



Original Research

Contribution of physical activity to intrinsic capacity differs in USA, UK, Europe and China

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ABSTRACT

BACKGROUND: Within-country studies show that physical activity is associated with better intrinsic capacity. **OBJECTIVES:** To examine whether the contribution of physical activity to intrinsic capacity varies between countries due to varying social determinants, and whether physical activity associates differently with only certain domains of intrinsic capacity.

DESIGN: Prospective cohort studies.

SETTING: Populations of the USA, UK, Europe, and China.

PARTICIPANTS: Nationally representative samples of middle-aged and older adults who were interviewed every two or three years.

MEASUREMENTS: Intrinsic capacity was assessed according to the following domains: locomotor, vitality, cognition, vision and hearing, and psychological health. Physical activity was defined as taking part in vigorous or moderate physical activity was more than weekly.

RESULTS: Physical activity was associated with better intrinsic capacity in both genders in USA, UK, and Europe, but not in China. In these developed countries, physical activity was associated with all domains of intrinsic capacity, except for cognition in men in the UK. The largest effect sizes were observed in the domains of locomotion, psychological health, and vitality. In China, physical activity was significantly and positively associated with two domains of intrinsic capacity (vitality and locomotion) for men and women only in rural areas.

CONCLUSIONS: Physical activity may contribute differently to intrinsic capacity, perhaps as a result of cultural and economic differences between countries.

1. Introduction

In the current United Nations' decade of Healthy Aging, the metric proposed to be used for monitoring country progress is intrinsic capacity [IC] [1]. The advantage of this metric is that it can be used as a summative score to reflect function in multiple domains, as well as the cumulative impact of social determinants of health throughout the life course. Physical activity [PA] has been widely promoted as one of the key healthy behaviours for good health outcomes [2–4]. The relationship between PA and IC has been reported in recent years. Previous studies reported that PA was associated with better IC [5–10]. Consistent associations were identified between better IC and PA, even when performed leisurely and at moderate intensity, suggesting its role in enhancing muscle strength and cardiorespiratory fitness, which in turn benefit mobility and vitality [10]. These were within-country studies. It is possible that the contribution of PA to IC may vary between countries

due to varying social determinants, such as living and working environment, culture, socioeconomic position, types of exercises etc. Furthermore, PA may associate differently with only certain domains of IC. These research questions were addressed using four population cohorts representing US, UK, Europe, and China.

2. Participants and method

This study utilized data from four longitudinal cohorts: the US Health and Retirement Study (HRS [USA]) [11], the English Longitudinal Study on Ageing (ELSA [UK]) [12], and the Survey of Health, Ageing and Retirement in Europe (SHARE [Europe and Israel]) [13], and the China Health and Retirement Longitudinal Study (CHARLS [China]) [14]. These cohorts allow cross-national comparisons by using similar longitudinal designs, which consist of nationally representative samples of middle-aged and older adults who were interviewed every two or three

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years. All cohorts were approved by the relevant local or national ethics committees and all participants provided informed consent. Supplementary Table 1 shows the waves and years included in the analyses. This study included waves 7–14 of HRS (2004–2019), waves 2, 4, 6, and 8 of ELSA (2004–2017), waves 1–2 and 4–8 of SHARE (2004–2019), waves 1–3 of CHARLS (2011–2016). Waves 1–6 of HRS, waves 1, 3, 5, 7, and 9 of ELSA, wave 3 of SHARE, and wave 4 of CHARLS were excluded, because measurements of vitality were not covered.

2.1. Physical activity

Participants reported how often they engaged in moderate or vigorous PA. A dichotomous variable was used to define physically active if the frequency of moderate or vigorous PA was more than once a week. Participants from HRS, ELSA, SHARE were asked how often they took part in vigorous or moderate PA (for example: running, swimming, cycling, or aerobics), with the following response options: (1) every day or more than once a week; (2) once a week; (3) one to three times a month; and (4) hardly ever or never. In CHARLS, participants reported the number of days engaging in vigorous or moderate PA (for example: heavy lifting, digging, plowing, aerobics, fast bicycling) for at least 10 min every week.

2.2. Intrinsic capacity

The measurements of IC consist of five domains [15]: (1) cognition: immediate recall, delayed recall, and orientation in time; (2) psychological health: Center for Epidemiological Studies Depression (CES-D) or EURO-D for assessing depression; (3) sensory functions: self-rated vision and hearing; (4) locomotion: self-rated walking difficulty and chair-stand difficulty; (5) vitality: grip strength and Body Mass Index (BMI). Each domain of IC was scored as 0 to 2, resulting in a total score ranging from 0 to 10. Higher scores indicated better IC within each domain. IC was considered as a continuous score in the subsequent analyses. More detailed measurements of each variable of IC in all cohorts were listed in Supplementary Table 2.

Wave 1 of SHARE was excluded because the volume of alcohol consumption was not measured, and this information was required as a covariate in examining the association between PA and IC. Participants were excluded for analyses of associations between PA and IC if they were: 1) aged <50 years at baseline, 2) missing baseline sampling weights, 3) missing information on any lifestyle (PA, smoking, alcohol consumption) or covariates at baseline, 4) missing any domains of IC at all waves. The flowchart of sample selections shown in Fig. 1.

All analyses were conducted separately for men and women, as previous research has shown that women often report poorer physical functioning in old age [16], which may influence the relationship between PA and IC. Gender differences were assessed using the Chi-squared test for categorical variables and the *t*-test for continuous variables, respectively.

Linear mixed models were used to investigate associations between PA and overall IC score, as well as individual domains of IC. Since the population in China consisted of both urban and rural participants, a stratified analysis based on urban and rural residency was conducted to take into account potential differences in socioeconomic position, access to healthcare, and other lifestyle factors (smoking and alcohol intake between urban and rural populations [17]. Urban and rural residents were recorded by the household living region at the community level and defined according to National Bureau of Statistics of the People's Republic of China.

Covariates were selected on the basis of previous evidence of associations with lifestyle and IC. Age, marital status (married/partnered or single/divorced), the highest educational levels (less than upper secondary [primary], upper secondary or vocational training [secondary], or tertiary), total household wealth, and number of chronic conditions

(0, 1, or ≥ 2), smoking habit and alcohol intake were included as covariates. Participants were asked if they ever had following conditions: high blood pressure, diabetes, cancer, lung diseases, heart problem, and stroke.

3. Results

Among the 51,943 participants, 23,634 (45.5 %) were men and 28,309 (54.5 %) women. Men were more likely to smoke, drink, and engage in PA than women at baseline across all cohorts ($p < 0.001$). Men had better IC than women in all cohorts ($p < 0.001$) [Table 1]. PA was significantly associated with better IC in both genders in HRS, ELSA, and SHARE, with β values ranging from 0.59 to 0.85 in men and 0.65 to 1.05 in women. However, in CHARLS, there was no significant association between PA and IC (β 0.11, 95 % CI $-0.03, 0.25$ for men; β 0.08, 95 % CI $-0.06, 0.22$ for women) [Fig. 2]. In HRS, ELSA, and SHARE, PA was associated with all domains of IC, except for cognition in men in ELSA (β 0.03, 95 % CI $-0.02, 0.08$). The largest effect sizes were observed in locomotion, psychological health, and vitality. In CHARLS, PA was only significantly associated with vitality (β 0.08, 95 % CI 0.02, 0.14 for men; β 0.12, 95 % CI 0.07, 0.18 for women) [Fig. 3].

In China, PA was significantly associated with better IC only in rural women (β 0.32, 95 % CI 0.13, 0.52). There was positive association between PA and two domains of IC in rural residents, including vitality (β 0.08, 95 % CI 0.01, 0.16 for men; β 0.17, 95 % CI 0.10, 0.24 for women) and locomotion (β 0.07, 95 % CI 0.01, 0.13 for men; β 0.10, 95 % CI 0.03, 0.16 for women). No significant associations between PA and IC or its composite domains were observed among urban residents [Fig. 4].

4. Discussion

This cross-national study observed that PA was positively associated with better IC for both sexes, with stronger associations observed in Western populations (HRS, ELSA, SHARE) compared to Chinese populations (CHARLS). Notably, in HRS, ELSA, and SHARE, PA was associated with various domains of IC, particularly locomotion, psychology, and vitality; however, in CHARLS, PA was associated only with the vitality and vitality domains.

4.1. Positive association between PA and IC

In line with previous literature [9,10], this study showed the positive relationship between PA and IC, and demonstrated these associations were consistent across different cohorts. Several studies have reported that PA was associated with improved IC, highlighting its role in promoting well-being among older adults [9,10]. Beyond studies focusing on IC, the positive relationship between PA and healthy aging has been extensively documented. Evidence from multi-cohort studies suggested a positive association between PA and healthy aging, potentially helping to mitigate declines in health and functioning [18]. A systematic review revealed that longitudinal observational studies consistently demonstrated a positive association between PA and healthy aging, particularly in high-income countries, regardless of the definitions and measurements used [19]. Utilizing harmonized data from four longitudinal aging cohorts, this study strengthens the evidence that enhancing PA can be a public health intervention for improving IC and overall health outcomes, thereby promoting in successful aging among older adults.

More specifically, the association between PA and IC was primarily reflected in three domains: locomotion, vitality, and psychological health. Previous studies have shown that PA was associated with better muscle and power measured by handgrip strength, chair stand test and gait speed, which are indicators of mobility and vitality [20,21]. Furthermore, regular physical exercise can alleviate symptoms of depression and anxiety and improve sleep quality, both of which may

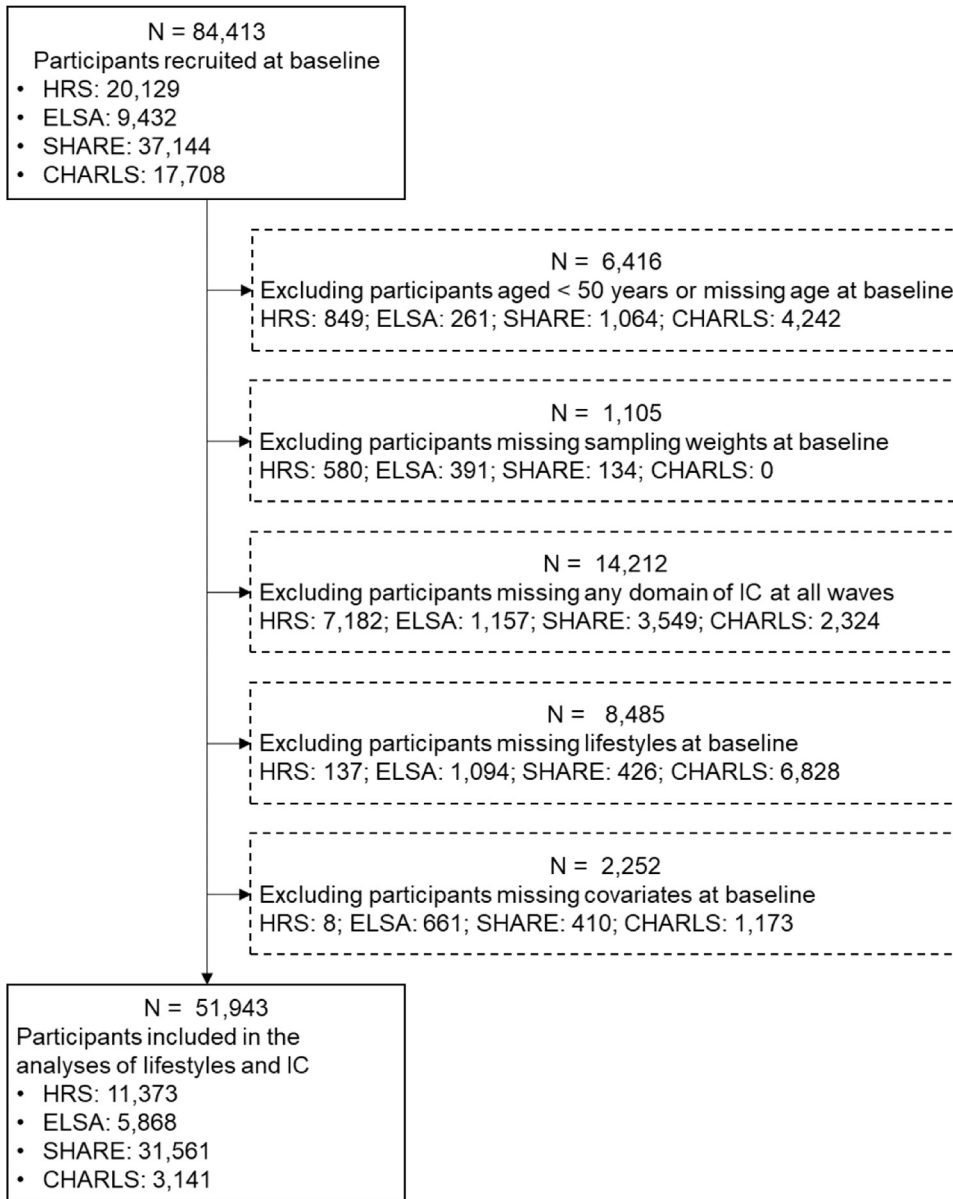


Fig. 1. Flowchart of sample selection.

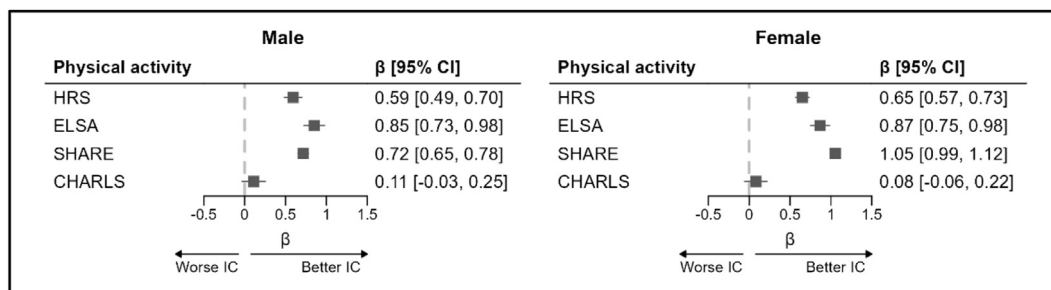


Fig. 2. Associations between PA and IC.

Linear mixed models were adjusted for age, marital status, education, wealth, follow-up years, smoking habit and alcohol intake, and number of chronic diseases (categorized as 0, 1, ≥ 2 , including hypertension, diabetes, stroke, cardiovascular diseases, lung diseases, and cancer). HRS = Health and Retirement Study. ELSA = English Longitudinal Study of Ageing. SHARE = Survey of Health, Ageing and Retirement in Europe. CHARLS = China Health and Retirement Longitudinal Study.

Table 1
Participants characteristics at baseline by cohort and sex.

Characteristics	HRS		p Value	ELSA		p Value	SHARE		p Value	CHARLS		p Value
	Women, N = 6559	Men, N = 4814		Women, N = 3089	Men, N = 2779		Women, N = 16,998	Men, N = 14,563		Women, N = 1663	Men, N = 1478	
Age (years)	68.2 (8.6)	68.1 (8.3)	0.7	65.7 (9.4)	65.3 (8.9)	0.4	64.2 (9.6)	64.7 (9.3)	<0.001	60.8 (7.6)	61.7 (7.7)	<0.001
Educational levels			<0.001			<0.001			<0.001			<0.001
Primary	1427 (21.8 %)	984 (20.4 %)		1406 (45.5 %)	867 (31.2 %)		8640 (50.8 %)	6165 (42.3 %)		1548 (93.1 %)	1279 (86.5 %)	
Secondary	4040 (61.6 %)	2557 (53.1 %)		1347 (43.6 %)	1399 (50.3 %)		5428 (31.9 %)	5011 (34.4 %)		98 (5.9 %)	163 (11.0 %)	
Tertiary	1092 (16.6 %)	1273 (26.4 %)		336 (10.9 %)	513 (18.5 %)		2930 (17.2 %)	3387 (23.3 %)		17 (1.0 %)	36 (2.4 %)	
Married/partnered	3833 (58.4 %)	4002 (83.1 %)	<0.001	1979 (64.1 %)	2266 (81.5 %)	<0.001	11,792 (69.4 %)	12,501 (85.8 %)	<0.001	1395 (83.9 %)	1324 (89.6 %)	<0.001
Total household wealth			<0.001			<0.001			<0.001			>0.9
Quartile 1 (lowest)	2402 (36.6 %)	1351 (28.1 %)		1087 (35.2 %)	850 (30.6 %)		5985 (35.2 %)	4437 (30.5 %)		554 (33.3 %)	483 (32.7 %)	
Quartile 2	2138 (32.6 %)	1619 (33.6 %)		1016 (32.9 %)	920 (33.1 %)		5564 (32.7 %)	4844 (33.3 %)		549 (33.0 %)	487 (32.9 %)	
Quartile 3 (highest)	2019 (30.8 %)	1844 (38.3 %)		986 (31.9 %)	1009 (36.3 %)		5449 (32.1 %)	5282 (36.3 %)		560 (33.7 %)	508 (34.4 %)	
Number of chronic diseases			<0.001			0.003			<0.001			0.042
No disease	2160 (32.9 %)	1426 (29.6 %)		1384 (44.8 %)	1215 (43.7 %)		7953 (46.8 %)	6514 (44.7 %)		883 (53.1 %)	849 (57.4 %)	
One disease	2500 (38.1 %)	1705 (35.4 %)		1153 (37.3 %)	971 (34.9 %)		5870 (34.5 %)	4870 (33.4 %)		526 (31.6 %)	434 (29.4 %)	
≥ 2 diseases	1899 (29.0 %)	1683 (35.0 %)		552 (17.9 %)	593 (21.3 %)		3175 (18.7 %)	3179 (21.8 %)		254 (15.3 %)	195 (13.2 %)	
Smoking			<0.001			<0.001			<0.001			<0.001
Never smoking	3420 (52.1 %)	1472 (30.6 %)		1377 (44.6 %)	783 (28.2 %)		10990 (64.7 %)	5297 (36.4 %)		1520 (91.4 %)	379 (25.6 %)	
Former smoking	2335 (35.6 %)	2699 (56.1 %)		1282 (41.5 %)	1581 (56.9 %)		3213 (18.9 %)	5841 (40.1 %)		31 (1.9 %)	232 (15.7 %)	
Current smoking	804 (12.3 %)	643 (13.4 %)		430 (13.9 %)	415 (14.9 %)		2795 (16.4 %)	3425 (23.5 %)		112 (6.7 %)	867 (58.7 %)	
Alcohol consumption			<0.001			<0.001			<0.001			<0.001
No drinking	3720 (56.7 %)	1998 (41.5 %)		398 (12.9 %)	209 (7.5 %)		10973 (64.6 %)	5556 (38.2 %)		1437 (86.4 %)	547 (37.0 %)	
Low-to-moderate drinking	2500 (38.1 %)	2512 (52.2 %)		2272 (73.6 %)	1980 (71.2 %)		4012 (23.6 %)	6811 (46.8 %)		189 (11.4 %)	615 (41.6 %)	
Heavy drinking	339 (5.2 %)	304 (6.3 %)		419 (13.6 %)	590 (21.2 %)		2013 (11.8 %)	2196 (15.1 %)		37 (2.2 %)	316 (21.4 %)	
Physical activity	4733 (72.2 %)	3934 (81.7 %)	<0.001	2379 (77.0 %)	2318 (83.4 %)	<0.001	14429 (84.9 %)	12712 (87.3 %)	<0.001	1016 (61.1 %)	994 (67.3 %)	<0.001
Intrinsic capacity	7.7 (1.8)	8.0 (1.6)	<0.001	8.2 (1.6)	8.5 (1.5)	<0.001	8.6 (1.6)	8.9 (1.3)	<0.001	7.7 (1.6)	8.2 (1.5)	<0.001

Notes: HRS = Health and Retirement Study; ELSA = English Longitudinal Study on Ageing; SHARE = Survey of Health, Aging and Retirement in Europe; CHARLS = China Health and Retirement Longitudinal Study. Differences between sexes in categorical variables were assessed using Chi-squared test, and differences in continuous variables were assessed using the t-test.

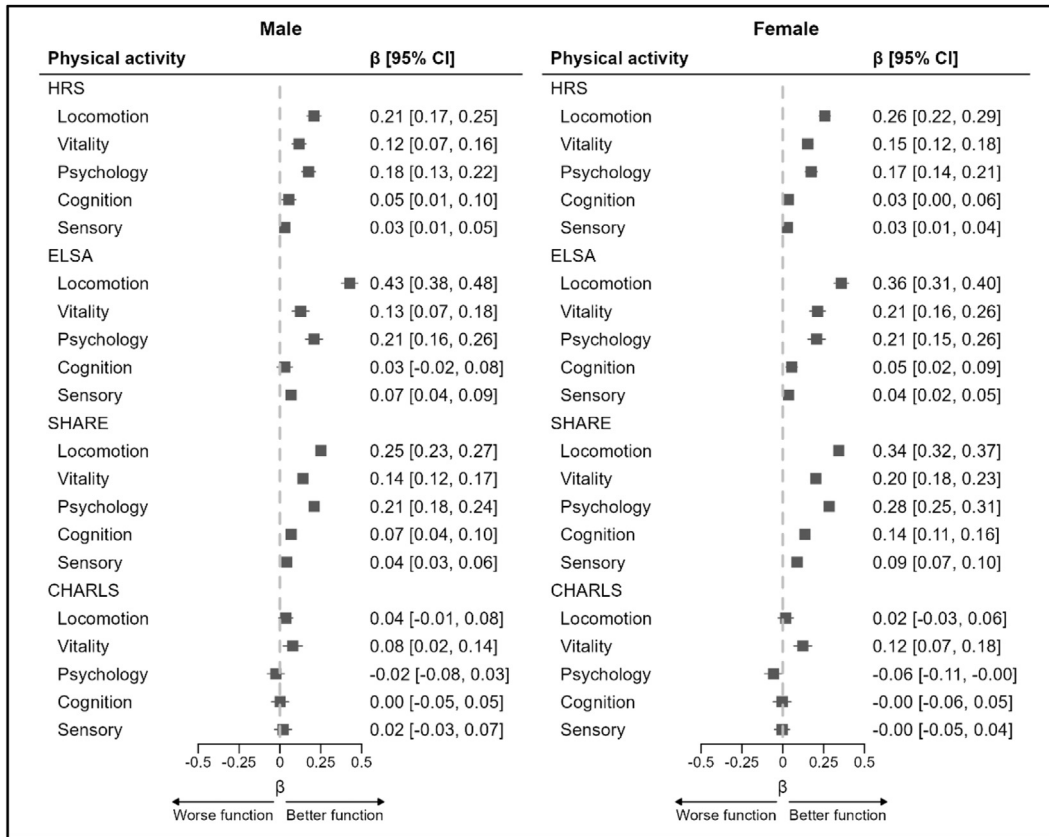


Fig. 3. Associations between PA and single domains of IC.

Linear mixed models were adjusted for age, marital status, education, wealth, follow-up years, smoking habit, alcohol intake, and number of chronic diseases (categorized as 0, 1, ≥2, including hypertension, diabetes, stroke, cardiovascular diseases, lung diseases, and cancer). HRS = Health and Retirement Study. ELSA = English Longitudinal Study of Ageing. SHARE = Survey of Health, Ageing and Retirement in Europe. CHARLS = China Health and Retirement Longitudinal Study.

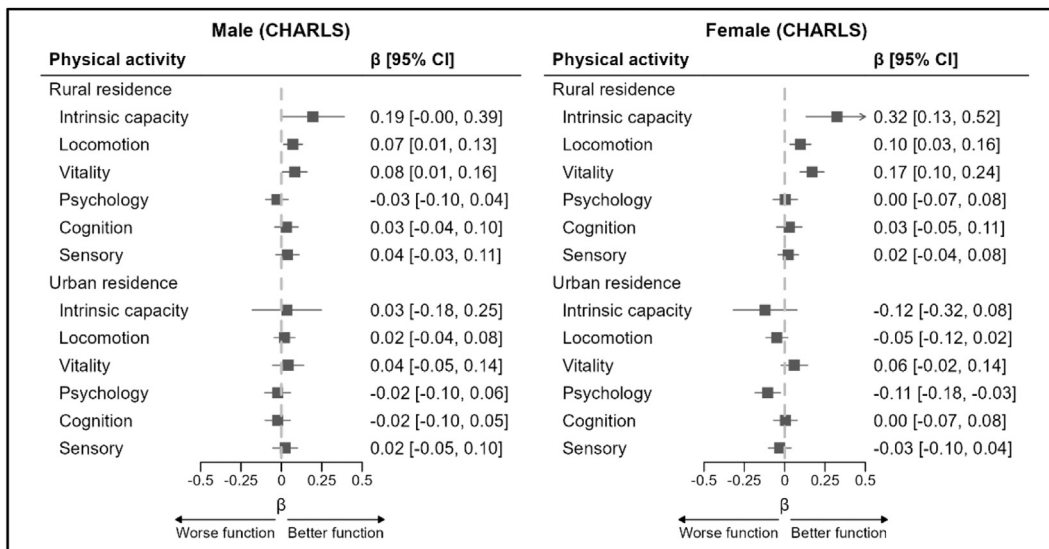


Fig. 4. Associations between PA and IC by sex and residence area in CHARLS.

Linear mixed models were adjusted for age, marital status, education, wealth, follow-up years, smoking habit, alcohol intake, and number of chronic diseases (categorized as 0, 1, ≥2, including hypertension, diabetes, stroke, cardiovascular diseases, lung diseases, and cancer). CHARLS = China Health and Retirement Longitudinal Study.

contribute to enhanced psychological health [22]. These findings suggest that engaging in PA not only supports physical capabilities but also plays a crucial role in promoting psychological well-being among older adults. By improving locomotion, vitality, and psychological health, PA serves as a multifaceted intervention that can ultimately enhance IC.

4.2. Cross-national differences in the association between PA and IC

Despite several studies exploring the relationship between PA and IC, most research has focused on single countries. To facilitate cross-national comparisons, this study harmonized data from four cohorts, revealing that the positive association between PA and IC was more pronounced in the US, UK, and European countries than in China. Furthermore, in Western countries, PA was positively associated with all domains of IC, especially locomotion, vitality, and psychological health, while in China, this association was primarily observed in the vitality domain.

The observed differences in the relationship between PA and IC may be attributed to the various types of physical activities commonly engaged in across different countries. Cultural backgrounds can influence the preferred types of PA among older adults. A prior study indicated that older adults in the US were more likely to utilize specialized equipment for exercise, such as aerobic machines, weightlifting, and strength training tools, and they also participated in cycling more frequently [23]. In contrast, older people in China tended to engage in traditional activities like Tai Chi [23]. These different types of exercise may offer varying benefits for physical and psychological health. For instance, a study conducted in the US found that team sports, cycling, and aerobic and gym activities were most strongly associated with improved mental health outcomes [24]. Therefore, to improve the PA levels of older adults, it is crucial to promote professional guidance in exercise programs and to provide facilities that cater to diverse exercise preferences. By offering more options, older adults can participate in activities that not only suit their interests but also support their overall health and well-being.

4.3. Differences in the association between PA and IC among urban and rural residents in China

This study explored the differences in the relationship of PA with IC in rural and urban populations using nationally representative data from China. The results showed that, for rural residents, PA had a positive effect on IC, particularly in terms of locomotion and vitality. In contrast, the association between PA and IC was not statistically significant among urban residents. Prior research has indicated that in China, job demand is a major motivator for PA, and the degree of socioeconomic inequality between active and inactive individuals differs between urban and rural areas [25,26]. In urban settings, older adults who engage in occupational PA tend to have lower socioeconomic position compared with those who are inactive [17]. In contrast, such socioeconomic disparities are less pronounced in rural areas [17]. Lower socioeconomic position is generally associated with poorer health outcomes, and the positive effects of PA may not be sufficient to offset the negative impact of lower socioeconomic position [17]. Additionally, in urban areas, individuals who engage in occupational PA often lack adequate healthcare coverage, or have limited insurance benefits, which may further influence health outcomes [27]. Another factor could be the difference in the intensity of PA between urban and rural residents. The proportion of individuals engaging in vigorous PA is higher in rural areas than in urban areas (58.1% vs 40.6%). Compared to moderate PA, vigorous PA is more closely linked to better outcomes in healthy aging [19], which might explain the observed differences in the association between PA and IC.

4.4. Limitations

There are limitations in this study. Information regarding PA is only captured using questionnaires, which do not include any objective mea-

surements such as actigraph data. While the pattern of association between PA and IC in the US, UK and Europe, representing developed countries, is observed to be different from China, a developing country, current data do not allow for an explanation for the difference. Further detailed research will be needed regarding types of PA in terms of leisure, occupation, and household categories, as well as the intensity. Nevertheless, this is the first study to show that PA may contribute differently to IC, perhaps as a result of cultural and economic differences between countries.

5. Conclusion

In this cross-national longitudinal study, we found that moderate to vigorous PA was related to better IC, with the exception of the urban Chinese population in which such association was not clearly observed. PA could be incorporated as part of the public health strategies for health ageing. Nonetheless, such interventions may need to be designed with reference to cultural and economic contexts.

Declaration of competing interest

The authors report no conflicts of interest.

CRedit authorship contribution statement

Z Huang: Data curation, Formal analysis, Writing – original draft, Writing – review & editing. **ETC Lai:** Supervision, Writing – original draft, Writing – review & editing. **J Woo:** Conceptualization, Writing – original draft, Writing – review & editing, Project administration, Supervision.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.jarlif.2025.100007.

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