Ageing & Society (2024), **44**, 2464–2483
doi:10.1017/S0144686X2200143X

ARTICLE

Longitudinal patterns and sociodemographic profiles of health-related behaviour clustering among middle-aged and older adults in China and Japan

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(Accepted 1 December 2022)

Abstract

Given inevitable age-related decreases in physical or mental capacity, studies on health-related behaviour (HRB) clustering in older people provide an opportunity to reduce health-care costs and promote healthy ageing. This study explores the clustering of HRBs and transition probabilities of cluster memberships over time, and compares socio-demographic characteristics of these clusters among Chinese and Japanese middle-aged and older adults. Using the China Health and Retirement Longitudinal Study (CHARLS) from 2011 to 2015 (N = 19614) and the Japanese Study of Ageing and Retirement (JSTAR) from 2007 to 2011 (N = 7,080), Latent Transition Analysis was applied to investigate the clustering and change in clustering memberships of smoking, alcohol consumption, physical activity and body mass index. Multivariate logistic regression was used to explore the sociodemographic characteristics of these longitudinal HRB cluster members. We identified four common clusters in CHARLS and JSTAR: 'smoking', 'overweight or obese', 'healthy lifestyle' and 'current smoking with drinking', and an additional cluster named 'ex-smoking with drinking' in JSTAR. Although HRB cluster members were largely stable in both cohorts, participants in China tended to move towards an unhealthy lifestyle, while participants in Japan did the opposite. We also found that participants who smoked and drank were more likely to be male, younger, less educated and unmarried in both cohorts, but the overweight or obese participants were female, urban and higher income in CHARLS but not JSTAR. Our study not only contributes to the knowledge of longitudinal changes in health-related behavioural clustering patterns in an Asian elderly population, but may also facilitate the design of targeted multi-behavioural interventions to promote healthy lifestyles among older people in both countries.

Keywords: health-related behaviours; longitudinal methods; socioeconomic status; transition models

Introduction

Healthy lifestyle has been shown to be beneficial to the physical and cognitive function of older people (Lai *et al.*, 2020; Li *et al.*, 2020). Moreover, increasing epidemiological studies have shown that health-related behaviours (HRBs) tend to cluster together (Liao *et al.*, 2019), and exert a synergistic effect on health (Loef and Walach, 2012; Noble *et al.*, 2015). Interventions on clustering of HRBs may render greater impacts than interventions on individual health behaviours (Poortinga, 2007; Noble *et al.*, 2015). Addressing these behaviours together holds the potential to promote healthy ageing and reduce health-care costs (Manuel *et al.*, 2019).

Prior studies have largely focused on the four major modifiable HRBs of smoking, nutrition, alcohol consumption and physical activity, commonly known as 'SNAP' risk factors (The Royal Australian College of General Practitioners, 2004). However, most of these studies were cross-sectional and only captured a snapshot of lifestyle at a single point in time, while little is known about how HRB clusters change over time. There was some evidence of longitudinal clustering of HRBs in older age with contradictory findings. A handful of studies suggested that HRB cluster membership was largely stable as people aged (Burgard *et al.*, 2018; Mawditt *et al.*, 2019). On the other hand, other studies showed that the proportion of clusters with risky HRBs (*i.e.* smoking, heavy alcohol consumption, low fruit and vegetable consumption, and low physical inactivity) was likely to decrease with age (Goodhind *et al.*, 2014).

Sociodemographic characteristics of the study participants may be key factors associated with longitudinal changes in multiple HRBs (Rabel *et al.*, 2019). In recent years, more evidence has emerged that sociodemographic characteristics, particularly gender, education (Stelmach *et al.*, 2004) and socioeconomic status (Kim *et al.*, 2004), may exert an impact on health outcomes through influencing the choice of HRBs. The findings are not consistent amongst countries of different economic development status. In developing countries, people of higher socio-economic status have less-positive lifestyles and higher prevalence of nutrition-related non-communicable diseases, whereas the opposite is found in developed countries (Kim *et al.*, 2004; McEniry *et al.*, 2019).

Unlike studies based on a single country (Hsu *et al.*, 2013; Burgard *et al.*, 2018; Mawditt *et al.*, 2020), cross-country comparison allows for the identification of similarities and differences of HRB patterns in older ages, and facilitates the adaption of population-based health promotion programmes globally (Kim *et al.*, 2004; Liao *et al.*, 2019). Our prior study has revealed variations in HRB clusters in the West and East cross-sectionally (Liao *et al.*, 2019), yet detailed comparisons over time and with reference to the study participants' socioeconomic status were not explored. To investigate these issues further on a more equivalent basis, the current study focused on China and Japan, considering their eastern Asia locations and shared Confucian culture. Moreover, the trajectory of population ageing in China largely resembles Japan's pattern with a 20-year lag time (United Nations, 2019). This comparison would be particularly beneficial for a fast-ageing China to gain insights from its neighbouring country, Japan, which has the oldest population structure in the world (Chen *et al.*, 2019).

We aimed to explore the longitudinal clustering of four major modifiable HRBs (*i.e.* smoking, alcohol consumption, physical activity and body mass index (BMI)) in China and Japan. Changes in and sociodemographic differences of these cluster memberships between countries were also explored. Our cross-country findings would contribute to the evidence on HRB clustering patterns over time in eastern Asian elderly populations, and facilitate the design of targeted multi-behavioural interventions to promote healthy lifestyles.

Methods

Study population

Data were derived from two nationally representative longitudinal cohorts of middle-aged and older adults, namely the China Health and Retirement Longitudinal Study (CHARLS) (Zhao *et al*., 2014) and the Japanese Study of Ageing and Retirement (JSTAR) (Hidehiko *et al*., 2009). The baseline (Wave 1) survey of CHARLS was conducted in 2011–2012 with 17,708 participants and follow-up surveys were conducted in 2013–2014 (Wave 2) and 2015–2016 (Wave 3), including 1,618 and 4,814 additional participants, respectively. JSTAR included 4,163 people on the baseline (Wave 1) survey in 2007, which added 1,567 new participants in 2009 (Wave 2) and 2,184 new participants in 2011 (Wave 3).

Harmonised data were available for three waves of CHARLS from 2011 to 2015 and JSTAR from 2007 to 2011. We restricted the age of participants to 50 years and older to make the study samples of the two datasets comparable, yielding a sample size of 21,094 for CHARLS and 7,116 for JSTAR. Among these, 1,480 (7.02%) CHARLS and 36 (0.50%) JSTAR participants were missing all HRB variables across waves. The final analysis samples were 19,614 for CHARLS and 7,080 for JSTAR, respectively, with 953 CHARLS and 285 JSTAR participants having only one HRB variable in at least one wave, although full-information maximum likelihood (FIML) could estimate the other HRB variables during the analysis.

HRB measures

Smoking, alcohol consumption, physical activity and BMI were included as four variables to capture the clustering of HRBs in this study. Whilst BMI is not considered to be a HRB, it is often used as a proxy for diet (Campostrini and McQueen, 2003). Smoking was categorised as 'non-smoking', 'ex-smoking' and 'current smoking', based on the participants' smoking history and current smoking behaviour. Drinking alcohol was divided into 'non-drinking', 'less than once per week' and 'once per week or more' in accordance with the frequency of drinking alcohol. Physical activity was grouped into two categories determined by whether or not people had 10 minutes of exercise per day. BMI was calculated by dividing the weight (in kilograms (kg)) by the square of the height (in metres (m^2)). Referring to the Asian adult BMI classification criteria by the World Health Organization (World Health Organization, Regional Office for the Western Pacific, 2000), we defined BMI < 18.5 kg/m^2 as 'underweight', BMI > 23 kg/m^2 as 'overweight/obese', with the range in-between defined as 'healthy weight'.

Sociodemographic variables

The sociodemographic variables of age, gender, urban/rural (only in CHARLS), income, education level and marital status were included in this study. Age was divided into three categories (50–60, 61–70, >70 years). Income was divided into four categories (<25%, 25 to <50%, 50–75%, >75%) using the national average income as the 50 per cent point. Education level was categorised as 'primary/lower secondary', 'upper secondary/vocational' and 'tertiary'. Marital status was classified into the following categories: 'married/partnered', 'separated/divorced/widowed' and 'never married'. All information was based on self-report.

Statistical analysis

We described the distribution of HRB variables and sociodemographic variables in three waves of the two cohorts using frequencies. Latent Transition Analysis (LTA) is a longitudinal extension of Latent Profile Analysis, which was applied to detect distinct HRB clusters across these two cohorts and measure the transitions of HRB cluster members in Waves 1–3, using Mplus version 8 (Muthén and Muthén, 2017). The LTA model was run in JSTAR and CHARLS separately. Log-likelihood, entropy, Akaike Information Criterion (AIC), Bayesian Information Criterion (BIC) and adjusted Bayesian Information Criterion (aBIC) fit statistics, from LTA models with between two and five clusters, were compared in order to determine the optimal LTA model (Collins and Lanza, 2010). Estimates from the LTA models were also examined to ascertain cluster interpretability.

The LTA model consists of three parameters (Collins and Lanza, 2010). The first is the probability of being in a particular HRB cluster at each time-point. The second is the probability of a participant's response to the observed variables given their HRB cluster membership at each time-point. These second parameters assess the degree of error in each observed indicator in capturing the latent variable. The third is the probability of transitioning to a HRB cluster at the next time-point (*e.g.* Wave 2) given membership in the HRB cluster at the previous time-point (*e.g.* Wave 1) (Mawditt *et al.*, 2019). The maximum likelihood solution was identified using the robust maximum likelihood estimator. The maximum likelihood estimate was determined by running multiple sets of random starts (4,000 partially, 1,000 fully). Missing data were handled with the FIML function in Mplus version 8 (Muthén and Muthén, 2017), utilising all available information in the data under a missing at random assumption (Enders, 2010).

A multivariate logistic regression method was used to characterise the social attributes of the members of the clusters identified through the LTA. Tests were two-tailed with a significance level of $p < 0.05$. Analyses were carried out using the statistical software Stata/MP 14.

Results

Descriptive statistics of HRB and sociodemographic variables

We included 19,614 participants in CHARLS and 7,080 in JSTAR aged 50 years and over. The sociodemographic characteristics of the sample are presented in Table 1. The mean age of both cohorts at the first wave was around 60 years and half were female.

The distributions of marital status, income, smoking and physical activity were similar in China and Japan, *i.e.* most people were married, more people were never smoking and exercising regularly, and income was distributed equally at all levels. However, there were differences between the two cohorts in the distribution of education, BMI and alcohol consumption, with more Chinese participants having lower levels of education and obesity, and more Japanese participants drinking alcohol more than or equal to once a week.

Cluster patterns of HRBs in three waves in Japan and China

The fit indices for all LTA models are shown in the online supplementary material. By comparing the fit indices, we found that the four-cluster model was the best fit for CHARLS, showing the lowest absolute log-likelihood (−98,703.189), and the smallest AIC (197,516.379), BIC (−197,949.999) and aBIC (197,775.211) amongst all multi-cluster models generated. Although its entropy was not the largest, it was still close to 1 (entropy = 0.902). Likewise, five clusters were chosen for JSTAR. Despite the differences in the number of HRB clusters obtained, we had several essentially similar clusters in CHARLS and JSTAR (*see* Table 2). Physical activity was not a main driver for these classifications, as the majority of the study participants were physically active.

In CHARLS, the profiles of the four clusters were as follows. (a) The cluster labelled 'smoking' was characterised by a higher probability of being a current smoker (item response probability (IRP) = 0.37) or an ex-smoker (IRP = 0.63). Individuals in this cluster had almost a 50 per cent probability of being overweight/obese (IRP = 0.47). (b) The 'overweight or obese' cluster was significantly different from the other clusters, with the absence of unhealthy behaviours other than overweight/obese (IRP = 0.94). Most members with this HRB pattern were non-smokers (IRP = 0.99) and non-drinkers (IRP = 0.76). (c) The group labelled 'healthy lifestyle' was characterised by more positive HRBs than the other groups (healthy weight, IRP = 0.79; never smoked, IRP = 1.00; never drank alcohol, IRP = 0.76). (d) The 'current smoking with drinking' group was characterised by the co-occurrence of current smoking (IRP = 0.72) and high frequency of alcohol consumption (IRP = 0.78). Moreover, individuals in the cluster had more than a 40 per cent probability of being overweight/obese (IRP = 0.44). Five clusters were found in JSTAR. Four of them are very similar to those mentioned above and the remaining cluster, labelled 'ex-smoking with drinking', was characterised by ex-smoking (IRP = 0.93), high alcohol consumption (IRP = 0.75), with over half of its members being overweight or obese (IRP = 0.58).

HRB cluster membership transitions across the three waves

The probability of transitioning from one HRB cluster to another over time in CHARLS and JSTAR is shown in Table 3. Participants in both cohorts tended to

Table 1. Sociodemographic characteristics and health-related behaviours of the China Health and Retirement Longitudinal Study (CHARLS) and the Japanese Study of Ageing and Retirement (JSTAR) samples over three waves

	CHARLS (N = 24,097)			JSTAR (N = 7,116)		
Variable and definition	Wave 1	Wave 2	Wave 3	Wave 1	Wave 2	Wave 3
N	16,816	16,872	16,700	3,742	4,122	5,138
	Frequencies (%)					
Age:						
50–60	6,266 (0.37)	6,464 (0.38)	6,765 (0.41)	1,520 (0.41)	1,651 (0.40)	1,231 (0.17)
61–70	4,639 (0.28)	5,373 (0.32)	6,213 (0.37)	1,536 (0.41)	1,668 (0.40)	2,062 (0.29)
71–80+	2,763 (0.16)	3,259 (0.19)	3,680 (0.22)	682 (0.18)	801 (0.19)	1,317 (0.19)
Urban/rural:						
Urban	5,488 (0.33)	6,119 (0.36)	6,743 (0.4)	–	–	–
Rural	8,207 (0.49)	9,001 (0.53)	9,957 (0.59)	–	–	–
Gender:						
Male	8,204 (0.49)	8,236 (0.49)	8,167 (0.49)	1,877 (0.50)	2,042 (0.50)	2,489 (0.48)
Female	8,612 (0.51)	8,635 (0.51)	8,526 (0.51)	1,865(0.50)	2,080 (0.50)	2,649 (0.52)
Education:						
Less than lower secondary	14,658 (0.87)	14,643 (0.87)	14,653 (0.88)	1,260 (0.34)	1,292 (0.31)	1,253 (0.24)
Upper secondary and vocational training	1,770 (0.11)	1,835 (0.11)	1,671 (0.1)	1,859 (0.50)	2,092 (0.51)	2,644 (0.51)
Tertiary	373 (0.02)	382 (0.02)	349 (0.02)	603 (0.16)	717 (0.17)	1,214 (0.24)

Marital status:						
Married/partnered	11,593 (0.69)	12,834 (0.76)	14,139 (0.85)	3,050 (0.82)	3,203 (0.78)	3,944 (0.77)
Separated/divorced/widowed	1,964 (0.12)	2,152 (0.13)	2,429 (0.15)	557 (0.15)	664 (0.16)	832 (0.16)
Never married	129 (0.01)	132 (0.01)	131 (0.01)	125 (0.03)	187 (0.05)	253 (0.05)
Income (%):						
<25	2,887 (0.17)	2,362 (0.14)	2,007 (0.12)	440 (0.12)	583 (0.14)	703 (0.14)
25 to <50	2,894 (0.17)	2,341 (0.14)	2,000 (0.12)	449 (0.12)	586 (0.14)	702 (0.14)
50–75	2,828 (0.17)	2,348 (0.14)	2,002 (0.12)	429 (0.11)	545 (0.13)	722 (0.14)
>75	2,869 (0.17)	2,350 (0.14)	2,003 (0.12)	439 (0.12)	571 (0.14)	683 (0.13)
BMI:						
Underweight	864 (0.05)	699 (0.04)	859 (0.05)	165 (0.04)	204 (0.05)	294 (0.06)
Healthy weight	4,625 (0.28)	4,197 (0.25)	5,000 (0.3)	1,664 (0.44)	1,784 (0.43)	2,351 (0.46)
Overweight/obese	5,190 (0.31)	5,837 (0.35)	7,249 (0.43)	1,838 (0.49)	2,030 (0.49)	2,373 (0.46)
Smoking:						
Never	7,951 (0.47)	8,326 (0.49)	9,046 (0.54)	1,849 (0.49)	1,994 (0.48)	2,596 (0.51)
Ex-smoker	1,234 (0.07)	1,191 (0.07)	2,846 (0.17)	903 (0.24)	951 (0.23)	1,375 (0.27)
Current smoker	3,909 (0.23)	2,305 (0.14)	4,676 (0.28)	814 (0.22)	748 (0.18)	807 (0.16)

(*Continued*)

Table 1. (*Continued.*)

Variable and definition	CHARLS (N = 24,097)			JSTAR (N = 7,116)		
	Wave 1	Wave 2	Wave 3	Wave 1	Wave 2	Wave 3
Drinking:						
Never	8,168 (0.49)	8,191 (0.49)	8,887 (0.53)	1,462 (0.39)	577 (0.14)	1,645 (0.32)
Less than once per week	2,438 (0.14)	3,576 (0.21)	4,180 (0.25)	429 (0.11)	138 (0.03)	1,238 (0.24)
Once per week or more	2,045 (0.12)	3,121 (0.18)	3,433 (0.21)	1,638 (0.44)	452 (0.11)	2,147 (0.42)
Physical activity[1]:						
<7 days per week; <10 minutes per day	1,194 (0.07)	1,098 (0.07)	1,742 (0.1)	229 (0.06)	198 (0.05)	287 (0.06)
≥7 days per week; ≥10 minutes per day	4,158 (0.25)	3,716 (0.22)	5,868 (0.35)	2,113 (0.56)	2,325 (0.56)	2,732 (0.53)

Notes: 1. CHARLS physical activity measured as <7 days per week; JSTAR physical activity measured as <10 minutes per day. BMI: body mass index.
Source: Data from CHARLS, 2011–2015 and JSTAR, 2007–2011.

Table 2. Health-related behaviours clusters of the China Health and Retirement Longitudinal Study (CHARLS) and the Japanese Study of Ageing and Retirement (JSTAR) across the three waves estimated by Latent Transition Analysis model

	CHARLS (N = 21,094)				JSTAR (N = 7,080)				
	Smoking	Overweight or obese	Healthy lifestyle	Current smoking with drinking	Smoking	Overweight or obese	Ex-smoking with drinking	Healthy lifestyle	Current smoking with drinking
Frequencies (%)									
Latent status prevalence:									
Wave 1	4,716 (24.04)	7,453 (38.00)	4,037 (20.58)	3,408 (17.38)	680 (10)	1,887 (27)	1,376 (19)	2,032 (29)	1,105 (16)
Wave 2	5,025 (25.62)	7,339 (37.42)	3,693 (18.83)	3,557 (18.14)	678 (10)	1,836 (26)	1,428 (20)	2,080 (29)	1,058 (15)
Wave 3	5,157 (26.29)	7,309 (37.26)	3,579 (18.25)	3,569 (18.20)	671 (9)	1,819 (26)	1,525 (22)	2,097 (30)	968 (14)
Item response probabilities (standard errors)									
BMI:									
Underweight	0.10 (0)	0	0.15 (0.01)	0.06 (0.01)	0.06 (0.01)	0	0.02 (0.01)	0.12 (0.01)	0.06 (0.01)
Healthy weight	0.44 (0.01)	0.06 (0)	0.79 (0.01)	0.50 (0.01)	0.41 (0.02)	0.07 (0.02)	0.40 (0.01)	0.85 (0.01)	0.51 (0.02)
Overweight/ obese	0.47 (0.01)	0.94 (0)	0.06 (0.01)	0.44 (0.01)	0.53 (0.02)	0.93 (0.02)	0.58 (0.02)	0.03 (0.01)	0.44 (0.02)
Smoking:									
Never	0	0.99 (0.01)	1.00 (0)	0.03 (0.01)	0.03 (0.02)	0.98 (0.01)	0.06 (0.01)	0.99 (0.01)	0.01 (0.01)
Ex-smoker	0.37 (0.01)	0.01 (0.01)	0	0.25 (0.01)	0.52 (0.03)	0.02 (0.01)	0.93 (0.01)	0.01 (0.01)	0.02 (0.01)
Current smoker	0.63 (0.01)	0	0	0.72 (0.01)	0.45 (0.03)	0	0.01 (0.01)	0	0.97 (0.01)

(*Continued*)

Table 2. (*Continued.*)

	CHARLS (N = 21,094)				JSTAR (N = 7,080)				
	Smoking	Overweight or obese	Healthy lifestyle	Current smoking with drinking	Smoking	Overweight or obese	Ex-smoking with drinking	Healthy lifestyle	Current smoking with drinking
Alcohol consumption:									
Never	0.56 (0.01)	0.76 (0.01)	0.76 (0.01)	0.01 (0)	0.90 (0.01)	0.54 (0.02)	0.01 (0.01)	0.51 (0.01)	0.01 (0.01)
Less than once per week	0.40 (0.01)	0.17 (0)	0.15 (0.01)	0.21 (0.01)	0.10 (0.01)	0.18 (0.01)	0.24 (0.01)	0.18 (0.01)	0.18 (0.02)
Once per week or more	0.03 (0)	0.06 (0)	0.08 (0)	0.78 (0.01)	0	0.27 (0.01)	0.75 (0.01)	0.30 (0.01)	0.81 (0.02)
Physical activity:									
<10 minutes per day	0.25 (0.01)	0.23 (0.01)	0.23 (0.01)	0.19 (0.01)	0.12 (0.01)	0.08 (0.01)	0.07 (0.01)	0.08 (0.01)	0.14 (0.01)
≥10 minutes per day	0.75 (0.01)	077 (0.01)	0.77 (0.01)	0.81 (0.01)	0.88 (0.01)	0.92 (0.01)	0.93 (0.01)	0.92 (0.01)	0.86 (0.01)

Source: Data from CHARLS, 2011–2015 and JSTAR, 2007–2011.

Table 3. Transition probabilities from one health-related behaviour (HRB) cluster to another over time in the China Health and Retirement Longitudinal Study (CHARLS) and the Japanese Study of Ageing and Retirement (JSTAR)

CHARLS					JSTAR					
HRB cluster membership	Smoking	Overweight or obese	Healthy lifestyle	Current smoking with drinking		Smoking	Overweight or obese	Ex-smoking with drinking	Healthy lifestyle	Current smoking with drinking
Transition probabilities (standard errors) from Wave 1 (rows) to Wave 2 (columns)										
Smoking	**0.96 (<0.01)**	0[1]	0[1]	0.04	Smoking	**0.98 (0.03)**	0[2]	0[2]	0[2]	0.01 (<0.01)
Overweight or obese	0.05 **(<0.01)**	**0.95 (<0.01)**	0[1]	0[2]	Overweight or obese	0[1]	**0.96 (0.02)**	0[2]	0.01 (0.01)	0[1]
Healthy lifestyle	0.05 **(<0.01)**	0.06 **(0.01)**	**0.87 (0.01)**	0.02	Ex-smoking with drinking	0[1]	0[2]	**0.99 (<0.01)**	0[1]	0[1]
Current smoking with drinking	0[1]	0[1]	0[1]	**1**	Healthy lifestyle	0[1]	0[2]	0[2]	**0.99 (<0.01)**	0[2]
					Current smoking with drinking	0[1]	0[2]	0.10 (0.01)	0.01 (<0.01)	**0.89 (0.01)**
Transition probabilities (standard errors) from Wave 2 (rows) to Wave 3 (columns)										
Smoking	**1 (<0.01)**	0[1]	0[1]	0[1]	Smoking	**0.98 (0.02)**	0.02 (0.01)	0[1]	0[1]	0[1]
Overweight or obese	0[2]	**0.99 (<0.01)**	0[2]	0[2]	Overweight or obese	0[1]	**0.96 (0.01)**	0[1]	0.03 (0.01)	0[2]

(*Continued*)

Table 3. (*Continued.*)

CHARLS					JSTAR					
HRB cluster membership	Smoking	Overweight or obese	Healthy lifestyle	Current smoking with drinking		Smoking	Overweight or obese	Ex-smoking with drinking	Healthy lifestyle	Current smoking with drinking
Healthy lifestyle	0.03 **(<0.01)**	0.02 **(0.01)**	**0.94 (0.01)**	0[2]	Ex-smoking with drinking	0[1]	0[2]	**0.99 (<0.01)**	0[1]	0[1]
Current smoking with drinking	0.02 **(<0.01)**	0[1]	0[1]	**0.98**	Healthy lifestyle	0[1]	0[1]	0[1]	**0.99 (0.01)**	0.01 (0.01)
					Current smoking with drinking	0[1]	0[1]	0.20 (0.01)	0[1]	**0.80 (0.02)**

Note: Transitions probabilities in bold correspond to staying in the same HRB cluster. Transition probabilities sum to 1.0 (with rounding error) across rows. 1. Transitions not estimated in model but instead fixed at 0 in Mplus version 8. 2. Transitions <0.001 and rounded to 0.
Source: Data from CHARLS, 2011–2015 and JSTAR, 2007–2011.

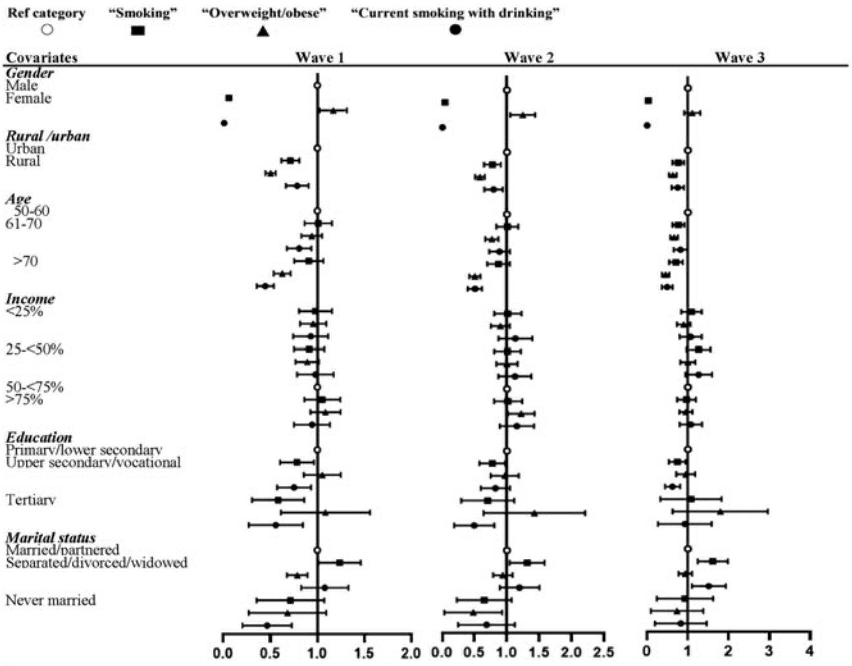

Figure 1. Estimating the association between cluster membership and sociodemographic factors in the China Health and Retirement Longitudinal Study (CHARLS).
Note:Data points represent the estimated association between cluster membership and sociodemographic factors and horizontal continuous lines represent ranges for *CI* (95%) of the association.
Source: Data from CHARLS, 2011–2015.

stay in the same cluster over time (minimum 80%, maximum 100%). However, differences in transition probabilities were observed across the two cohorts. For example, we observed a modest probability of transitioning from the 'healthy lifestyle' cluster to the 'smoking' and 'overweight or obese' clusters over time in CHARLS (5 and 6%, respectively). JSTAR participants showed a 10 per cent probability of transitioning from the 'current smoking and drinking' cluster to the 'ex-smoking and drinking' cluster.

Sociodemographic characteristics of HRB cluster members

Figure 1 illustrates the sociodemographic characteristics of the HRB cluster members in CHARLS. Compared to the 'healthy lifestyle' cluster, the 'smoking' cluster was characterised by being male, younger, urban, less educated and separated/divorced/widowed; the 'overweight or obese' cluster was characterised by being female, younger, urban and higher income; the 'current smoking with drinking' cluster was male, younger, less educated and separated/divorced/widowed. Similar sociodemographic characteristics were found in JSTAR (Figure 2), except that members of the 'overweight or obese' cluster were more likely to be male and less educated.

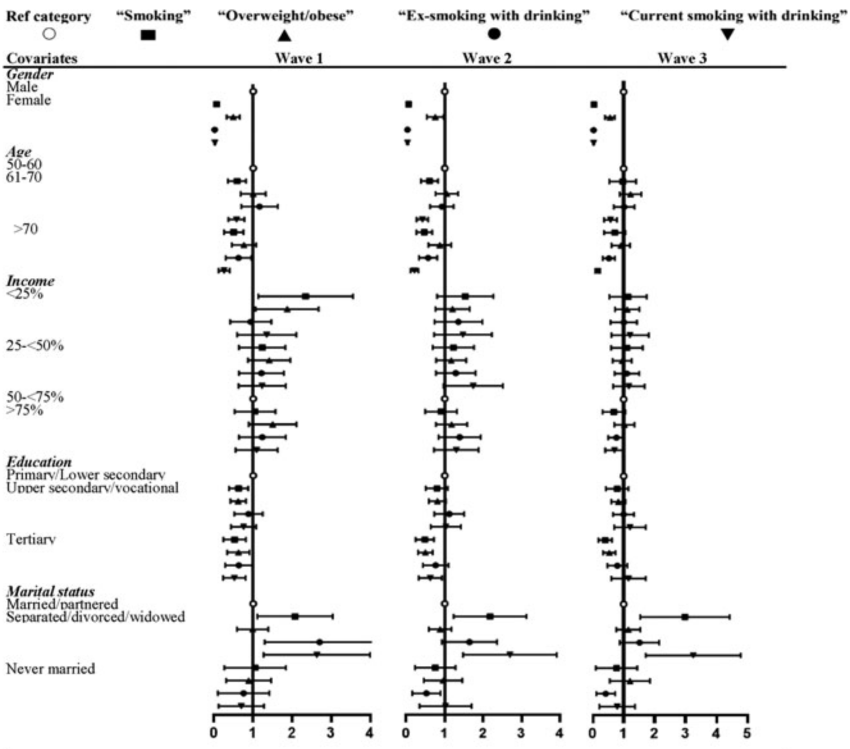

Figure 2. Estimating the association between cluster membership and sociodemographic factors in the Japanese Study of Ageing and Retirement (JSTAR).
Note:Data points represent the estimated association between cluster membership and sociodemographic factors and horizontal continuous lines represent ranges for CI (95%) of the association.
Source: Data from JSTAR, 2007–2011.

Discussion

Using data from two nationally representative ageing cohorts, we identified four common HRB clusters among Chinese and Japanese older adults ('smoking', 'overweight or obese', 'healthy lifestyle' and 'current smoking with drinking'), with an additional cluster named 'ex-smoking with drinking' in JSTAR. We further found that HRB cluster membership was largely stable over time, albeit variations in the direction of HRB cluster transitions and sociodemographic characteristics associated with these clusters differed between countries.

The clustering patterns that we identified are largely consistent with prior review articles, particularly these reporting the clustering of healthy lifestyle and the clustering of smoking and alcohol abuse (Noble *et al.*, 2015; Meader *et al.*, 2016). Our previous cross-sectional study also identified similar clusters in China and Japan (Liao *et al.*, 2019). These findings provided additional evidence for a strong correlation between smoking and alcohol consumption (Jensen *et al.*, 2003; Chou, 2008). As regards BMI, we further found a significant proportion of 'overweight or obese' cluster in China and Japan, particularly in China with more than one-third of participants.

These two countries are facing a serious challenge of overweight or obesity in older adults. Because of the decline in organ function, older adults will be at greater risk of developing chronic diseases associated with overweight and obesity, such as cardiovascular disease, diabetes and cancer, resulting in serious health and economic burdens (Bai *et al.*, 2020). So, concentrations on populations with risk factors should be enhanced to prevent a further increase in obesity across the two countries.

Similarities and differences in the transition of HRB cluster members between China and Japan

We found that most of the members of the HRB clusters remained stable across the two countries over time. This finding was consistent with evidence from previous studies in the United States of America (Burgard *et al.*, 2018), the United Kingdom (Mawditt *et al.*, 2019) and Taiwan (Hsu *et al.*, 2013). Another trajectory study of a single health-impairing behaviour found that HRBs appeared to remain stable much earlier in the lifecourse (adolescence to young adulthood) (Nora *et al.*, 2015). This may be a hint that preventive interventions for HRBs need to be carried out earlier in the population to promote a good lifestyle which may otherwise be difficult to change in the future.

Nevertheless, the cross-country difference was that in China, the probability of maintaining an unhealthy lifestyle pattern was more than 95 per cent, while a relatively low percentage of people were able to maintain a healthy lifestyle pattern. In contrast, in Japan, the probability of maintaining a healthy lifestyle pattern was 99 per cent, and a minority (3%) of people with unhealthy lifestyle patterns also tended to become healthier over time. This improvement in HRBs in Japan may be linked to the Japanese government's lifestyle intervention programme. All health insurance companies in Japan have been required since 2008 to provide health checkups and health guidance to those aged 40–74 years at higher risk of lifestyle-related diseases, to encourage behavioural change towards a healthier lifestyle (Kohro *et al.*, 2008). A three-year follow-up of the programme found that participants showed greater and steady improvements in metabolic syndrome risk factors, such as waist circumference, body weight and BMI (Tsushita *et al.*, 2018). Although China has also been conducting 'China Healthy Lifestyle for All' since 2007, this universal health education-based initiative has been found to improve knowledge and awareness of healthy lifestyles, but the long-term effects on improving health behaviours have yet to be evaluated further (Yuan *et al.*, 2013). This suggests that further policy measures may be needed in China to promote improvements in HRBs among those at high risk of lifestyle diseases.

Another difference we found in the transitions in HRB clustering memberships between the two countries was the occurrence of smoking cessation among the Japanese study population. Between each wave of the JSTAR cohort, there was a transition from the 'current smoking and drinking' cluster to the 'ex-smoking and drinking' cluster, indicating that over time this group of Japanese people began to quit smoking. This also demonstrated an improvement in health-risk behaviours among middle-aged and older adults in Japan, and is consistent with evidence from studies of single health behaviours, such as the declining prevalence of smoking in Japan (Ministry of Health, Labour and Welfare, 2020). Such changes may be related to the tobacco control measures taken by the Japanese government (Goto *et al.*, 2011), the increase in the price of cigarettes (Matsubayashi *et al.*, 2021), the increase in public awareness of the dangers of smoking and possibly changes brought about by the development of age-related non-communicable diseases (Stelmach *et al.*, 2004). Furthermore, in Japan, smoking cessation treatment has been included in health insurance since 2006 (Li *et al.*, 2019). In China, however, we did not find a cluster characterised by ex-smoking, which may be related to the low cessation rate in China (less than 10%), although the study found an increasing number of smokers who stopped smoking, rising from 3 per cent in 1991 to 9 per cent in 2006 (Chen *et al.*, 2015). Therefore, our study could not identify smoking cessation among Chinese smokers, but we found a transition from the 'healthy lifestyle' group to the 'smoking' group, who started smoking over time. This may be related to changes in their marital status, as we found more separations/divorces/widowhoods in the second and third waves of the 'smoking' cluster, and some studies have found lower smoking rates among married men (Lindström, 2010).

Similarities and differences in the sociodemographics of HRB cluster members in China and Japan

Using multiple regression models, we found that the smoking and drinking alcohol populations in China and Japan possessed similar sociodemographic characteristics. Our findings are consistent with existing evidence that smoking and alcohol consumption are more likely to occur in men, in those with low levels of education and in those who are unmarried or divorced (Cho *et al.*, 2008; Lindström, 2010). Moreover, our findings also indicate that participants aged 60 years and above were likely to have more positive HRBs than those aged 50–60, in line with findings reported previously (Schneider *et al.*, 2009; Morris *et al.*, 2016). This may be related to changes in HRBs associated with retirement (the official retirement age was 60 for men and 55 for women in China, and 65 in Japan), such that retired people would have increased time and frequency of outdoor activity (Sjösten *et al.*, 2012; Syse *et al.*, 2017), as well as reduced alcohol consumption and smoking due to fewer work-related social engagements (Liao *et al.*, 2019; Yan *et al.*, 2022).

We also found differences in gender and socioeconomic statuses of the 'overweight or obese' cluster across the two countries, with more females and higher income in China and the opposite in Japan. The variation in gender that we found is consistent with evidence from studies of obesity alone. In China, the prevalence of obesity is significantly higher among women than men (Wang *et al.*, 2001), while in Japan the opposite was true (Nakamura *et al.*, 2018). Although the political and cultural backgrounds of both countries are strongly influenced by Confucianism, differences in stages of socioeconomic development and social perceptions may be able to explain the differences in socioeconomic status of the 'overweight or obese' cluster (Dinsa *et al.*, 2012). For example, in a developing country like China (Noh *et al.*, 2017; The World Bank, 2019), where overweight and obesity are more often seen as symbols of wealth and health, there is greater social tolerance of overweight (Noh *et al.*, 2017). Low socioeconomic status groups are more likely to adopt affordable lifestyles such as low- to moderate-intake diets and higher physical activity, and higher socioeconomic status groups are more likely to adopt high-fat and high-sugar diets and less physical activity due to more options, leading to nutritional non-communicable diseases (*e.g.* obesity) being more prevalent (Kim *et al.*, 2004; Bai *et al.*, 2020). Whereas Japan is a high-income developed country (The World Bank, 2019) that is heavily influenced by Western culture (Noh *et al.*, 2017), and people have become accustomed to unhealthy eating patterns. Moreover, there is a greater social stigma attached to obesity (Noh *et al.*, 2017), and so higher socioeconomic groups are able to make more-considered choices about healthier lifestyles (Nakamura *et al.*, 2016).

The strength of this study lies in the use of comparable nationally representative ageing cohorts from China and Japan to provide additional information on the clustering of HRBs and related sociodemographic characteristics in both countries. This study was expanded to include the 50–65-year-old population compared to the more focused 65+ study. Moreover, longitudinal research allows us to investigate changes in HRB cluster membership over time in each cohort. To contribute to the evidence of change in the clustering of HRBs over time in an Asian elderly population, we applied LTA, a powerful method that considers the interrelationships between multiple HRBs, to identify information on changes in HRB clusters over time. However, there are some limitations to this study. First, measures of HRBs were self-report and respondents may tend to be more likely to underestimate health-damaging behaviours in an attempt to respond in a socially desirable manner (Ferrari *et al.*, 2021). Second, the present study was constrained to the variables and measures available; we were not able to completely harmonise HRB and sociodemographic variables (*e.g.* physical activity and urban/rural) across the two cohorts, nor could we cover all HRBs, but the 'SNAP' risk factors covered common and critical health-related modifiable factors (The Royal Australian College of General Practitioners, 2004). Similarly, restricted by harmonised variables comparable across the two cohorts, this study can only make relatively broad categories of smoking, alcohol consumption and physical activity, and use BMI instead of diet (Campostrini and McQueen, 2003). Future cross-national studies would benefit from more co-ordinated and detailed measures of lifestyle activities. Third, the dates we used differed in the time periods, so participants in both cohorts at the same age would have lived in different conditions early in their lifecourse due to differences in social context (*e.g.* policies, economic and social development, *etc.*) (Lei *et al.*, 2021), thus affecting their current HRBs and limiting comparisons between the same period in China and Japan. However, it also showed the improvement of HRBs in Japan at an earlier time. Finally, the current study only compared the clustering of HRBs and associated sociodemographic characteristics in middle-aged and older adults in China and Japan, without taking health status into consideration. We intend to extend this work by exploring the bidirectional association between HRB cluster membership and health outcomes in the future.

In conclusion, this study found that, in both China and Japan, the clustering profiles of HRBs were highly consistent with several clusters of multiple unhealthy behaviours identified in previous studies, and that people with specific sociodemographic backgrounds were more likely to be in these clusters. These findings could help facilitate the design of targeted multi-behavioural health interventions to promote healthy lifestyles among older adults in both countries. We also found that the majority of HRB cluster members remained stable over time. However, a minority of members in Japan were more inclined to transition to healthier lifestyles, while the opposite was true in China, especially among the overweight or obese and smoking populations. Despite the measures taken by both governments, the positive improvements in BMI and smoking among middle-aged and older adults in Japan could suggest that China can gain insights and experiences from neighbouring Japan and develop nationally appropriate health behaviour promotion policies.

Supplementary material. The supplementary material for this article can be found at https://doi.org/10.1017/S0144686X2200143X.

Author contributions. MW and CY contributed equally to this research.

Financial support. This work was supported by the Guangdong Basic and Applied Basic Research Foundation (grant number 2018A0303130046).

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Cite this article: Wu M, Yang C, Zhang Y, Umeda M, Liao J, Mawditt C (2024). Longitudinal patterns and sociodemographic profiles of health-related behaviour clustering among middle-aged and older adults in China and Japan. *Ageing & Society* **44**, 2464–2483 https://doi.org/10.1017/S0144686X2200143X