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Exploring the physical and mental health of high-speed rail commuters: Suzhou-Shanghai inter-city commuting

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ABSTRACT

Introduction: High-speed rail (HSR), with its remarkable time-space shrinkage, has potentially enlarged labour market catchment areas and encouraged inter-city commuting; much literature, however, links long-distance commutes with health risks.
Methods: This study develops a conceptual framework in which a set of HSR-informed independent variables (shift in long-commute modes, transfer modes and travel time to and from HSR stations, job prospects and living conditions, and socio-economic attributes) are explored to discern physical and mental health variations. Ordinal logistic regression models are used to analyse 288 questionnaire samples from a cross-sectional study of HSR commuters travelling between Suzhou and Shanghai, China.
Results: Gaining insight into factors associated with HSR commuters' physical and mental health, the findings from descriptive analyses reveal a slightly negative association. While travel-related instrumental factors (shift long commute from non-HSR to HSR, active transfer modes, shorter travel times to and from HSR stations) and noninstrumental factors (intimate family and social relationships) show significantly positive health benefits, commuters, such as technicians and professionals, with low rent/mortgage levels (implying lower quality of residence and relative inability to afford home ownership), report significantly negative associations with their health.
Conclusion: This paper concludes that HSR commuting requires personal commitment and a healthy work/life balance. Association with physical and mental health reflects a combination of structural inequality and personal travel experiences and living conditions. To promote the health of HSR commuters, a coordinated spatial-economic strategy at the mega-city regional level should be implemented to improve distribution of employment opportunities and consider users' perspectives on long-distance commuting, taking a holistic approach to door-to-door travel, infrastructure provision, and services operation.

1. Introduction

Commuting is an important part of working life, closely associated with personal health. Evidence shows that long commuting times and distances are closely linked with health hazards resulting from lack of sleep, high blood pressure, psychological stress and

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anxiety. These studies have largely focussed on physical and mental health in relation to long-distance commuting by urban and metropolitan rail transit, such as subways. Variables affecting the health of long-distance commuters have been extensively studied to confirm that instrumental factors, including commuting time, travel mode and travel efficiency; and socio-economic attributes, such as gender, income and marital status, impact commuters' health.

High-speed rail (HSR) has revolutionised time-space perception between cities connected by HSR, potentially enlarging labour market catchment areas and encouraging long-distance commuting from conventional metropolitan areas to inter-city travel. Scholars have demonstrated that commuting time remains relatively stable, while technological evolution has successively extended the limit of how far and fast people can travel (Lyons and Urry, 2005; Metz, 2008; Urry, 2007; Van Wee et al., 2006).

Firstly, evidence from the Japanese Shinkansen shows commuting time has reduced by 25% across Tokyo, Osaka & Hakats, demonstrating increased numbers of inter-city HSR commuters (Kojima et al., 2017). Similarly, many French TGV users from cities within an hour of Paris have season tickets (Chen and Hall, 2015) and, using upgraded HSR (Greater Western and East Coast Main lines), towns within 1 h of London have been included in London's economic and commuting zone (Chen and Hall, 2011). Secondly, faster rail services facilitate the inter-city travel mode shift from use of private cars or taxis to trains; e.g., the New Jersey suburban train station has attracted commuters who no longer commute by car (Pucher and Renne, 2005). Thirdly, faster rail services have expanded the range of jobs-housing distribution. Following the opening of the HSR line, a survey of Beijing-Tianjin inter-city commuters illustrated an increase of 21.6% in the number of people willing to live and work in different places (Ho et al., 2011). Similarly, construction of the Beijing-Shijiazhuang HSR line has enabled inter-city commuters to move from large cities to benefit from more desirable environments, lower-cost housing, and the efficient transportation systems of smaller towns (Ma, 2015).

However, a caveat is necessary. HSR's potential time-saving does not necessarily result in reduced commuting time when the door-to-door journey (both the first and the last mile) is taken into account. Wang et al. (2013), taking a total-travel-time approach, demonstrate that poor accessibility of HSR stations hinders the effectiveness of HSR. Moreover, the urban metro/express rail and inter-city HSR differ fundamentally in terms of time-space perception and associated opportunities and challenges; e.g. attaining higher incomes, broadening professional fields and networks, maintaining family relationships, adapting to new work and life-styles.

With rapid expansion of the HSR network across the world, inter-city travel (including commuting) is widely encouraged to facilitate integrated economic growth and wider territorial development. However, there is growing concern that potential benefits of HSR for emerging inter-city commuting are not automatically guaranteed. There is a scarcity of research exploring HSR commuting and health. The purpose of this study is to fill a critical gap in knowledge and evidence, contributing to deeper understanding of the health status of HSR commuters by focussing specifically on HSR commuters in China where, over merely a decade, rapid expansion of the HSR network has ranked top in the world, having, by 2018, a network of around 30,000 km, and potentially transforming the built environment, economy, society and lifestyle. The Yangtze River Delta has demonstrated a maximum average commuting time of 59.56 min between the three mega-city regions (Beijing, Tianjin and Hebei, the Yangtze River Delta and the Pearl River Delta) (Zhang, 2016). With a cross-sectional study of self-reported health and behaviour of Suzhou-Shanghai inter-city HSR commuters, this case study explores the physical and mental health of HSR commuters and underlying factors.

2. Literature review

2.1. Long-distance commuting: the role of high-speed rail and labour mobility

Long-distance commuting is not new. Two decades ago, British scholars studied such a trend for substituting migration and its issues and implications (Green et al., 1999). A recent study reported increases in commute distance and duration in England (1988–2015) and, above all, increased flexibility in both work and commuting practices (DfT, 2016). The complexity of interactions between commuting, migration, housing and the labour market is captured by Haas and Osland (2014).

The role of HSR in facilitating labour mobility for long-distance commuting is a relatively new phenomenon, which, in theory, significantly reduces inter-city rail journey times, thus expanding labour markets into a wider territory that was unfeasible in the pre-HSR era (Blum et al., 1997; Vickerman and Ulied, 2009). In Spain, evidence shows HSR services within an hour of major cities boost metropolitan integration either through reinforcing an existing tendency or creating new mobility patterns (Garmendia et al., 2011). Heuermann and Schmieder (2014) show improved German ICE services to large cities is associated with productivity (wage) gains for workers living in peripheral regions.

Regional wage differentials appear to be a driving force for workers travelling between two distant cities. Interactions of variables involved in decisions relating to HSR commutes have been explored largely from economic perspectives (Guirao et al., 2017, 2018, 2020); namely, regional wage disparities, housing rental prices and unemployment rates. The location of HSR stations was also identified as a key indicator for HSR commuting (Guirao et al., 2018). Moyano (2016) stressed that ticket cost and travel time were critical for commitment to HSR commuting. While the complex relationship of factors constituting the HSR commuting phenomenon have been explored, little research has explored the social dimensions of HSR commuting and associated health conditions.

2.2. The influencing factors of long-distance commutes on physical and mental health

Much research has focussed on instrumental factors – travel mode, commuting time, travel conditions – affecting the physical and mental health of long-distance commuters.

Firstly, travel mode choices influence the health of long-distance commuters differently. A study in Dublin found that rail transit commuters were the most stressed and negative, followed by car and bus commuters, while walkers were the least stressed and the

most positive (O'Regan and Buckley, 2003). However, a relatively recent study has found improved health conditions of public transit commuters, while commuting by car is shown to have a negative impact on health (Zhu et al., 2014). Improvements in public transport and congestion resulting from increased car ownership may explain this. Inconsistencies in these studies (Qin et al., 2018; Zhou, 2017) may reflect differences in public transport facilities, road conditions, stage of development, etc., at the time.

Secondly, commuting time and distance are also found to affect long-distance commuters' physical and mental health. Much literature has confirmed that increased commuting time can cause stress, low subjective well-being, low life satisfaction and fatigue (Choi et al., 2013; Costa et al., 1988; Koslowsky et al., 2013; Palmer, 2005; Simón et al., 2020; Stutzer and Frey, 2008). Long commuting time and distance can also cause health hazards, such as reduced physical activity, poor sleep quality, high blood pressure, absences through sickness, mental stress, anxiety, negative mood, low work enthusiasm, and unhappiness (Lyons and Chatterjee, 2008; Abou-zeid, 2009; Oliveira et al., 2015; Kunn Nelen, 2016; Wheatley, 2014; Wu, 2016). According to Fu et al. (2018), the link between commuting time and distance with health is not simply linear but U-shaped, indicating that a moderate commute might be beneficial to health, while excessive commutes would significantly increase health risks. Long-distance commutes, especially those over 60 min, not only result in personal health problems, but also reduce time available for healthy activities (Ettema et al., 2010; Zhou, 2017). A survey of 223 white-collar workers in Japan indicates that one-way commuting for over 90 min is more likely to result in symptoms of chronic stress and obesity, leading to cardiovascular disease and heart-related dysfunction (Kageyama et al., 1998).

Thirdly, travel conditions, including congestion, pollution, noise, crowding and poor thermal conditions during a long-distance commute, are found to affect physical and mental health (De Nazelle et al., 2009; McNabola et al., 2008; Stutzer and Frey, 2008; Wener et al., 2003). Congestion causes delays, reducing travel efficiency and commuters' ability to predict and control the commuting process, thus increasing stress and negativity (Anderson et al., 2016; O'Regan and Buckley, 2003). Prolonged exposure to severe traffic pollutants can result in a variety of respiratory and cardiovascular illnesses, associating negatively with commuters' physical and mental health (Buckeridge et al., 2002; Gulliver and Briggs, 2004; Riediker et al., 2004).

Socio-economic attributes, such as gender, age, education, income, occupation and marital status, are also relevant to the health of long-distance commuters. Costa et al. (1998) claims that female long-distance commuters are at a greater disadvantage than men, having more family-related difficulties, more complaints, and higher job absenteeism. However, Wheatley (2014) indicates that as men's commuting time and working hours are generally longer than women's, this generates dissatisfaction in men; thus, the relationship between commuters' health and long-distance commutes is multifaceted. Age and education have a significant association with the mental health of long-distance commuters living in the suburbs. Zhou and He (2017) shows that elderly groups and those with an education level below junior high school have a lower life satisfaction and higher probability of mental illness. Income and occupation also affect long-distance commuters' health. As income levels of long-distance commuters rise, the risk of depression increases significantly (Fu et al., 2018). In relation to occupation, labourers are less likely to take sick leave than staff in government agencies. Conversely, business managers' risk of exhaustion is significantly lower, while their risk of depression is significantly higher (Fu et al., 2018). Lastly, marital status is also proven to affect long-distance commuters' health. Wheatley (2014) shows that commuters with children have lower life satisfaction, which echoes an earlier study by Wener et al. (2003), which shows commuters with children are concerned about duration of commutes and would benefit from new rail lines that shorten commuting time.

2.3. The effects of faster rail services on the physical and mental health of long-distance commuters

Although studies have been undertaken on the health of long-distance commuters using faster urban or inter-city rail services, none of these rail lines qualifies as a HSR line as defined by the International Union of Railways (1998); i.e., having an operational speed of 250 kph for newly-built lines and 200 kph for upgraded lines. Ex-ante evidence from Stokes et al. (2008) estimates that the newly-opened light rail line in Charlotte would save up to $12.6 million on public health spending within nine years because faster rail services could have physical and mental health benefits for long-distance commuters; however, they acknowledge that, compared with the high cost of building and operating such a rail transit system, public health benefits would be relatively small.

Empirical evidence from the USA shows that shorter commuting time and changes in travel modes affect the health of long-distance commuters. Cross-sectional and longitudinal comparisons of commuters' travel modes and health conditions before and after the arrival of rail services on the New Jersey-New York inter-city railway and the light rail in Charlotte demonstrate that commuters taking the newly-opened railways had shorter commuting times, were more physically active, experienced less pressure, lower BMI, and improved physical and mental health (Wener et al., 2003, 2005; Evans and Wener, 2006; MacDonald et al., 2010). Similarly, Cao (2013) shows that Hiawatha LRT (Minneapolis, USA) users positively demonstrate satisfaction with life through enhanced access to different activities, improved transit service, and enhanced accessibility – although satisfaction with travel is marginal.

3. Conceptual framework

The above literature review has established that several travel-related instrumental factors (time, distance, travel mode, and travel conditions such as congestion, pollution, noise, crowding) can be associated, at urban and metropolitan levels, with the health of long-distance commuters, who are also conditioned by socio-economic attributes. On the other hand, with inter-city HSR commuting being a relatively new phenomenon for labour mobility in an enlarging labour market, little has been studied to comprehend the specific nature of HSR commuting and associated health conditions. Non-instrumental factors, including good housing conditions, living environments, and job opportunities, have also proven to be important factors for promoting health (Rueda et al., 2012; Dastrup and Ellen, 2016; Chen et al., 2019). Clark et al. (2019) confirm that high income, improved career development opportunities, property ownership, and proximity to family members, significantly enhance the well-being of Chinese residents.

In order to grasp the practice of HSR commuting and barriers to health, a conceptual framework, instrumental to research design, has been developed to explore a tailored set of attributing factors for the physical and mental health of HSR commuters (see Fig. 1).

The dependent variables refer to the HSR commuters' self-reported assessment of physical and mental health. The question posed is 'what do you think about your physical and mental health after commuting by high-speed railway?'. The commuters are required to select an appropriate answer from a spectrum of five levels; i.e., significant negative association, slight negative association, no association, slight positive association, and significant positive association.

The independent variables are operationalised in four dimensions for measurement, as illustrated below.

The first dimension identifies either a shift to, or a beginning of, HSR commute following introduction of HSR; i.e., whether or not they were long-distance commuters by other means between Suzhou and Shanghai before the arrival of HSR. The corresponding question in the questionnaire is 'which situation below is true for you? (1) I was a long-distance commuter prior to HSR; (2) I became a long-distance commuter following introduction of HSR'. Respondents answering '1' = 'Yes' are considered 'original long-distance commuters'. Those answering '2' = 'No' are regarded as 'new long-distance commuters'.

The second dimension specifies two journeys' transfer modes, and time to and from HSR stations; namely, transfer from home to HSR stations, and transfer from HSR stations to the workplace. The questions about transfer time are 'how long does it take for you to travel (1) from home to HSR stations; (2) from HSR stations to the workplace?'. Three transfer time durations are classified; namely, less than 30 min, 30–60 min, over 60 min. The questions about transfer modes suggest eight modes, grouped in four themes: bus, subway and company shuttle services are classified as 'public transport'; taxi (including online hailing systems) and private car are classified as 'car'; walking and cycling are classified separately as 'on foot' and 'by bicycle'.

The third dimension comprises six factors relating to job prospects and living conditions, measured by responses to 'What benefits of work-related long-distance commuting are relevant to your current experiences?'. The six options are (1) Enables me to get a job with higher salary; (2) Enables me to get a job that fits my profession with career development opportunities; (3) Enables me to extend my professional fields; (4) My residence provides better quality of life; (5) Enables me to stay close to friends and relatives living at a distance; (6) I can live in an affordable area. Each question is evaluated using a five-point Likert scale from 1 to 5, including: strongly disagree, disagree, neutral, agree, and strongly agree.

The fourth dimension consists of fourteen socio-economic attributes of HSR commuters, covering gender, age, education, industrial sector, occupation, income, weekly working hours, household structure, cohabitation, car ownership, home ownership, rent or mortgage, travel allowance and proportion of HSR costs. For some attributes, the answers require further categorisation for statistical analyses.[1]

4. Study area and data

4.1. Study area

This conceptual framework was tested at an intra-regional level of Suzhou-based HSR commuters on two inter-city HSR lines (Shanghai-Nanjing '*Huning*' and Shanghai-Beijing '*Jinghu*') in the Yangtze River Delta on the east coast of China, where the HSR network is rapidly expanding and expected to facilitate an efficient system of inter-city flow in the 'same-city' HSR catchment for both businesses and residents (see Fig. 2). Since the opening of the Shanghai-Nanjing HSR in 2010, the Yangtze River Delta has witnessed rapid expansion of inter-city HSR lines. At the end of 2019, twenty HSR lines were operating, with 25 more under either construction or planning.

Shanghai, the largest city in the Yangtze River Delta, is the centre of the most advanced economies, attracting highly-skilled talents from surrounding cities and towns for high-paid jobs. Its main attraction reflects in its maximum average commuting time of 59.56 min, experienced by Shanghai-bound commuters (Zhang, 2016). The arrival of *Huning* and *Jinghu* HSR lines has triggered a new phenomenon: 'life in-between two cities'; i.e., residents in HSR cities outside Shanghai travelling to work in Shanghai. In this paper, Suzhou, a prefecture-level city adjacent to the west border of the Shanghai administrative boundary, can be reached by HSR in about 30 min, with regular trains (289 per day) running between Suzhou and Shanghai, mainly via Suzhou Station and Suzhou Industrial Park Station. Niu et al. (2018) argue that Suzhou-based commuters have become the main 'inter-city commuters' into Shanghai. Their evidence is derived from mobile signal data of inter-city commuters between residence and workplace, showing that tens of thousands of 'Yangtze River Delta residents' travel to and from Shanghai every day, of which 80% are from Suzhou.

[1] The education attribute is classified on three levels; namely, low (without education or attending primary, junior high or high school); middle (undergraduate); and high (Master, PhD and above). The industrial sector attribute is classified into five clusters. The 'IT and science industry' cluster includes information transmission, computer services, software, scientific research, technical service and geologic prospecting; the 'education and culture industry' cluster includes education, culture, sports and entertainment; the 'finance and business industry' cluster includes finance, real estate and business; the manufacturing industry is a single one in a cluster; the 'others' cluster includes farming, forestry, animal husbandry and fishery, mining and quarrying, manufacturing, electric power, gas and water production and supply, construction, transportation, storage and post, wholesale and retail trades, hotel and catering services, environment and public facility management, residential services, health care, social security and social welfare, public management and social organisations, and international organisations. The occupation attribute includes managers (official and company managers); professionals (lawyers, architects, consultants, researchers, artists, designers, programmers), technicians, clerks, and others (service and sales workers, plant and machine operators, private enterprise owners, students). Finally, the respondents living with a spouse, children or others are classified as cohabiting, while those living alone are categorised as non-cohabiting.

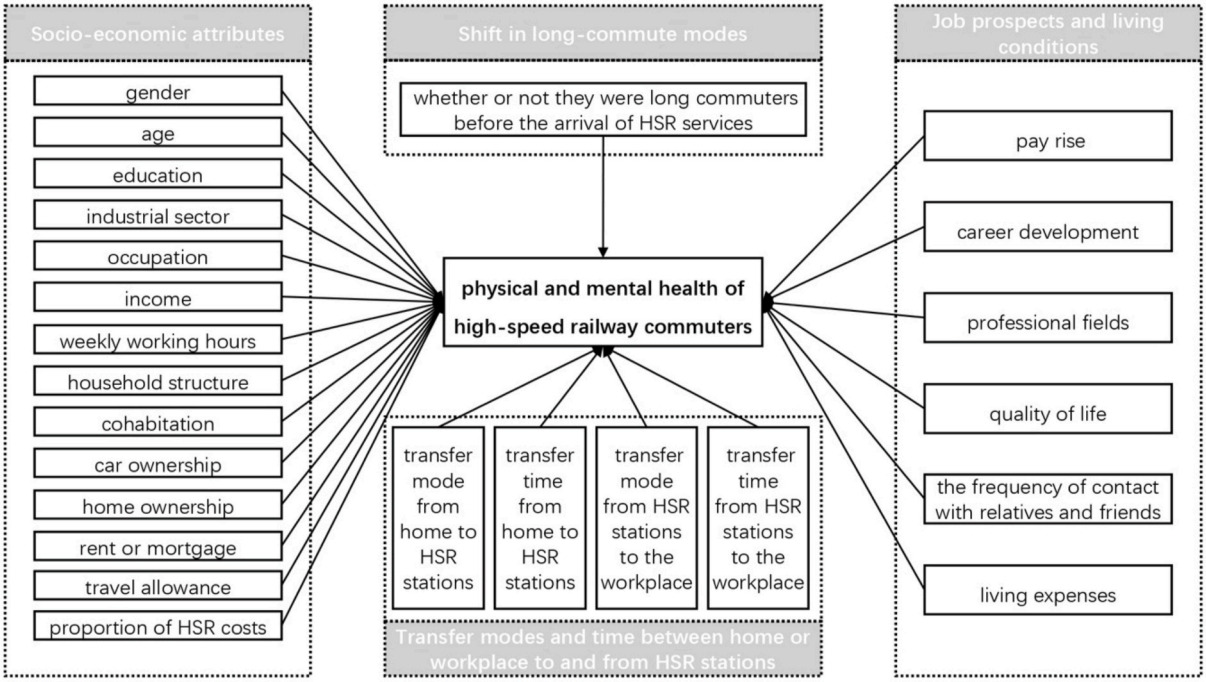

Fig. 1. The conceptual framework (Source: Authors).

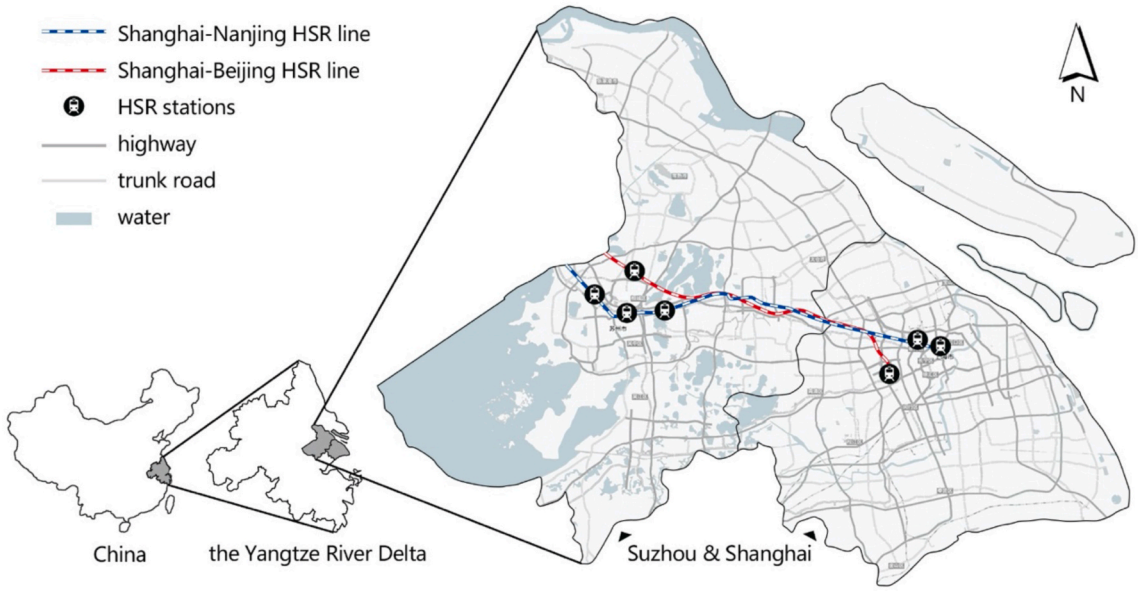

Fig. 2. Map of Suzhou and Shanghai including inter-city HSR lines and stations (Source: Authors).

4.2. Study sample and data collection

For a snapshot of the phenomenon of HSR commuting, a cross-sectional questionnaire survey was carried out for sample collection during 10th July and July 18, 2018 to assess the self-reported health of HSR commuters. The survey participants were targeted at Suzhou-based outbounds, long-distance commuters who use the HSR services from four Suzhou HSR stations. Given that the total number of Suzhou HSR commuters is unknown, to elicit insights from HSR commuters, this paper adopts a purposive sampling method (Battaglia, 2008).

A questionnaire survey is widely used in cross-sectional studies. There are two common approaches to questionnaire design. One

Table 1
Descriptive statistics.

		All	Self-reported physical health variation			Self-reported mental health variation		
			Negative association	No association	Positive association	Negative association	No association	Positive association
Number of participants		**288**	111	90	87	105	102	81
Percentage of total share (%)		**100%**	38%	32%	30%	36%	36%	28%
Shift in long-commute modes								
Whether or not long-distance commuters before HSR	**No**	**74%**	98	69	47	88	82	44
	Yes	**26%**	13	21	40	17	20	37
Transfer modes and time to and from HSR stations								
Transfer mode from home to HSR stations	**On foot**	**5%**	2	3	8	3	2	8
	By bicycle	**5%**	8	3	2	7	5	1
	By public transport	**36%**	42	32	31	35	43	27
	By car	**55%**	59	52	46	60	52	45
Transfer time from home to HSR stations	**< 30 min**	**69%**	71	64	62	69	69	59
	30~60 min	**27%**	33	24	22	30	30	19
	> 60 min	**4%**	7	2	3	6	3	3
Transfer mode from HSR stations to the workplace	**On foot**	**9%**	7	9	10	8	8	10
	By bicycle	**2%**	1	1	5	1	1	5
	By public transport	**77%**	90	69	62	88	76	57
	By car	**12%**	13	11	10	8	17	9
Transfer time from HSR stations to the workplace	**< 30 min**	**28%**	32	24	26	30	27	25
	30~60 min	**49%**	55	44	42	50	51	40
	> 60 min	**23%**	24	22	19	25	24	16
Job prospects and living conditions								
Pay rise	**Strongly agree**	**19%**	18	20	17	13	23	19
	Agree	**57%**	69	46	49	67	56	41
	Disagree or neutral	**24%**	24	24	21	25	23	21
Career development	**Strongly agree**	**25%**	22	30	21	18	29	26
	Agree	**55%**	65	46	46	64	53	40
	Disagree or neutral	**20%**	24	14	20	23	20	15
Professional fields	**Strongly agree**	**24%**	22	29	18	17	28	24
	Agree	**52%**	57	46	48	55	55	41
	Disagree or neutral	**24%**	32	15	21	33	19	16
Quality of life	**Strongly agree**	**14%**	12	14	13	12	14	13
	Agree	**33%**	32	29	34	32	29	34
	Neutral	**31%**	38	27	25	38	27	25
	Disagree or strongly disagree	**22%**	29	20	15	29	20	15
Frequency of contact with relatives and friends	**Strongly agree**	**11%**	10	9	14	4	15	14
	Agree	**41%**	41	40	37	39	47	32
	Neutral	**28%**	27	29	24	32	26	22
	Disagree or strongly disagree	**20%**	33	12	12	30	14	13
Living expenses	**Strongly agree**	**16%**	17	12	16	17	12	16
	Agree	**36%**	41	29	33	41	29	33
	Neutral	**31%**	32	31	27	32	31	27
	Disagree or strongly disagree	**17%**	21	18	11	21	18	11
Socio-economic attributes								
Gender	**Male**	**80%**	91	66	72	87	79	63
	Female	**20%**	20	24	15	18	23	18
Age	**20~29 years old**	**24%**	25	25	20	29	22	19
	30~39 years old	**62%**	73	53	53	64	65	50
	40~59 years old	**14%**	13	12	14	12	15	12
Education	**High-level**	**31%**	30	33	26	31	34	24
	Middle-level	**67%**	80	55	58	72	67	54
	Low-level	**2%**	1	2	3	2	1	3
Industrial sector	**IT and science industry**	**26%**	29	25	20	31	27	16
	Education and culture industry	**4%**	5	4	4	4	6	3
		20%	18	19	20	17	18	22

(*continued on next page*)

Table 1 (*continued*)

		All	Self-reported physical health variation			Self-reported mental health variation		
			Negative association	No association	Positive association	Negative association	No association	Positive association
	Finance and business industry							
	Manufacturing industry	25%	30	20	21	25	26	20
	Others	25%	29	22	22	28	25	20
Occupation	Manager	40%	40	35	39	31	49	34
	Professional	16%	21	16	10	22	14	11
	Technician	25%	29	24	20	33	23	17
	Clerk	7%	8	4	8	8	5	7
	Others	12%	13	11	10	11	11	12
Income	< 10000 RMB	17%	18	16	16	13	21	16
	10000~14999 RMB	21%	27	17	17	28	19	14
	15000~19999 RMB	17%	22	14	13	21	17	11
	> 20000 RMB	44%	44	43	41	43	45	40
Weekly working hours	< 40 h	28%	28	25	28	30	27	24
	40~50 h	53%	64	50	40	59	54	41
	> 50 h	18%	19	15	19	16	21	16
Household structure	Married without children	9%	13	7	7	15	9	3
	Married with one child	54%	63	47	45	61	51	43
	Married with two children	14%	16	12	11	11	16	12
	Single	23%	19	24	24	18	26	23
Cohabitation	Cohabiting	78%	95	64	67	86	79	61
	Living alone	22%	16	26	20	19	23	20
Car ownership	More than 2	17%	15	12	22	18	10	21
	1	58%	71	53	43	66	63	38
	0	25%	25	25	22	21	29	22
House ownership	Own	79%	89	74	64	85	82	60
	Not own	21%	22	16	23	20	20	21
Rent or mortgage	< 2000 RMB	29%	38	21	25	36	24	24
	2000~3999 RMB	21%	25	18	18	19	24	18
	4000~5999 RMB	17%	12	22	14	14	22	12
	6000~7999 RMB	12%	16	10	8	15	10	9
	8000~9999 RMB	6%	8	5	5	8	7	3
	> 10000 RMB	15%	12	14	17	13	15	15
Travel allowance	Yes	40%	44	35	36	38	48	29
	No	60%	67	55	51	67	54	52
The percentage of HSR transportation expenses to monthly income	1~5%	39%	37	38	36	37	36	38
	5~15%	48%	60	39	39	56	50	32
	15~25%	3%	2	3	4	1	3	5
	>25%	10%	12	10	8	11	13	6

Source: Authors

uses self-reported health scales; e.g. Short Form 36-item Health Survey (SF-36), to calculate the comprehensive score of a series of questions to measure the respondents' self-reported health level (Harris et al., 2006). The other approach is to set a single question, such as 'How do you feel now, physically and psychologically, considering your health and your well-being?' or 'Would you say that your health is excellent, good, fair or bad?', and require the respondents to choose from the options (Hansson et al., 2011; Galán et al., 2013). This study focusses on the health evaluation of the individual before and after commuting by HSR; thus, the second approach is adopted to obtain straightforward answers about comparative effects to the questions, which are guided by the conceptual framework (Fig. 1).

During the data collection process, survey participants were invited using a combination of both onsite face-to-face (F2F) contact and online questionnaire.

F2F contact, which was carried out while potential participants waited for trains in HSR stations, enabled the research purpose to be better understood by participants who were then willing to help spread the word (Gottholmseder et al., 2009; Darviri et al., 2011; Wiklund et al., 2012). On the first day of onsite survey, 50 full paper questionnaires and a few small-size pamphlets with QR-codes were prepared. However, in the limited train waiting time during rush hours it was difficult to complete the questionnaires. A more effective way was devised, as shown below. Participants were approached by research team members who explained the research aim with an information sheet and a QR-code, which could be scanned by mobile phones for accessing the online questionnaires. Participants completed the survey on their mobiles during train journeys to Shanghai within around 30 min. Most participants spread

the word within their social networks to those with similar HSR commuting practices. When approaching the participants, the research team prepared small incentives for their participation (a little notebook and a pen showing the logo of the research institute). This effectively assured them of the seriousness and legitimacy of the research project.

Eight research team members distributed survey questionnaires during peak hours (7am–10am) in four HSR stations. One survey was conducted once in one station, while two major HSR stations, Suzhou station and SIP, were visited on two days because of the greater train frequency and large number of passengers. An F2F contact survey was conducted one evening (Tuesday, 17 July) at Shanghai station to approach commuters returning from work.

As online surveys can be widely circulated to targeted groups (Davis et al., 2018; Ramo et al., 2011), an online questionnaire with QR-code was circulated among potential participants. Having been informed that two social groups formed on the Wechat platform, widely used in China and an equivalent of 'WhatsApp', existed (one with around 100 members, the other with around 300) for sharing information and experiences among HSR commuters travelling between Suzhou and Shanghai, two research team members joined. The random F2F survey contact proved a necessary step to capture HSR commuters who were not necessarily members of the WeChat groups, thus helping to avoid research bias.

During the data collection process, the number of completed questionnaires was monitored constantly, numbers stagnating towards the end of the period. In total, 288 questionnaires were identified as valid and stored on an online cloud-based platform (Wenjuanxing). (www.WJX.cn).

5. Results and discussion

5.1. Descriptive analyses

Of the 288 HSR commuters, 74% were 'new long-distance commuters' who had become long-distance commuters after the arrival of HSR, while 26% were 'original long-distance commuters' who had used other modes of travel for their Suzhou-Shanghai commute.

Table 1 details results in relation to four sets of factors under study. Overall, HSR commuters report higher proportions of negative associations in both physical and mental health conditions. In terms of physical health, commuters who perceive a negative association account for 38%, while positive associations account for 30%. In terms of mental health, a negative association accounts for 36%, while positive associations account for 28%.

5.1.1. Shift in long-commute modes

The results show a marked contrast in self-reported physical and mental health variations between the 'original long-distance commuters' and the 'new long-distance commuters'. The 'original long-distance commuters' are more likely to experience positive physical and mental health effects. More than half express that HSR commuting positively associates with physical and mental health, while about one-fifth identify negative associations. In contrast, the 'new long-distance commuters' are more inclined to experience negative physical and mental health. The negative association with physical and mental health accounts for 46% and 41%, respectively, whereas positive associations with physical and mental health are 22% and 20%, respectively.

5.1.2. Transfer modes and time

The car is the major transfer mode for commuters travelling from home to HSR stations, while public transport is the most usual mode from HSR stations to the workplace. 96% of commuters travel less than 60 min from home to HSR stations, while 77% travel less than 60 min from HSR stations to the workplace. Commuters transferring to and from stations by public transport or by car appear more likely to identify negative physical and mental health effects. In comparison, commuters travelling to and from stations by bicycle or on foot seem more likely to report a positive association with their physical and mental health, although only a few commuters walk or cycle to and from stations.

With details of the transfer mode and time, insights into the transfer journey conditions at both ends could be revealed. More than 55% of the transfer modes from home to HSR stations in Suzhou are by car, largely accounting for nearly 70% of the under 30 min transfer journeys. This could reflect 75% car ownership among the participants but also that the time saving and transfer mode of public transport in Suzhou could not compete with the car. On the other hand, 77% transfer mode by public transport from HSR stations to the workplace in Shanghai contributed greatly to nearly 50% of the transfer time in the 30–60 min category. This reflects the large scale of major cities accessible to the workforce by public transport. The negative health association resulting from these two transfer journeys illustrates the need for improvement.

5.1.3. Job prospects and living conditions

Respondents tend to agree that HSR commutes help them find jobs with higher salaries (76%), gain more development opportunities (80%), and expand professional fields (76%); but fewer identify improved quality of life (47%), more frequent contact with distant relatives and friends (52%), or a more affordable cost of living (52%). However, commuters who strongly agree that HSR commuting enables more frequent contact with distant relatives and friends seem more likely to perceive negative physical health. While commuters who strongly agree that HSR commuting helps them find better-paid jobs, career development opportunities, professional fields and more frequent contact with distant relatives and friends, are more likely to report positive mental health benefits. These findings suggest career prospects and financial security contribute more to mental health than good family and social relationships, which may involve more visiting travel and thus more negative physical health.

Table 2
Results from the two models: physical and mental health variations.

Parameter		Model 1: Physical health variations			Model 2: Mental health variations		
		Wald Chi-Square	P	OR	Wald Chi-Square	P	OR
Shift in long-commute modes							
Whether or not long-distance commuters before HSR	**No**	31.46	0.00***	0.20	23.45	0.00***	0.25
	Yes (Ref)			1.00			1.00
Transfer modes and time to and from HSR stations							
Transfer mode from home to HSR stations	**On foot**	5.32	0.02 **	4.63	2.89	0.09	3.12
	By bicycle	0.59	0.44	0.64	1.02	0.31	0.55
	By public transport	0.68	0.41	1.27	0.55	0.46	1.25
	By car (Ref)			1.00			1.00
Transfer time from home to HSR stations	**< 30 min**	10.19	0.00***	8.48	4.75	0.03 **	4.27
	30~60 min	7.42	0.01 **	6.17	2.21	0.14	2.68
	> 60 min (Ref)			1.00			1.00
Transfer mode from HSR stations to the workplace	**On foot**	1.19	0.28	1.83	0.02	0.88	1.09
	By bicycle	9.12	0.00***	16.81	4.52	0.03 **	7.80
	By public transport	0.01	0.91	0.95	0.23	0.63	0.82
	By car (Ref)			1.00			1.00
Transfer time from HSR stations to the workplace	**< 30 min**	0.35	0.56	0.80	0.41	0.52	1.27
	30~60 min	0.69	0.41	0.77	0.35	0.55	1.20
	> 60 min (Ref)			1.00			1.00
Job prospects and living conditions							
Pay rise	**Strongly agree**	0.30	0.59	1.33	0.13	0.72	1.21
	Agree	1.12	0.29	1.46	0.09	0.77	0.90
	Disagree or neutral (Ref)			1.00			1.00
Career development	**Strongly agree**	0.02	0.88	0.91	0.01	0.92	1.07
	Agree	0.12	0.72	0.86	0.05	0.82	0.90
	Disagree or neutral (Ref)			1.00			1.00
Professional fields	**Strongly agree**	0.48	0.49	0.69	0.00	0.96	1.03
	Agree	1.12	0.29	1.52	0.90	0.34	1.46
	Disagree or neutral (Ref)			1.00			1.00
Quality of life	**Strongly agree**	0.51	0.47	1.48	3.36	0.07	2.79
	Agree	0.00	0.96	0.98	0.03	0.87	1.07
	Neutral	0.44	0.51	0.78	0.08	0.78	0.90
	Disagree or strongly disagree (Ref)			1.00			1.00
Frequency of contact with relatives and friends	**Strongly agree**	6.51	0.01 **	4.07	3.98	0.05 **	3.02
	Agree	2.98	0.08	1.92	0.82	0.36	1.41
	Neutral	6.11	0.01 **	2.49	2.39	0.12	1.77
	Disagree or strongly disagree (Ref)			1.00			1.00
Living expenses	**Strongly agree**	0.01	0.93	0.96	0.86	0.35	0.61
	Agree	0.04	0.85	0.92	0.33	0.57	1.27
	Neutral	0.77	0.38	1.41	0.51	0.47	1.32
	Disagree or strongly disagree (Ref)			1.00			1.00
Socio-economic attributes							
Gender	**Male**	0.00	0.96	1.02	0.00	0.97	1.01
	Female (Ref)			1.00			1.00
Age	**20~29 years old**	0.10	0.75	0.85	1.99	0.16	0.47
	30~39 years old	0.96	0.33	0.69	1.45	0.23	0.63
	40~59 years old (Ref)			1.00			1.00
Education	**High-level**	0.00	0.96	0.96	0.78	0.38	2.20
	Middle-level	0.07	0.80	0.80	0.68	0.41	2.04
	Low-level (Ref)			1.00			1.00
Industrial sector	**IT and science industry**	0.14	0.71	1.14	0.81	0.37	0.73
	Education and culture industry	1.52	0.22	2.18	0.15	0.70	0.78
	Finance and business industry	1.00	0.32	1.43	0.33	0.56	1.23
	Manufacturing industry	1.41	0.24	1.50	0.21	0.65	1.17
	Others (Ref)			1.00			1.00
Occupation	**Manager**	1.39	0.24	0.60	1.05	0.31	0.64
	Professional	2.32	0.13	0.48	5.84	0.02 **	0.31
	Technician	2.36	0.12	0.49	5.50	0.02 **	0.33
	Clerk	0.02	0.90	1.08	0.24	0.63	0.76
	Others (Ref)			1.00			1.00
Income	**< 10000** RMB	2.42	0.12	0.45	0.03	0.87	0.92
	10000~14999 RMB	0.15	0.70	0.87	0.39	0.53	0.80

(*continued on next page*)

Table 2 (*continued*)

Parameter		Model 1: Physical health variations			Model 2: Mental health variations		
		Wald Chi-Square	P	OR	Wald Chi-Square	P	OR
	15000~19999 RMB	0.63	0.43	0.75	0.63	0.43	0.75
	> 20000 RMB **(Ref)**			1.00			1.00
Weekly working hours	**< 40 h**	0.28	0.60	0.82	1.04	0.31	0.69
	40~50 h	1.33	0.25	0.69	1.03	0.31	0.72
	> 50 h (Ref)			1.00			1.00
Household structure	**Married without children**	0.83	0.36	0.60	2.89	0.09	0.38
	Married with one child	0.03	0.87	0.92	0.54	0.46	0.71
	Married with two children	1.38	0.24	0.52	0.69	0.41	0.62
	Single (Ref)			1.00			1.00
Cohabitation	**Cohabiting**	0.89	0.34	0.69	0.19	0.67	0.84
	Living alone (Ref)			1.00			1.00
Car ownership	**More than 2**	0.65	0.42	1.44	0.01	0.92	1.05
	1	0.42	0.52	0.80	1.25	0.26	0.67
	0 (Ref)			1.00			1.00
Rent or mortgage	**< 2000** RMB	9.69	0.00***	0.28	1.17	0.28	0.64
	2000~3999 RMB	1.59	0.21	0.58	1.95	0.16	1.85
	4000~5999 RMB	0.31	0.58	1.28	1.87	0.17	1.83
	6000~7999 RMB	1.53	0.22	0.56	0.35	0.55	0.75
	8000~9999 RMB	1.01	0.32	0.56	0.28	0.60	1.36
	> 10000 RMB **(Ref)**			1.00			1.00
House ownership	**Own**	1.37	0.24	0.65	0.41	0.52	0.79
	Not own (Ref)			1.00			1.00
Travel allowance	**Yes**	0.95	0.33	1.29	0.48	0.49	1.20
	No (Ref)			1.00			1.00
The percentage of HSR transportation expenses to monthly income	**1~5%**	0.06	0.81	0.90	0.73	0.39	1.47
	5~15%	0.79	0.37	0.68	0.29	0.59	1.27
	15~25%	1.90	0.17	3.20	2.67	0.10	4.14
	>25% (Ref)			1.00			1.00

**P < 0.05; ***P < 0.01.
Source: Authors

5.1.4. Socio-economic attributes of commuters

With a 4:1 ratio of male to female, most HSR commuters are male. Results illustrate that while men perceive more negative physical and mental health relating to HSR commutes, women report more negative physical than mental health. HSR commuters represent a relatively young-age profile (average 34.6 years), with middle-to-high levels of education (98% had a bachelor's degree or above). More than a quarter of commuters engage in IT and science industry (26%), followed by manufacturing industry (25%), others (25%), finance and business industry (20%), and education and culture industry (4%). About 40% are managers, followed by technicians (25%) and professionals (16%). Nearly half HSR commuters (44%) are high-income earners with a monthly income above 20,000 RMB (equivalent to US$2500 per month). Most commuters (75%) have at least one car. Meanwhile, over half the commuters (53%) work 40–50 h per week. Similarly, over half HSR commuters (54%) are married with one child. Commuters living alone or cohabiting account for 22% and 78% respectively. Most commuters (87%) spend less than 15% of their monthly income on HSR transportation, and 40% commuters receive a company travel allowance.

Considering factors combining industrial sectors and occupational profiles, nearly twice as many commuters working in IT and the science industry as professionals or technicians identify HSR commuting as being negatively associated with mental health. Married HSR commuters are more inclined to identify negative health associations, while single commuters are more likely to identify positive associations.

5.2. Ordinal logistic regression modelling

Apart from descriptive analyses, for a full comprehension of commuters' various conditions and self-reported health assessments, the relationship between four sets of factors is explored further. The dependent variable in this study is the self-reported physical and mental health variation, which is an ordinal five-category variable. Ordinal logistic regression is adopted to model HSR commuters' variations in both physical and mental health. Use of the Ordinal logistic regression (OLR) tool is justified for the following reasons. Linear regression analysis is commonly used if the dependent variable (Y) is a numeric type of data, while logistic regression analysis tends to be used (though not exclusively) if Y is a categorical type of data. Three types of logistic regression models exist; namely, binary logistic regression, multi-category logistic regression, and ordinal logistic regression. These three types are respectively applicable to three types of dependent variable, including two-category variable, multi-category variable, and ordinal multi-category variable. Existing studies involving self-reported health as the dependent variable tend to adopt ordinal logistic regression (de Castro et al., 2010; Clark et al., 2019) to obtain the weighting of independent variables, enabling relevant determinants to be identified.

The four sets of independent variables derived from the conceptual framework are all embraced in the model. A collinearity

diagnosis shows that the tolerances are much greater than 0.1 and the variance inflation factors less than 10, validating the absence of high correlation between the independent variables. Moreover, parallel line test results of physical and mental health models are $\chi2 = 156.68$, $P = 0.90$ and $\chi2 = 165.77$, $P = 0.77$, respectively, suggesting that the regression equations are parallel to each other and the models do not violate the proportionality assumption of ordinal logit. The variables satisfy the premise of establishing an ordinal logistic regression model. SPSS 24.0 is used to process data for two ordinal logistic regression models; namely, self-reported physical and mental health variations of HSR commuters, as shown below.

5.2.1. Findings from comparison of two models: physical and mental health variations

Both self-reported 'physical' and 'mental health' of HSR commuters appear significant, with acceptable levels of explanation ($\chi2 = 111.77$, $p = 0.00$; $\chi2 = 110.46$, $p = 0.00$). Deviance test results show that both models achieve a good fitting effect ($\chi2 = 764.27$, $P = 1.00 > 0.05$; $\chi2 = 743.25$, $P = 1.00 > 0.05$). Juxtaposing two models respectively on physical and mental health sheds light on factors underlying health variations (see Table 2).

Firstly, from the perspective of shift in long-commute modes, the experience of long-distance commuting before the advent of HSR is a statistically significant factor. Using 'original long-distance commuters' as a reference, the 'new long-distance commuters' accrue substantially lower odds of reporting that HSR commuting has a positive association with both physical and mental health (OR = 0.20, $\chi2 = 31.46$, $p = 0.00$; OR = 0.25, $\chi2 = 23.45$, $p = 0.00$). This may be due to a sharp comparison between former and current experiences, in which HSR provides 'original long-distance commuters' with a faster, more reliable and efficient mode than taking long-distance conventional rail, taxis, private cars or company shuttle buses. Conversely, 'new long-distance commuters' have no prior experience of the hardships of long-distance commutes. Therefore, for the 'original long-distance commuters', HSR appears to ease the hardship of long-distance commutes, but for the 'new long-distance commuters', HSR has motivated some to begin long-distance commutes, which may be unexpectedly arduous. This finding is similar to that of earlier studies, which show public transit improvement and new transit systems improved commuters' physical and mental health (Wener et al., 2003; MacDonald et al., 2010).

Secondly, concerning transfer modes and travel time to and from HSR stations, commuters who walk from home to HSR stations in Suzhou are significantly more likely to associate HSR commuting positively with physical and mental health. Meanwhile, walking transfer shows a stronger positive association with physical health than car transfer (OR = 4.63, $\chi^2 = 5.32$, $p = 0.02$). However, commuters utilising cycling transfers tend to report a negative association with physical and mental health (statistically insignificant); whereas HSR commuters using public transport for transfers tend to report a positive association with physical and mental health (statistically insignificant). With commuters taking more than 60 min to travel from home to HSR stations in Suzhou as a reference, commuters taking less than 30 min are significantly more likely to report a positive association with physical and mental health (OR = 8.48, $\chi2 = 10.19$, $p = 0.00$; OR = 4.27, $\chi2 = 4.75$, $p = 0.03$), and those taking between 30 and 60 min significantly tend to report a positive association with physical health (OR = 6.17, $\chi2 = 7.42$, $p = 0.01$).

However, commuters transferring by bicycle from HSR stations in Shanghai to the workplace indicate a more positive association with physical and mental health than those transferring by car (OR = 16.81, $\chi^2 = 9.12$, $p = 0.00$; OR = 7.80, $\chi^2 = 4.52$, $p = 0.03$). Commuters transferring on foot also tend to report a positive association with physical and mental health, though statistically insignificant; and commuters transferring by public transport tend to report a negative association with physical and mental health (statistically insignificant). Reasons for this may be that walking and cycling are considered active modes that promote physical activities and generate positive moods, while congestion during peak traffic hours and limited parking space at HSR stations may cause inconvenience to commuters. Positive health association with walking and cycling, and negative health association with driving have been identified in previous studies (Morris and Guerra, 2015; Gatersleben and Uzzell, 2007; Paez and Whalen, 2010), and are confirmed in this study.

It is noteworthy that commuters who cycle from home to HSR stations tend to consider HSR commuting to have a more negative health association than that reported by those driving from home to the station (though statistically insignificant); whereas commuters who cycle from HSR stations to the workplace are significantly more likely to regard the association with physical and mental health as positive. These findings may reflect the complex relationship between commute modes and resulting physical and mental health, which is widely reflected in the controversy and inconsistency in existing studies (Qin et al., 2018; Zhou, 2017; O'Regan and Buckley, 2003). Moreover, as the respondents in this study are Suzhou-based commuters working in Shanghai, it is necessary to be aware of the varied nature of the major HSR locations and their surroundings in Suzhou and Shanghai, and the diverse locations of commuters' homes and workplaces. Commuters in Suzhou do not necessarily live near HSR stations, therefore the transfer experience from home to HSR stations is critical. This implies that cycling facilities and infrastructures are insufficient and incomplete. In fact, HSR stations in Suzhou are located outside the old city centres, thus wide roads and flyovers prioritise cars, resulting in an unsatisfactory and dangerous environment for cycling, whereas the cycling environment from HSR stations to workplaces in the relatively denser city centre of Shanghai has been significantly improved for cyclists (Cai, 2018) in accordance with a comprehensive review of traffic flow and parking as defined in the Shanghai Street Design Guidelines (2016).

Thirdly, from the perspective of job prospects and living conditions, commuters who agree that HSR commuting helps them to stay close to distant friends and relatives are significantly more likely than those who disagree or strongly disagree to report that HSR commuting has a positive association with both physical and mental health, especially physical health. In terms of physical health, commuters who either strongly agree or remain neutral are significantly more likely to express a positive association (OR = 4.07, $\chi2 = 6.51$, $p = 0.01$; OR = 2.49, $\chi2 = 6.11$, $p = 0.01$). In terms of mental health, commuters with a strongly agree attitude are also significantly more likely to report a positive association (OR = 3.02, $\chi2 = 3.98$, $p = 0.05$), while the result of the neutral commuters is not statistically significant. A possible explanation is that the 'new long-distance commuters', who constitute the majority of the respondents, might have had to move to Shanghai, far from their hometown and relatives, prior to introduction of the HSR services, in

order to secure better-paid work or improved development opportunities. However, because of the new inter-city HSR services, which enable a substitute for migration, they are able to achieve better working conditions whilst also living close to family and friends. It is, therefore, reasonable that this factor has had a significant positive association with both physical and mental health, confirming the point made in a recent study that having relatives nearby can significantly enhance the subjective well-being of Chinese residents (Clark et al., 2019).

Fourthly, two socio-economic attributes show significant associations with the health variations of commuters. Rent or mortgage appear significant in the physical health model, while occupations appear significant only in the mental health model. Considering the levels of rent or mortgage, commuters paying below 2000 RMB are significantly less likely than those paying above 10,000 RMB to perceive HSR commuting as positive (OR = 0.28, $\chi2 = 9.69$, p = 0.00). This result can be explained by the fact that as levels of home ownership in China are high, commuters who rent properties are likely to be relatively low-income workers. Moreover, a rent level below 2000 RMB further implies a poor quality of residence, thus closely reflecting the reason for the negative health association with lower levels of rent or mortgage. In terms of occupation, commuters working as technicians or professionals (such as lawyers, architects, consultants, researchers, artists, designers, programmers, etc.) are significantly less likely than those categorised as 'others' (including service and sales workers, plant and machine operators, private enterprise owners, students, etc.) to agree that HSR commuting has a positive association (OR = 0.33, $\chi2 = 5.50$, p = 0.02; OR = 0.31, $\chi2 = 5.84$, p = 0.02). Similarly, managers and clerks report negative associations, albeit with much higher OR values and without statistical significance. Regarding industrial sectors, although no OR findings show statistical significance with health associations, with the 'others' category of industry as a reference, commuters from IT and science industry, and the education and culture industry show negative mental health associations, albeit of statistical insignificance. The result suggests that the nature of occupation matters for health association. Technicians and professionals – highly-skilled employees – differ from those in managerial and administrative activities and appear more stressful and insecure, resulting in their negative associations with mental health.

5.2.2. Sensitivity test

Two sensitivity tests were undertaken with ordinal logistic regression models, in which binary outcomes were shown with different thresholds of cut-points. In the first sensitivity test, 'slight positive association' and 'significant positive association' were merged into 'positive association' (see Appendix: Supplementary Material Table S1). In the second test, based on the first test model, 'significant negative association' and 'slight negative association' were also merged into 'negative association' (see Appendix: Supplementary Material Table S2). Overall, results from the sensitivity analyses show that signs of coefficients for all variables above a significance level of 0.05 in the original models were consistent across models, albeit the varied magnitude of coefficients. This confirms the stability of ordinal logistic regression results. Model fitting information of the first sensitivity tests were $\chi2 = 102.28$, p = 0.00, $\chi2 = 106.90$, p = 0.00; and the second were $\chi2 = 100.76$, p = 0.00; $\chi2 = 104.85$, p = 0.00. Both were slightly lower than the original models, thus we suggest using the original models that had higher explanation levels.

5.3. Strengths and limitations

Two innovative strengths should be highlighted. First, compared with previous studies examining single factors (travel time, distance, mode), this paper, for the first time, develops a conceptual framework to explore multidimensional factors affecting the physical and mental health of inter-city HSR commuters. To avoid bias, some data are examined in which some health variations of HSR commuters are explored while others are controlled. Second, concerning the limitation of cross-sectional studies that tend to be carried out at one time point with no indication of the sequence of events (Levin, 2006), this questionnaire design is innovative by presenting the key question 'what do you think about your physical and mental health after commuting by high-speed rail?' as the dependent variable, which enables a cross-sectional study to compare the change in individual health before and after commuting by HSR.

Five limitations are recognised below for further research. The first one is related to the inherent nature of subjectivity. Nevertheless, although the self-report assessment of personal experiences is subjective in nature, results from a physical and mental health report authorised by medical services might be attributed to other diverse and complicated factors, thus individual underlying factors are difficult to identify. This leads to the second limitation on the over-simplified measure of physical and mental health in this paper. Future research should advance health measures in more depth. Third, questions related to sleep, high blood pressure, stress and anxiety are not included in this survey. In future studies, these can be included to make interesting comparison across studies. Fourth, this paper does not examine variables related to the experience of the HSR commuting process itself. For instance, whether the HSR coaches are comfortable, whether the transfer from and to the stations is convenient, whether the HSR ticketing system is user-friendly or could be available with discounted season tickets, whether timetabling is integrated and frequency is sufficient, etc. A wide range of supply-side facilities and operational factors during the commuting process (including the first and last miles) could be analysed in subsequent studies. Fifth, since HSR commuting in China is an emerging phenomenon, data are not available regarding numbers of HSR commuters. Other well-established HSR countries, such as Japan and France, have shown that seasonal tickets are a good indicator of capturing of HSR commuter groups, while it is not available as an option for travellers in China. Due to lack of reliable figures to estimate an overall population of HSR commuters, this paper adopts non-probability purposive sampling to collect as many completed questionnaires as possible during the survey period.

6. Conclusion

The emerging phenomenon – inter-city HSR commuting via HSR – has been largely embraced and driven by technological and economic perspectives, which leads to paucity of deeper understanding of responses to such potentials from commuters' perspectives and associated health. For the first time, this paper explores inter-city HSR commuting and its association with physical and mental health through a newly-tailored conceptual framework and with new empirical evidence, identifying key factors underlying health variation of HSR commuters. Positive personal health is found to closely link with (1) people who experienced long-distance commutes before HSR and are relatively satisfied with the improved commuting experience; (2) people who take active transfer mode choices and experienced shorter transfer time; (3) people who enjoy close proximity to friends and relatives.

Meanwhile, negative personal health is shown to be associated with low rent/mortgage (implying lower quality of residence and relative inability to afford home ownership) and occupational stress found in mobile high-skilled workers. In conclusion, HSR commuting is a personal commitment by those seeking a healthy balance between work and personal life while being predisposed to a wide range of conditions – a combination of deep-rooted structural inequality (income and the nature of high-skilled occupations) and various personal travel experiences and living conditions.

Drawing on a pilot case study – Suzhou-Shanghai inter-city HSR commuters' self-reported health and behaviour – these findings draw critical attention to HSR commuting and associated health issues, not only in China but wherever HSR is implemented. How can factors relating to positive health be enhanced and promoted while factors relating to negative health are also addressed? Three wider implications for policy and practice could be considered to promote health.

First of all, there is a need for a coordinated spatial-economic strategy and implementation at the mega-city regional level which can address a fundamental question – 'why travel to work by HSR?'. Labour mobility through inter-city HSR commuting reflects the regional wage differences in enlarging labour markets where the larger cities, with high value-added jobs, dominate as a magnet drawing in workers from surrounding towns and cities. If high value-added opportunities can be decentralised to smaller places with HSR connections, inter-city commuting could possibly be better distributed among a range of different sized places. This is closely related to the persistent debate: 'can a small intermediate city, connected by HSR to a major city, gradually become a strong economic sub-centre?' (Vickerman, 2015). It remains to be seen whether Suzhou could evolve in the direction of polycentricity in the Yangtze River Delta Megalopolis, alongside Shanghai and fourteen other prefecture-level cities in the future (Chen et al., 2019).

Secondly, a holistic door-to-door travel experience beyond a narrow view of reduced train time by HSR should be placed in the centre of integrated urban planning and design in practice. This paper highlights that a good walking and cycling environment around HSR stations and shorter transfer time is important for personal health. As HSR stations in China tend to be located outside dense urban areas, poor accessibility, both to and from stations, has been reported as being problematic in existing literature (Wang et al., 2013; Chen and Wei, 2013; Dai, 2015). Thus, decision-making of new HSR locations should include efficient, well-designed and improved infrastructure for interchanges with HSR for both the first and last miles to ensure reasonable total commuting time and encourage active travel modes of walking and cycling. Meanwhile, negative health associated with public transport reflects much-needed improvement to offer more freedom of transfer choices with high-quality services.

Lastly, from the HSR operation's perspective, it is still debatable whether, and to what extent, inter-city HSR services should cater for commuting, because most national and regional rail operators welcome business trips and discourage commuting. As a result, HSR commuting is largely a users' aspiration and struggle rather than the intention of HSR operators. This paper argues that to improve and promote the health of HSR commuters, it is necessary to take the users' perspectives into account, including train frequency, train timetabling integration, ticketing, price, etc., which could be properly realised.

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Declaration of competing interest

No potential conflict of interest was reported by the authors.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jth.2020.100902.

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