	6443	15.35 (14.65–16.74)	11752	25.97 (24.71–27.23)	
Female	13679	32.47 (30.48–34.47)	8861	21.60 (20.54–22.67)	7250	16.85 (16.09–17.61)	13852	29.07 (27.60–32.54)	
Age (years)									<0.01
18–24	737	35.38 (32.04–38.72)	447	23.81 (20.33–27.29)	319	15.46 (13.30–17.62)	561	25.35 (21.96–28.74)	
25–34	2868	35.04 (32.48–37.61)	2010	24.40 (23.11–25.68)	1240	17.09 (15.84–18.33)	1892	23.48 (21.62–25.34)	
35–44	5106	35.70 (33.24–38.16)	3338	23.18 (21.85–24.51)	2297	16.37 (15.12–17.62)	3612	24.75 (23.16–26.34)	
45–54	10262	34.61 (32.71–36.51)	6283	22.04 (21.16–22.92)	4581	15.28 (14.43–16.13)	8361	28.07 (26.39–29.75)	
55–64	10185	32.22 (30.41–34.02)	5987	18.83 (17.82–19.84)	5256	15.72 (15.05–16.38)	11178	33.24 (31.76–34.71)	
Education									<0.01
Less than primary school	8091	39.76 (37.58–41.95)	4125	19.33 (17.98–21.69)	3226	13.78 (13.00–14.56)	6429	27.12 (25.51–28.73)	
Primary school	6246	39.25 (36.54–41.96)	3582	22.02 (20.67–23.37)	2416	13.78 (12.84–14.72)	4601	24.95 (23.27–26.62)	
Junior high school	10079	38.06 (36.06–40.16)	6291	23.27 (22.15–24.38)	4489	14.59 (13.79–15.39)	8141	24.08 (22.63–25.53)	
Senior high school	3436	27.86 (25.64–34.07)	2621	21.56 (20.18–22.95)	2309	19.06 (17.73–28.38)	4275	31.52 (29.67–33.38)	
College or higher	1306	21.81 (19.66–23.96)	1446	24.06 (22.18–25.93)	1253	20.98 (19.36–22.62)	2158	33.16 (30.33–35.98)	
Location									<0.01
Urban	9711	28.22 (26.24–36.20)	7371	22.35 (21.28–23.43)	6314	18.21 (17.33–19.28)	12370	31.22 (29.63–32.84)	
Rural	19447	41.38 (38.97–43.78)	10694	22.07 (20.87–23.28)	7379	13.56 (12.96–14.17)	13234	22.99 (21.60–24.37)	
Region									<0.01
Eastern	11484	35.05 (32.39–37.77)	6856	21.98 (20.79–23.16)	5207	15.76 (14.82–16.71)	9578	27.21 (25.21–29.28)	
Middle	8668	36.49 (32.50–45.48)	5576	23.38 (21.53–25.24)	4114	16.25 (15.11–17.41)	6656	23.87 (21.68–26.65)	
Western	9006	31.12 (28.78–33.47)	5633	21.16 (19.75–22.57)	4372	16.01 (15.00–17.33)	9370	31.71 (29.83–33.59)	
LTSB-lifestyle									<0.01
No	21309	36.42(34.45–38.39)	12740	22.08(21.08–23.27)	9699	15.14(14.44–15.84)	18086	26.36(25.07–27.66)	
Yes	7849	31.49 (29.61–33.36)	5325	22.45 (21.40–23.49)	3994	17.33 (16.19–18.47)	7518	28.74 (27.11–39.35)	

CMRF, cardiometabolic risk factor (hypertension, diabetes, dyslipidemia, or obesity); LTSB-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; LTSB-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)	9969	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 (23.41–27.28)
4	484	31.68 (27.20–36.17)	399	27.89 (24.86–37.92)	238	13.66 (10.78–16.54)	432	26.76 (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.

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 population with >50% overweight or obese people in China, PAEE adjusted for body weight was introduced based on the recommendations in this study. Accordingly, PAEE ≥6 kJ/kg/day and ≥12 kJ/kg/day are equivalent to moderate (≥ 600 MET-min/week) and vigorous (1200 ≥ MET-min/week) activity. To our knowledge, this is the first report in China to use nationally representative, large-scale data to translate PA recommendations, which may be used practically to evaluate PA levels or set targets in a population with a considerably high body weight profile.[37]

Association between PA and CMRF clustering

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.[38] 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.[39,40]

Both PA level and CMRFs vary geographically and socioeconomically in China.[41–43] 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]

Table 4
Adjusted *ORs* of physical activity levels according to number of CMRFs in 2015.

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	1.05 (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; CMRF, 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.

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.[17] On analyzing PAEE from transportation and leisure-time domains, our study detected a similarly inverse linear dose-response association between a higher PA level and a lower percentage of CMRF clustering among Chinese patients aged 18–64 years in 2015. Those with inactivity had a 9% reduction in having 2 CMRFs if they met PA recommendations, and this benefit was doubled in those having 4 CMRFs. There are variations in the PA domains that have been studied to influence CVD development, which may be unfit for understanding the dose-response relationship. With the evidence of decreasing trends in the intensities of occupational and household activity, MVPA from leisure-time and transportation domains should be addressed in CVD management practice.

With the increasing epidemic of a single major factor, CMRF clustering has been attracting more attention in China. Data from the China Kadoorie Biobank project showed an increasingly rapid trend of multimorbidity (i.e., coexistence of ≥2 chronic conditions) in that the prevalence of multimorbidity rose from 33.5% to 58.1% over 8 years and that the most common multimorbidity pattern comprised obesity, hypertension, diabetes, stroke, and heart disease.[4] Regarding CVDMRFs, several large cross-sectional studies presented the highly striking and seemingly increasing prevalence of its clustering in Chinese adults over the last 20 years.[3,17] As such, focusing on CMRF clustering may be helpful in individual-level cardiovascular health management practice.

Epidemiological characteristics of CMRFs and PA

Our findings were consistent with recent large-scale surveys in China regarding the epidemic of CMRFs.[17,42,44] 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 favorable 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.[41,45]

An interesting finding in our study was a similar prevalence of LTSB-lifestyle among patients with different numbers of CMRFs in contrast to its decreasing trend with activity levels. It has been well-established that excessive sedentary behavior is positively associated with CMRFs or CVD.[10,18] Our study only involved patients having CMRF(s), which might have been a reason for this finding; future studies should be comprehensively carried out in highly diverse populations 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.[46] 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.[11] 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) 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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