Urban-rural differences in the association between occupational physical activity and mortality in Chinese working population: evidence from a nationwide cohort study

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Summary

Background Despite emerging studies suggesting that occupational physical activity (OPA) might be harmful to health, the available evidence is not definitive. Most of these research studies were conducted in high-income Western countries or in urbanized setting. In China, where over one-third of the population resides in rural area, the impact of OPA on health is not well understood. The goal of this study is to investigate how the association between OPA and mortality vary by urban-rural settings.

Methods Baseline data on OPA was gathered using the Global Physical Activity Questionnaire from 30,650 urban and 49,674 rural working adults as part of the 2013–2014 China Chronic Disease and Risk Factor Surveillance. Participants were followed for a median of 6.2 years, and death records were retrieved from the National Mortality Surveillance System until December 31, 2019. The multivariable Cox proportional hazard model was used to examine urban-rural differences in the association between OPA and all-cause and cardiovascular disease (CVD) mortality. Subgroup analyses were performed by sex, socioeconomic status, leisure time, transportation, and non-occupational physical activity.

Findings During the study period, 1342 deaths were recorded, of which 426 were caused by CVD. In rural area, working adults engaging in occupational moderate-to-vigorous physical activity (MVPA) for ≥40 h per week, compared to those without any, had an adjusted hazard ratio of 0.60 (95% CI: 0.49–0.73) for all-cause mortality and 0.55 (95% CI: 0.37–0.83) for CVD mortality. However, no significant association was found in urban area (0.84 [0.61–1.15] for all-cause mortality, $P_{interaction}$ = 0.036; and 0.94 [0.53–1.66] for CVD mortality, $P_{interaction}$ = 0.098). The negative associations of occupational MVPA with mortality were more pronounced in women, non-smokers, and those with less non-occupational physical activities. Hypertension, heart rate, and diabetes were important contributors to the relationship between occupational MVPA and mortality.

Interpretation The findings from the current study did not support the notion that high levels of OPA would induce harm. On the contrary, in rural setting, higher levels of OPA were associated with lower mortality risks. Furthermore, the observed urban-rural differences in the association between OPA and mortality underscored the need for context-specific public health guidelines on physical activities.

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Research in context

Evidence before this study

Various studies have been published on the association between occupational physical activity (OPA) and mortality. For example, the Copenhagen General Population Study, conducted in Copenhagen, found that OPA was associated with a higher risk of all-cause mortality. Many of these studies focused on urban populations, and information about rural populations remains sparse. Our literature search on PubMed and Google Scholar from January 1, 2013 to September 30, 2023, using terms related to OPA, mortality, cardiovascular disease, and rural, yielded fewer than 10 studies. The majority of these studies are small-scale, with limited generalizability and representativeness. With regard to China, a study based on data from the China Kadoorie Biobank examined the relationship between total physical activity and CVD mortality in urban and rural settings. The results indicated distinct exposure–response relationships for total physical activity with CVD deaths between urban and rural populations. The study, however, did not specifically address the differences in OPA and mortality between the two settings.

Added value of this study

Using nationally representative data, our study examined the association between occupational moderate-to-vigorous physical activity (MVPA) and all-cause and CVD mortality in urban versus rural populations. A cohort of 30,650 urban and 49,674 rural working adults were followed up from 2013 to 2019. Leveraging detailed sociodemographic, behavioural and lifestyle risk factors, anthropometric and mortality information, Cox proportional hazard models were fitted separately for urban and rural samples. The results revealed systematic differences between the two settings, where protective benefits of occupational MVPA were observed in rural but not in urban cohorts.

Implications of all the available evidence

Driven by the sociodemographic and lifestyle differences between urban and rural settings, the impact of OPA diverged. This divergence, however, should not be construed as a dismissal of the importance of physical activities on health. Rather, our findings highlighted that the benefits of OPA, as a component of total physical activity, is contextually sensitive. Public health policies regarding physical activity should take into account these contextual variations to tailor appropriate recommendations.

Introduction

Physical inactivity is an important modifiable risk factor for non-communicable diseases and premature mortality. In 2019, an estimated 15.7 million disability-adjusted life years and 832,000 deaths were attributed to low physical activity globally.[1,2] Although extensive studies have purported the health benefits of physical activity in any form and intensity,[3] this notion is challenged by an increasing body of evidence distinguishing the health benefits associated with leisure time physical activity from occupational physical activity (OPA). The latter, at a high level of intensity, seemed to be harmful in some cases.[4–6] This potential discrepancy has been denoted as the "physical activity paradox". Several possible mechanisms, such as higher cardiovascular burden, have been proposed to explain this paradox, although none have been rigorously tested.[4]

Some of the earliest studies on OPA and health outcomes date back to the 1950s. Pioneering research by Morris et al. and Paffenbarger et al. demonstrated that individuals engaging in more physically demanding work appeared to have better health outcomes.[7,8] However, recent population-level studies in Europe and the US, using self-reported degree of manual and standing/walking work or perception of OPA level to categorize OPA and adjusting for sociodemographic factors, lifestyle, diet, and prevalent disease, have found higher risks of all-cause and cardiovascular mortality with increased levels of baseline OPA.[9–11] A meta-analysis consisting of 17 studies with 193,696 participants found an 18% increased risk of premature mortality among men with high levels of OPA compared to those with low levels.[12] Meanwhile, several studies have observed the opposite results based on similar classification of OPA.[13,14] A Norwegian cohort study, which involved more comprehensive adjustment for confounding factors such as time-varying socioeconomic status and detailed gradient of smoking status, found a significant prospective association between engaging in walking/lifting and heavy labour work and longevity,[13] and a study based on UK Biobank found no significant connection between OPA at baseline and mortality.[15] An umbrella review of 158 observational studies concluded that the impact of OPA depended on health outcomes, with benefits observed for stroke, coronary heart disease, and some cancers.[16] In general, considerable variations can be observed across population and regions.

To-date, research on OPA and health outcomes has predominantly been conducted in Western countries or urban areas. In China, a study using data from over 142,000 urban residents in the China Kadoorie Biobank showed no significant effect of manual work on mortality after adjusting for sociodemographic and risk factors.[17] Limited information is available on whether these results are generalizable to rural settings. Given that over one-third of China's population live in rural area where occupational activities differ substantially from those in urban area, and within urban and rural areas there are also variations in diverse characteristics with OPA levels, there is a need to understand potential differences in the relationship between OPA and health outcomes across these settings.

In this study, we leveraged data from two national databases—China Chronic Disease and Risk Factor Surveillance (CCDRFS) and the National Mortality Surveillance System (NMSS)—to examine the associations between OPA level and risk of all-cause and cardiovascular disease (CVD) mortality in both urban and rural settings. Given existing evidence suggestive of stronger associations among men and those more educated and active,[12,17] we also explored how the associations varied by individual characteristics, such as sex, levels of education, and lifestyle factors.

Methods

Data source and participants

The CCDRFS is a nationwide survey conducted every three years. In 2013, in order to improve national and provincial representativeness, CCDRFS was expanded to include 298 disease surveillance points (DSP). Participants in each DSP were selected using a multistage cluster sampling strategy, detailed elsewhere.[18] In this study, data from the 2013 wave of CCDRFS was used as the baseline. A total of 177,099 individuals who had lived in the reported residence for at least six months in the past year were considered. The final number of individuals included in the analysis was 80,324 after applying exclusion criteria (Appendix Supplementary method and Supplementary Fig. S1). The study was approved by the ethical review committee of the National Center for Chronic and Noncommunicable Disease Control and Prevention. All participants provided written informed consent. In addition to CCDRFS, NMSS was used to retrieve vital status and cause of death. NMSS provides national and provincial level mortality surveillance covering 605 DSPs, a total of 324 million people, which is 24.3% of China's population.

OPA and covariates

As part of CCDRFS, OPA data was assessed through face-to-face interviews using the Global Physical Activity Questionnaire (GPAQ) developed by the World Health Organization (WHO).[19] For this study, data were collected on the intensity, duration, and frequency of physical activity in a typical week across three different domains (work, transportation, and leisure time). Work and leisure time physical activity were categorized into moderate and vigorous according to intensity, while the intensity of transportation physical activity was considered moderate (Appendix Supplementary Table S3). Moderate intensity refers to physical activity that induces small increases in breathing or heart rate for at least 10 min continuously, with a metabolic equivalent of task (MET) value of 4.0. Vigorous intensity is defined as physical activity that triggers large increases in breathing or heart rate for at least 10 min continuously, with a MET value of 8.0. Occupational moderate-to-vigorous physical activity (MVPA) was defined as the sum of work-related moderate physical activity (MPA) and work-related vigorous physical activity (VPA) multiplied by 2. Non-occupational MVPA was defined as the sum of leisure time and transportation physical activity using the same intensity weight (Appendix Supplementary Table S1).

Urban or rural classification was based on the zoning code of the village or committee, the lowest administration level in China, provided by the National Bureau of Statistics. Other covariates included in this study were: individuals' demographic characteristics such as age, gender, educational level, income, and lifestyles. Height, weight, blood pressure, heart rate, plasma glucose and lipid profile were also measured, and hypertension, diabetes, and dyslipidaemia were subsequently defined (See appendix Supplementary method for definitions).

Outcomes

The primary outcomes of interest were all-cause mortality and mortality associated with CVD as defined using the International Classification of Diseases, 10th Revision (ICD 10) codes: I00–I99. Each individual identified from the CCDRFS 2013 baseline data was linked to the NMSS that covered all 298 DSPs using personal details including unique ID numbers, names, sex, residential addresses, and other identifiers. Deaths occurred between recruitment (August 2013–April 2014) to December 31, 2019 were extracted and included for this study.

The data quality of NMSS is maintained following the WHO data quality strategies and guidelines. A series of activities, including annual quality control meetings, site quality inspection, regular staff training courses, and regulation development, are implemented. Overall, the corresponding coding inaccuracy rate was 2.7%.[20]

Statistical analysis

Mean, standard deviation, median and interquartile range were calculated for continuous variables and percentages were calculated for categorical variables. Cox proportional hazard model was used to examine the associations between OPA and all-cause and CVD mortality, with age as the underlying timescale. Schoenfeld residuals were examined to validate the proportional hazard assumption and no violation was found. Hazard ratio (HR) and 95% confidence interval

(CI) were estimated for occupational MVPA categorized as 0, less than 10, 10–19.9, 20–39.9, and equal or over 40 h per week, with cutoff equivalent to 0, 2, 4, and 8 h of MPA based on a 5-day workweeks.

An initial analysis examining the interaction between occupational MVPA and urban/rural areas, on both multiplicative and additive interaction scales, was performed using cox models. HR and relative excess risk due to interaction (RERI) were evaluated.[21] An HR of interaction term >1 and an RERI > 0 indicated positive multiplicative interaction and synergistic additive interaction, respectively. Based on the results, subsequent analyses were performed separately for urban and rural areas.

We constructed two models, both accounting for sex and county/district-level clustering. Model 1 adjusted for educational level, household income, smoking status, alcohol consumption, vegetable and fruit intake, and sedentary behaviour. Model 2 included the same covariates as Model 1 with the addition of BMI and non-occupational MVPA. The extent to which hypertension, diabetes, dyslipidaemia, and heart rate contributed to the observed significant associations between OPA and mortality was determined by calculating the proportion of attenuation using the formula $(HR_{additional\ adjustment}-HR_{model2})/(1-HR_{model2})*100$.[22] Finally, the dose–response curves were generated based on Model 2 by fitting a restricted cubic spline function with 4 degrees of freedom. The curve was truncated at the 95th percentile of occupational MVPA due to data sparsity.

Stratified analyses by sex, educational level, smoking status, leisure MVPA, transportation physical activity, and non-occupational MVPA were also performed. Wald test was applied to determine joint significance of multiplicative interaction terms. Moreover, comparisons were made between occupational MPA and VPA to provide supplemental insights into urban-rural differences. Extensive sensitivity analyses were conducted to evaluate the robustness of our results against potential issues including selection bias, missing data, reverse causation, residual confounding, measurement error, potential changes in OPA patterns, and alternative model specification (See appendix Supplementary Table S2 for details).[23] All statistical analyses were conducted with R statistical software (version 4.3.1), and a two-sided $P < 0.05$ indicates statistical significance.

Role of the funding source

The funder of the study had no role in study design, data collection, data analysis, data interpretation, or writing of the report. The corresponding author had full access to all data in the study and had final responsibility for the decision to submit for publication.

Results

Among the 80,324 participants, 30,650 were from urban area and 49,674 were from rural area (Table 1). Systematic differences were observed when comparing socioeconomic status (SES) across OPA groups between urban and rural settings. For example, in urban area, only 14.6% of individuals in the highest occupational MVPA group had at least a high school education, compared to 51.4% in the lowest occupational MVPA group. This disparity was less pronounced in rural area, with 7.5% and 17.6% in the highest and lowest occupational MVPA group. Additionally, in both areas, participants engaging in higher OPA were more likely to be frequent drinkers, vegetable and fruit consumers, and had lower BMI and prevalence of diabetes and dyslipidaemia.

The total number of person-years follow-up was 481,985, and the median follow-up time was 6.2 years. During the study period, a total of 1342 deaths were recorded, 433 deaths in urban and 909 deaths in rural areas. Among all the recorded deaths, 426 were CVD-related, with 140 CVD deaths in urban and 286 CVD deaths in rural areas. Initial interaction analyses suggested negative multiplicative interaction of engaging no occupational MVPA with urban/rural residency on mortality ($P_{interaction} = 0.036$ and 0.098 for all-cause and CVD mortality, respectively), with a weaker association observed in urban area (Appendix Supplementary Table S4). Multivariable Cox proportional hazards regression model showed no significant association between occupational MVPA and all-cause mortality or CVD mortality in urban setting (Table 2). In contrast, a significant negative association was found between occupational MVPA and all-cause mortality as well as CVD mortality in rural setting. Additional adjustments for BMI and non-occupational MVPA yielded similar results. In Model 2, the hazard comparing individuals with occupational MVPA ≥ 40 h per week to those without any occupational MVPA, was 40% (HR 0.60, 95% CI 0.49–0.73) lower for all-cause mortality and 45% (HR 0.55, 95% CI 0.37–0.83) lower for CVD mortality. These associations were attenuated with progressive adjustment of hypertension, diabetes, and heart rate, with the greatest HR reduction observed when all 3 factors were simultaneously included, resulting in an attenuation of 15.40% for all-cause mortality and an attenuation of 15.18% for CVD mortality (Appendix Supplementary Table S5).

To determine whether the association with occupational MVPA was unique or represented a general pattern that existed in other types of physical activities, analyses were also conducted separately for leisure and transportation physical activities. The results indicated that leisure MVPA was negatively associated with all-cause mortality in urban area, with an HR of 0.69 (0.50–0.96) when comparing individuals with leisure MVPA ≥ 4 h/week to those without any leisure MVPA. However, no significant relationship was found between transportation physical activity and mortality (Appendix Supplementary Table S6).

Variables	All	Occupational MVPA (hours/week)				
		0	0.1–9.9	10.0–19.9	20.0–39.9	≥40.0
Urban						
N	30,650	6325	11,801	4457	3855	4212
Age, years	45.8 ± 11.0	44.8 ± 11.6	44.7 ± 11.1	47.4 ± 10.5	47.7 ± 10.3	46.8 ± 10.0
Men	48.1	63.7	43.2	33.5	41.9	59.8
Education						
Primary school or below	26.7	17.4	19.2	32.2	40.7	43.5
Middle school	34.5	31.2	31.7	35.9	39.2	41.9
High school or above	38.8	51.4	49.1	31.9	20.1	14.6
Household income, CNY						
<20,000	12.0	7.9	11.0	13.2	15.8	16.3
2000–39,999	25.2	21.1	23.9	26.8	28.9	29.8
≥40,000	42.2	46.9	45.6	39.6	35.1	34.5
Unknown/refuse to answer	20.6	24.1	19.5	20.4	20.2	19.4
Smoking status						
Never	67.3	60.7	70.9	75.8	69.5	56.2
Former	4.5	5.2	4.3	3.6	3.9	5.5
Current	28.2	34.1	24.8	20.6	26.6	38.3
Alcohol consumption						
0 day/week	59.2	57.8	58.8	65.6	61.9	53.4
<3 days/week	26.9	25.7	30.1	24.1	23.5	25.6
≥3 days/week	13.9	16.5	11.1	10.3	14.6	21.0
Inadequate intake of vegetable and fruit	43.3	48.5	41.5	41.6	43.2	42.0
Non-occupational physical activity, hours/week	2.5 (0.0–7.0)	1.7 (0.0–5.0)	3.3 (0.5–7.0)	3.5 (0.0–7.0)	2.5 (0.0–7.0)	1.5 (0.0–5.0)
Sedentary behaviour, hours/day	5.0 (3.0–7.0)	5.0 (3.5–8.0)	5.0 (3.5–7.5)	4.7 (3.0–6.5)	4.0 (3.0–6.0)	4.0 (2.5–5.0)
BMI, kg/m^2	24.5 ± 3.6	24.7 ± 3.7	24.5 ± 3.6	24.5 ± 3.5	24.3 ± 3.5	24.1 ± 3.5
Hypertension	28.7	30.0	27.3	29.2	30.3	28.5
Diabetes	11.9	14.7	11.9	10.8	11.4	9.5
Dyslipidemia	35.4	41.2	35.5	33.5	32.3	30.8
Heart rate, beats per minute	77.4 ± 10.5	77.5 ± 10.6	77.6 ± 10.3	77.7 ± 10.5	77.1 ± 11.0	76.4 ± 10.7
Rural						
N	49,674	5408	11,373	8331	10,848	13,714
Age, years	47.2 ± 10.8	46.7 ± 11.8	47.1 ± 11.3	47.5 ± 10.9	47.6 ± 10.5	47.0 ± 10.1
Men	48.6	61.2	42.8	39.0	43.1	58.5
Education						
Primary school or below	54.2	43.3	49.5	55.9	59.4	56.9
Middle school	35.3	39.1	36.4	34.1	33.0	35.6
High school or above	10.5	17.6	14.1	10.0	7.6	7.5
Household income, CNY						
<20,000	25.2	20.6	24.5	25.6	26.4	26.7
2000–39,999	30.2	28.1	29.7	30.3	30.6	31.0
≥40,000	23.6	28.0	24.5	22.3	22.9	22.3
Unknown/refuse to answer	21.0	23.3	21.3	21.8	20.1	20.0
Smoking status						
Never	64.7	58.9	68.4	71.1	68.5	57.1
Former	3.9	5.7	4.7	4.3	4.4	5.4
Current	30.4	35.4	26.9	24.6	27.1	37.5
Alcohol consumption						
0 day/week	62.7	61.0	65.9	67.1	64.9	56.5
<3 days/week	21.4	21.0	21.0	20.1	21.4	22.8
≥3 days/week	15.8	18.0	13.1	13.8	13.7	20.7
Inadequate intake of vegetable and fruit	49.2	53.6	53.0	48.5	48.2	45.7
Non-occupational physical activity, hours/week	1.2 (0.0–4.0)	0.0 (0.0–3.5)	1.0 (0.0–3.5)	1.5 (0.0–5.0)	1.5 (0.0–5.0)	1.2 (0.0–4.6)
Sedentary behaviour, hours/day	4.0 (3.0–5.0)	4.0 (3.0–6.0)	4.0 (3.0–6.0)	4.0 (3.0–5.0)	4.0 (3.0–5.0)	3.5 (2.5–4.5)

(Table 1 continues on next page)

Variables	All	Occupational MVPA (hours/week)				
		0	0.1–9.9	10.0–19.9	20.0–39.9	≥40.0
(Continued from previous page)						
BMI, kg/m^2	24.1 ± 3.6	24.5 ± 3.7	24.4 ± 3.7	24.2 ± 3.6	24.0 ± 3.5	23.8 ± 3.4
Hypertension	29.7	34.0	31.1	30.1	29.3	26.8
Diabetes	9.3	12.9	10.6	9.6	8.6	7.1
Dyslipidemia	30.3	36.5	32.4	30.1	29.1	27.1
Heart rate, beats per minute	76.9 ± 11.0	77.7 ± 11.3	77.8 ± 11.0	77.5 ± 11.0	76.9 ± 11.0	75.6 ± 10.9

MVPA, moderate to vigorous physical activity. Data are presented as mean ± SD, %, or median (P_{25}–P_{75}).

Table 1: **Baseline characteristics of study participants by area and occupational MVPA.**

The exposure-response curve for the association between occupational MVPA and all-cause mortality in rural area showed a steeper decrease upon 30 h per week, after which the curve flattened (Fig. 1). The association with CVD mortality was generally linear, although caution must be taken when interpreting this result due to the wide CIs. No significant association between occupational MVPA and mortality was found in urban area based on the exposure-response analysis.

The associations between occupational MVPA and all-cause mortality in rural area remained generally consistent across subgroups, with slightly greater magnitudes observed in women, non-smokers and those less engaged in leisure and non-occupational physical activity (Fig. 2). For example, women with occupational MVPA 0.1 to 9.9 h/week had an HR of 0.61 (0.42–0.88), compared to men (HR: 0.98 [0.77–1.25]) in the same category. The HR comparing highest and lowest occupational MVPA groups was 0.53 (0.40–0.70) among individuals with less than 105 min per week of non-occupational physical activity and 0.69 (0.49–0.98) among those with over 105 min per week. Similar differences across subgroups were seen for associations with CVD mortality (Appendix Supplementary Fig. S2).

When assessing the associations with occupational MPA and VPA separately, our results suggested a stronger relationship of mortality with occupational VPA than with MPA (Appendix Supplementary Table S7), which aligned with the urban-rural contrast observed, as a larger proportion of individuals in rural area were engaged in occupational VPA. Sensitivity analyses including inverse probability weighing, imputing missing data, exclusion of deaths occurring in the first two years of follow-up, restriction of analysis to non-smokers, further adjustment for occupation, using unweighted occupational MVPA, exclusion of occupational MVPA at upper end, restriction of analysis to those aged between 30 and 50 years old, incorporating unemployed participants, and Fine–Gray sub-distribution models, showed little difference from our original analysis (Appendix Supplementary Tables S8 and S9).

Discussion

Using two nationally representative databases, we examined the associations of occupational MVPA with

Occupational MVPA (hours/week)	Person-years	All-cause mortality			Cardiovascular disease mortality		
		Events	Model 1[a]	Model 2[b]	Events	Model 1[a]	Model 2[b]
Urban							
0	38,113	93	Ref	Ref	33	Ref	Ref
0.1–9.9	70,917	155	1.05 (0.82, 1.34)	1.06 (0.83, 1.36)	46	0.86 (0.56, 1.34)	0.88 (0.57, 1.36)
10.0–19.9	26,778	63	0.97 (0.71, 1.34)	0.99 (0.72, 1.36)	17	0.74 (0.41, 1.34)	0.77 (0.42, 1.39)
20.0–39.9	23,188	60	0.94 (0.66, 1.34)	0.95 (0.66, 1.37)	21	0.95 (0.54, 1.67)	0.99 (0.56, 1.76)
≥40.0	25,329	62	0.83 (0.60, 1.13)	0.84 (0.61, 1.15)	23	0.89 (0.50, 1.57)	0.94 (0.53, 1.66)
Rural							
0	32,346	144	Ref	Ref	44	Ref	Ref
0.1–9.9	68,042	231	0.85 (0.69, 1.05)	0.85 (0.69, 1.04)	73	0.85 (0.58, 1.24)	0.85 (0.58, 1.25)
10.0–19.9	49,976	152	0.77 (0.61, 0.98)	0.76 (0.60, 0.96)	55	0.88 (0.61, 1.28)	0.89 (0.61, 1.30)
20.0–39.9	65,027	174	0.67 (0.54, 0.83)	0.66 (0.53, 0.81)	58	0.72 (0.48, 1.08)	0.73 (0.48, 1.10)
≥40.0	82,269	208	0.61 (0.50, 0.75)	0.60 (0.49, 0.73)	56	0.54 (0.36, 0.81)	0.55 (0.37, 0.83)

MVPA, moderate to vigorous physical activity. [a]Adjusted for age (time scale), sex, educational level, household income, smoking status, alcohol consumption, inadequate intake of vegetable and fruit, and sedentary behaviour. [b]Adjusted for the same covariates as model 1 plus BMI and non-occupational MVPA.

Table 2: **Hazard ratio (95% CI) of all-cause and cardiovascular disease mortality by area and occupational MVPA.**

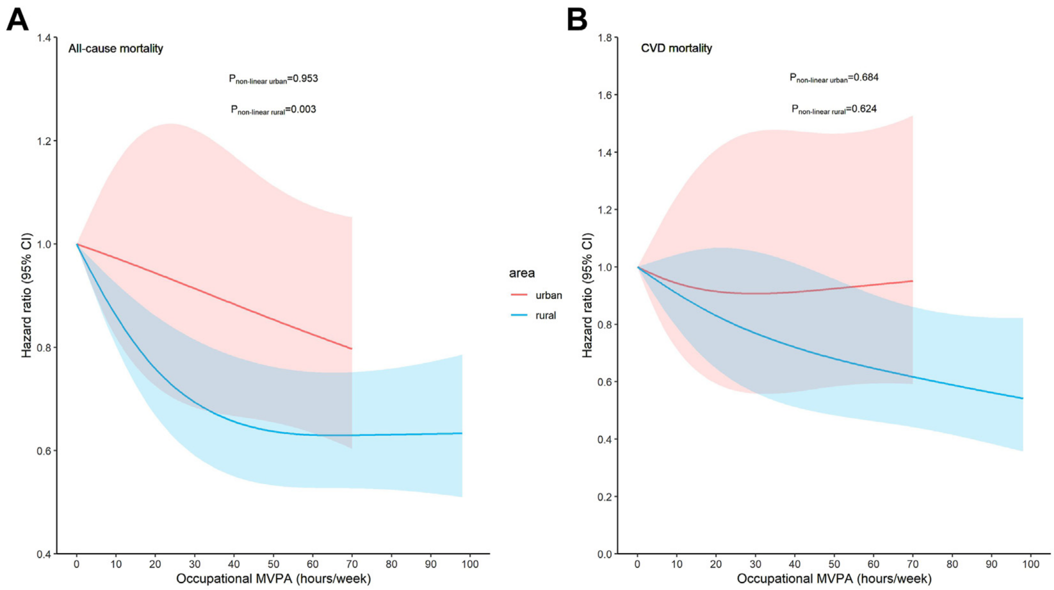

Fig. 1: Associations of occupational moderate to vigorous physical activity (MVPA) with all-cause (A) and cardiovascular disease mortality (B) in urban and rural areas, adjusted for age (time scale), sex, educational level, household income, smoking status, alcohol consumption, inadequate intake of vegetable and fruit, sedentary behaviour, BMI, and non-occupational MVPA. Curves within the 95th percentile of occupational MVPA in urban (70 h/week) and rural (98 h/week) areas are shown.

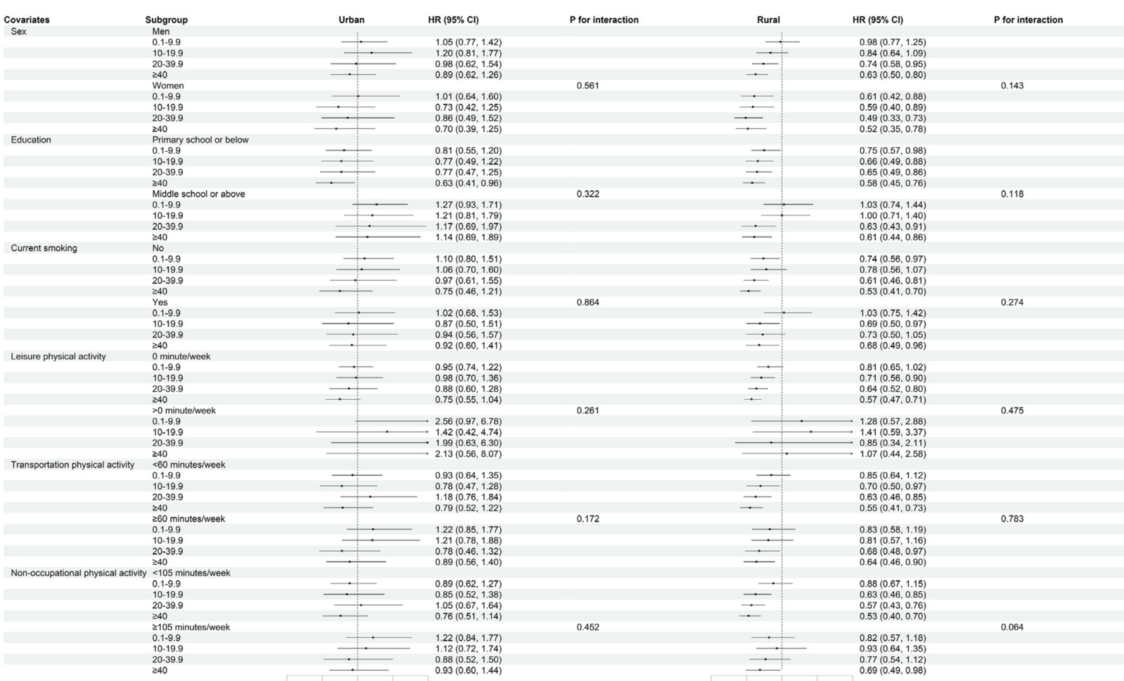

Fig. 2: Associations between occupational moderate to vigorous physical activity (MVPA) and all-cause mortality in urban and rural areas stratified by sex, educational level, smoking status, leisure MVPA, transportation physical activity, and non-occupational physical activity. The median of leisure MVPA, transportation physical activity, and non-occupational MVPA was 0 min/week, 60 min/week, and 105 min/week, respectively. All models were adjusted for adjusted for age (time scale), household income, alcohol consumption, inadequate intake of vegetable and fruit, sedentary behaviour, BMI, non-occupational MVPA, and for sex, educational level, smoking status whenever applicable.

all-cause and CVD mortality across urban and rural populations. Our analysis revealed a significant interaction effect of urban and rural settings on the relationship between occupation MVPA and all-cause mortality. Although no significant association between occupational MVPA and mortality within the urban cohort, a significant inverse association was observed in the rural cohort, wherein a higher level of occupational MVPA was associated with a lower risk of all-cause and CVD-specific mortality as high as 40%. The associations with occupational MVPA were particularly pronounced in women, non-smokers, and those with lower non-occupational physical activities.

In our study, we observed no significant association of occupational MVPA with mortality in urban setting. Despite a relatively small number of events in urban area, our results were consistent with those of Luo et al., who followed 142,302 urban workers from the China Kadoorie Biobank over a median of 10.2 years and reported no significant association between OPA and mortality risk.[17] However, in rural setting, occupational MVPA was negatively associated with both all-cause and CVD mortality. Our research extends the body of existing literature by considering rural population and demonstrating differences between rural and buran settings. This is in line with results from previous research showing the impact of OPA was protective among the less educated.[17] Similar patterns were also found when examining the impact of total physical activity on cardiovascular risk in urban and rural settings. Specifically, it has been shown that the risk of cardiovascular deaths declined in rural area but escalated in urban area with higher quintiles of total physical activity.[24]

Although we cannot fully ascertain the underlying reasons driving the urban-rural differences, one plausible explanation is the systematic differences in SES disparities across occupational MVPA groups between urban and rural settings. In urban settings, agriculture workers constituted only 19.7% in the lowest MVPA group but rose to 57.1% in the highest group (Appendix Supplementary Table S10). However, in rural settings, over 70% of workers in each MVPA group were in agriculture. Therefore, in urban settings, individuals with higher levels of occupational MVPA tended to have a considerably lower SES than those with lower levels of occupational MVPA, while in rural settings, this SES disparity was less pronounced. Large SES disparity often implies less favourable to health outcomes, which cannot be easily modified by behavioural factors including higher OPA. Besides, it has been noted that a large gap existed for quality healthcare in urban settings, where access to top-tier medical services is primarily driven by health consciousness and income. The absence of a significant link between occupational MPVA and mortality risk may reflect the lack access to quality healthcare among the SES disadvantaged in urban area, specifically individuals in the highest occupational MVPA group. Uninsurance, an indicator of less access to healthcare, has been associated with higher mortality.[25] Thus, the effects of occupational MVPA might have been obscured and could made more apparent if the confounding of healthcare access was eliminated, which warrants validation in future studies. In contrast, recent policies have markedly enhanced medical infrastructure in rural settings and equalized access to healthcare across different SES demographics.[26,27] Another explanation is that a larger proportion of OPA in urban setting belongs to the MPA as opposed to the VPA. Our explorative analysis and previous research demonstrated that VPA is more closely associated with mortality than MPA.[28]

Our exposure-response curve indicated that the benefits of occupational MVPA began to subside beyond 30 h per week, which equates to an average of 6 h of MVPA per workday. Similar plateauing pattern has been previously reported based on OPA or non-recreational physical activity.[24,29] The reduction of mortality risk flattened around 5000–6000 MET minutes per week. The higher value of inflection point in our curve may reflect the fact that the subjects in other studies were relatively older, among whom the influence of high OPA is less obvious. Nevertheless, the L-shape curves observed across the studies implied that OPA in general confers sustained survival benefits up to certain level, and no evidence indicated higher risk of mortality beyond any activity threshold.

Proponents of the physical activity paradox have suggested that high OPA does not deliver the same health benefits as those of leisure-time activities, citing increased cardiovascular burden, particularly an association with a 24-h elevation in blood pressure and heart rate, leading to a heightened mortality risk.[4] In contrast, other researchers contended that the average level of exertion for ‘heavy’ workers constitutes roughly 30% of maximal aerobic power, rendering a sustained increase in blood pressure improbable.[30] Moreover, utilizing data from the China Health and Nutrition Survey (CHNS), Li et al. observed a reduction in HRs for new-onset hypertension associated with higher levels of OPA.[31] Similarly, other studies have reported lower DBP and heart rate levels in association with higher levels of OPA.[32,33] Results from our analysis align with these latter findings, indicating that within the rural population, the negative association between OPA and mortality risk may be explained by a lower prevalence of hypertension and more optimal heart rate. Since heart rate is an indicator of cardiorespiratory fitness, our result highlighted the role of OPA in improving the cardiorespiratory fitness relative to physical demand of work. Additionally, diabetes might also be a potential mediator for our association, which is supported by CHNS showing reduced incidence of diabetes associated with OPA.[34] Future studies are needed to better understand the mechanisms through which OPA influences mortality.

Contrary to previous reports suggesting men might be more susceptible to the impacts of OPA,[12] our study found a significant inverse relationship between occupational MVPA and mortality for both sexes, with a slightly greater association in women. This is likely because men tended to be exposed to other risk factors, such as smoking, which offset the benefit of occupational MVPA. The benefits of OPA were less evident among smokers, particularly with regard to CVD. This result aligns with a previous study that demonstrated that compared to smokers, non-smokers experienced more positive impact of physical activity on improving life expectancy.[35] Moreover, our subgroup analysis revealed that the association between occupational MVPA and mortality was potentially stronger, with marginally significant interaction, among individuals with a lower level of non-occupational physical activity in rural setting. This result suggested the complementary role of occupational MVPA and non-occupational physical activity. Occupational MVPA played a significant role in reducing the risk of all-cause and CVD mortality among individuals who are otherwise physically inactive.

The present study is unique in several aspects. First, this is the first nationally representative study focusing on urban-rural differences in the associations between OPA and mortality in China. Previous studies that investigate urban-rural differences typically consider total physical activity, rather than focusing on OPA, and research on OPA in China has omitted the rural population due to difficulties in standardizing the definition of OPA.[17] Second, our study leveraged data from two national databases to compile a representative cohort. By integrating socio-demographic and health-related data from the CCDRFS with mortality specifics from the NMSS, we conducted comprehensive multivariable analyses to ascertain the distinctive influence of OPA on mortality accounting for potential confounders. Third, we employed the GPAQ, a well-validated instrument devised by the WHO, to gather data on physical activity. The agreement of GPAQ and objective accelerometer was satisfactory for MVPA, and the test-retest reliability was reasonable.[23,36] The intensity, duration, and frequency of physical activities were aggregated using a standardized methodology, enabling consistent assessment of physical activities across settings. Finally, leveraging a wealth of baseline characteristic data, we were able to conduct analysis by sub-segments, which reveal variations in the OPA-mortality association cross different demographics such as gender and smoking status.

There are several limitations in this study. First, the data on OPA was self-reported and collected through GPAQ. Participants response might be subjected to recall bias. Potential confusion between working MVPA duration and total working hours may inflate the results. Sensitivity analysis, with truncated occupational MVPA at the upper end suggested study findings were robust. Second, an underlying assumption in this study was that baseline level of OPA remained stable over the study period. It is entirely possible that individuals switched jobs and their corresponding OPA level changed. However, due to data limitations, we are unable to assess OPA changes over time. Sensitivity analyses excluding younger and older participants who had higher occupational instability yielded similar results. Third, the NMSS is subject to some degree of underreporting and potential coding error. However, as the Chinese national death registry, it is considered the gold standard dataset for mortality. Fourth, the duration of follow-up is not sufficient to ascertain long-term outcomes. Fifth, several potential residual confounding might not be adequately captured, such as individual's engagement in light-intensity occupational physical activity, working conditions, work-related stress, work duration, and non-occupational physical activity. However, variables related to work characteristics tends to be heterogeneous, resulting in analytic noise that hinders the detection of underlying relationship between OPA and mortality. Sixth, the inherent nature of observational studies means that our results were susceptible to reverse causation. To mitigate this issue, we excluded participants with pre-existing severe diseases and conducted a two-year landmark analysis. The results suggested that our models and conclusions remained robust. Finally, the generalization of our findings to other low-and middle-income countries may be limited due to diverse cultural, socioeconomic, and health system factors.

In conclusion, our prospective cohort study has unveiled systematic differences in the associations of occupational MVPA with all-cause and CVD mortality risks between urban and rural settings in China. While higher OPA levels were tied to a lower mortality risk in rural setting, this association was not observed in urban setting. The current WHO Guidelines on Physical Activity and Sedentary Behaviour recommends physical activities in any form for health promotion.[37] Although this recommendation remains sound, the urban-rural disparities identified in this study underscore the advocation of other healthy lifestyles for urban working population who receive less benefits from OPA. For instance, promoting leisure-time physical activities may be relevant in urban context but less so in rural context where majority of the population regularly engaged in vigorous OPA. Further studies with objective measures of OPA are needed to validate our results and support the development and implementation of context-relevant policies around physical activities to reduce health inequality.

Contributors

JL and XZ contributed equally to the paper as joint first authors. MZ, LW, and MN are joint corresponding authors. MZ, LW, and MN conceived and designed the study. MZ, LW, and XZ verified the underlying data. JL and XZ performed the statistical analysis and drafted the manuscript. All authors contributed to the interpretation of the results and critical revision of the manuscript and approved the final version of the manuscript.

Data sharing statement

The study data underlying the results of this article are available for investigators upon approval by the Chinese Center for Disease Control and Prevention (Beijing, China). Please email the corresponding author for more information.

Declaration of interests

The authors declare they have no actual or potential competing financial interests.

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Appendix A. Supplementary data

Supplementary data related to this article can be found at https://doi.org/10.1016/j.lanwpc.2024.101083.

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