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The effect of housework, psychosocial stress and residential environment on musculoskeletal disorders for Chinese women

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ABSTRACT

Historically, discussions of work-related musculoskeletal disorders (MSDs) have focused on paid work factors. However, the relation between housework (unpaid work) and MSDs for women is important. Little is known about the relationship between housework and MSDs and how this relationship can be influenced by physical environment factors and psychosocial stress, as well as other individual characteristics. Therefore, this study proposed a model to disentangle interactions between housework, residential indoor environment, psychosocial stress and MSDs for women, using the structural equation modeling approach, based on the cross-sectional data in the Central Plain of China. Model results showed housework (0.23) and psychosocial stress (0.44) were risk factors for the development of MSDs, while indoor environmental satisfaction (−0.27) was the protective factor for MSDs. Moreover, housework had a significant effect on psychosocial stress (0.20) while indoor environment satisfaction showed negative effect on psychosocial stress (−0.22). Furthermore, multiple group analysis suggested individual characteristics, including age, BMI, education, length of residence, household size and floor area, could change the strength of relationships in the model. This paper formulated and validated a model to define interactions between housework, residential indoor environment, psychosocial stress and MSDs for women, which would help improve knowledge on impact of housework on MSDs.

1. Introduction

In recent years, work-related musculoskeletal disorders (MSDs, such as neck, shoulder, waist and low back pain) have attracted huge public attention, and have been linked to sleep disturbance, restrictions in daily activities, depression, hypertension, undernutrition, social interaction and suicide (Spencer et al., 2018; European Agency for Safety and Health at Work (EU-OSHA), 2019). Population-based estimates of musculoskeletal disorders among Chinese adults ranged from 7.3% to 24.8% (Jia et al., 2021), and nearly 11.2% of all disability-adjusted life years (DALYs) resulted from musculoskeletal disorders (Wu et al., 2021). Therefore, it is urgent to understand drivers of work-related MSDs and draw up relevant control and prevention measures to MSDs.

There has been an undeniable improvement in understanding the connection between conditions of the paid work and musculoskeletal disorders over the past decade. Previous studies have found that physical stress contributed by workplace conditions, such as awkward postures, carrying loads, hand/arm vibration, wrist deviations and contact stress, can significantly affect the musculoskeletal system (da Costa & Vieira, 2010; Punnett & Wegman, 2004; European Agency for Safety and Health at Work (EU-OSHA), 2010). Physical environment factors in the workplace, including low temperature (Pienimaki, 2002), humidity (Telfer & Obradovich, 2017), noise and vibration (Magnavita et al., 2011) and poor lighting (Pirmoradi et al., 2018), may directly or indirectly lead to physiological reactions that can potentially increase musculoskeletal load, which raise the risk of MSDs. Associations have also been found between MSDs and psychosocial (or organisational) stress results from high work demands, low social support, discrimination in the workplace, working long hours, lack of breaks, and low job satisfaction (European Agency for Safety and Health at Work (EU-OSHA), 2021; Hauke et al., 2011; Lang et al., 2012). Furthermore, psychosocial factors can combine with physical factors, and may lead to fatigue, anxiety, sleeping problems or other reactions, which increase the risk of MSDs (European Agency for Safety and Health at Work (EU-OSHA), 2021). In addition, sociodemographic factors and individual factors can influence the prevalence of MSDs (Roquelaure, 2018).

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As mentioned above, discussions of work-related MSDs frequently tended to address the physical/psychosocial factors in traditional workspaces (i.e., paid work) and MSDs in previous years. However, residential indoor environment as a workspace of housework (often performed by women) and MSDs attracted relatively little attention from occupational health research. In fact, the housework can pose risk factors to homemakers similar to those in paid-work settings. Housework activities include everyday household tasks (e.g., cooking, doing laundry, room cleaning, washing dishes and shopping), which require much substantial physical and emotional labor. Research has shown that the intensity of some housework activities (e.g., sweeping, window cleaning, vacuuming) are not low than several types of paid work, and most homemakers cannot "go home and relax" (Brooks et al., 2004; Sujatha et al., 2003). Some studies have demonstrated that there are strong associations between housework activities and musculoskeletal pain, including neck pain, low back pain and upper extremity for homemakers (especially housewives) (Habib et al., 2010; Habiba et al., 2012; Josephson et al., 2003). This mainly is due to the fact that everyday household tasks often involve the repetition, force and awkward postures, such as washing dishes and clothes, lifting of objects or children, cleaning carpets and windows, and vacuuming. These physical risk factors often work in combination, and may lead to musculoskeletal pain for homemakers. In addition, psychosocial factors can affect the development of MSDs among homemakers, including child or elderly care demands, work stress, workload of housework, housework repetitiveness and low residential indoor environment satisfaction (Apostoli et al., 2012; Fazli et al., 2016; Rosano et al., 2004).

Furthermore, residential indoor environment parameters are remarkably related to ergonomic analysis. The physical stresses caused by the residential indoor environment conditions, such as the dimensions and the sizes of indoor space, tools and furniture, have an important effect on the development and exacerbation of MSDs. For instance, Domingos et al. (Domingos & Souto, 2018) Suggested that the most common risks of MSDs for the housework were constituted by inadequate postures, prolonged standing positions, repeatability of movements with spinal flexion, bad organization of the activities due to the poor design and narrow size of the residential indoor environment. Kaur et al.'s study contributed evidence that awkward postures due to poor designing of work area in the kitchen, such as the full and half forward bending, side bending on knees, standing with stretched arm, standing with the raised feet and squatting postures, are strongly associated with moderate pain in lower and upper back, shoulder joint for housewives (Kaur et al., 2014). Habib et al. (Habib et al., 2006) found that musculoskeletal pain among homemakers was closely associated with awkward postures (such as bending, kneeling and squatting) caused by narrow or difficult to reach indoor spaces. Moreover, psychosocial stressors caused by residential indoor environment parameters (thermal, acoustic and lighting) can negatively affect the musculoskeletal systems often similar to those in paid-work settings (Magnavita et al., 2011). Millions of Chinese people in modern society spend approximately 65% of their entire life inside their home (Duan et al., 2015). The figure was even higher in the context of the COVID-19 pandemic because the pandemic has forced people to rethink homes as the "new offices". It was reported that more than 80% of workforce were affected by workplace closures during the COVID-19 pandemic, including the requirement for people to work from home (International Labour Organization, 2020). Hence, residential indoor environment as the non-traditional workspace has far-reaching implications for occupants' musculoskeletal disorders, especially with homemakers.

Complex relationships exist between residential indoor environment, housework, psychosocial stress and MSDs for homemakers. Few studies have disentangled this complex connection, especially for Chinese women. Therefore, we chose women as research subjects. There are three reasons for this. First, Chines women remain largely responsible for household duties. According to the Annual Report on Chinese Women's State of Life, more than 65% of Chinese women were often responsible for the housework, and average hours of housework per day reached about 2.6 h (Women of China, 2018). Second, housework may have a greater impact on Chinese women in the development of MSDs than women in other countries. Because most Chinese women also participate in the paid work while taking on household work. Statistics indicated that the labor participation rate of Chinese women has reached 70%, while American women, French women, Japanese women and Indian women were 58%, 50%, 30% and 28%, respectively (Bureau of Labor Statistics, 2010). Third, MSDs are more common in women than in men. Studies suggested that women were 1.5 times more likely to suffer from MSDs than men. Moreover, an estimated 39.92% of Chinese women had musculoskeletal disorders, including low back pain, neck pain, and osteoarthritis (Jia et al., 2021).

The aim of this paper is to identify the relationship between housework and MSDs for women from the Central Plain of China, and how this relationship can be influenced by residential indoor environment factors and psychosocial stress, based on the structural equation modeling (SEM). The SEM approach is a powerful multivariate statistical tool that disentangles networks of casual relationships among a set of variables in high dimensional data (Hair et al., 2014). The major novelty of our work resides in simultaneously combining the residential indoor environment and psychosocial stress to comprehensively investigate the complex interactions of housework and MSDs. This paper will promote understanding of the underlying causes of MSDs for homemakers, which providing a basis to develop strategies for improving musculoskeletal health in the residential indoor environment.

2. Materials and methods

2.1. Survey description

2.1.1. Questionnaire

The survey instrument was based on the questionnaire applied in the Japanese project of Housing and Community for Promotion of Health/Wellbeing and Nordic Musculoskeletal Questionnaires (Kuorinka et al., 1987; Nagasawa et al., 2013). After proper translations and modifications, a pretest was carried out to verify the validity and reliability of this questionnaire. 30 women with different age and education level were asked for advice on this questionnaire and difficulties in the survey. Relevant advice and feedback from the pilot testing was adopted to form the final questionnaire. The reliability of the questionnaire was tested by Cronbach's alpha, and the calculated value was above the acceptable level (>0.7).

This questionnaire includes personal characteristics, dwelling information, housework activities, psychosocial stress, residential indoor environment satisfaction and musculoskeletal disorders symptoms (see Table 1 and Appendix).

Personal characteristics involve age, height, weight, length of residence, time spent at home, education level, household size, smoking habits and alcohol consumption. Information on dwelling is comprised of floor number, floor area, height/size of kitchen, and size of bathroom.

Table 1
Main components in the questionnaire.

Topics	Variables
Personal characteristics	Age, height, weight, length of residence, time spent at home, education level, household size, smoking habits and alcohol consumption
dwelling information	Floor number, floor area, height/size of kitchen, and size of bathroom, elevator
Housework activities	Cooking, doing laundry, room cleaning, washing dishes, shopping for household goods and groceries
Psychosocial stress	Housework, child care, elderly care paid work
Residential indoor environment	Thermal, acoustic, lighting, air quality, floor area, indoor decoration
Musculoskeletal disorders symptoms	Neck/shoulder pain, waist/back pain

Housework activities consist of the five major tasks: 1) cooking; 2) doing laundry; 3) room cleaning; 4) washing dishes; 5) shopping for household goods and groceries. These domestic activity levels were measured by the synthesis of the frequency and duration of activity. The 6-point scale was used to assess the frequency of activities per week, coded from 1 to 6 (i.e., 'Every day' = '6', '1–2 days' = '5', '3–4 days' = '4', '5–6 days' = '3', 'Less than once a week' = '2', 'Less than once a month' = '1'). For the duration of each activity, response options are '<5 min', '5–10 min', '10–20 min', '20–30 min', '30–60 min', '1–3 h', '3–5 h' and '>5 h', scored from 8 to 1. Psychosocial stressors considered in this study include the housework, child care, elderly care and work (paid work). A 5-degree one-pole scale was applied to reflect the intensity of stress, i.e., 'Never' = 1, 'Seldom' = 2, 'Sometimes' = 3, 'Often' = 4, and 'Always' = 5. Residential indoor environment is defined by the satisfaction of thermal, acoustic, lighting and air quality environments, as well as the satisfaction of floor area and indoor decoration. Each environmental aspect was measured by the 5-point satisfaction scale ('Very Satisfied' = 5, 'Satisfied' = 4, 'General' = 3, 'Not Satisfied' = 2, 'Very Dissatisfied' = 1). Musculoskeletal disorders symptoms include neck/shoulder pain and waist/back pain, which are extremely common in the population of Chinese women (Jia et al., 2020). The musculoskeletal pain measurement was characterized by the synthesis of information on the frequency and intensity (Haweaker et al., 2011). Five-point ranking scales were used for the intensity of pain ('Not at all' = 0, 'Mildly' = 1, 'Moderately' = 2, 'Severely' = 3, 'Extremely' = 4). Frequency of musculoskeletal pain was evaluated using the Five-point Likert Scales ('Never' = 0, 'Rarely' = 1, 'Sometimes' = 2, 'Often' = 3 and 'Very often' = 4). Furthermore, this questionnaire also collected the information on the extent of burden of neck/shoulder and waist/back associated with specific housework activities, including washing dishes, up and down stairs, vacuuming and lifting or pulling. The respondent was instructed to select 'Never', 'Seldom', 'Sometimes', 'Often' or 'Always'. It should be noted that the recall period for all the items was in the past 3 months.

2.1.2. Study areas and subjects

The cross-sectional study was carried out from September 2021 to December 2021 in Zhengzhou (34°16′N-35°58′N, 112°42′E−114°14′E), the capital of Henan Province in the Central Plain of China. Zhengzhou has been recognized as a major central city in central China, with a permanent population of 12.6 million and a total area of 7567 km^2. The purpose of our study was to identify the complex relationship between housework and MSDs. Therefore, the study subjects were Chinese women taking on the responsibility of housework often in the past year. That is, not doing housework or doing little housework were excluded. This study was approved by the Ethics Committee of Zhengzhou University and all participants gave informed consent.

2.1.3. Sampling strategy

Of 16 districts in Zhengzhou, 10 districts of the downtown were selected. Because these selected districts are all in the central downtown of Zhengzhou city. Moreover, the population of these districts accounted for about 70% of the total population of Zhengzhou, according to the demographic data for 2020 (Henan Provincial Bureau of Statistics, 2023). Second, the minimum sample size $n = 1842$ was calculated by the formula: $n = 1.96^2\ p(1\text{-}p)\ (DEFF)/d^2$ (Where p: prevalence of musculoskeletal disorders, 0.399; *DEFF*: design effect, 5; d: desired level of absolute precision, 0.05) (Gorstein et al., 2007). The female prevalence rate of musculoskeletal disorders was 0.399 according to a national survey in China (Jia et al., 2021). Moreover, the sample size should be increased by 20% of the calculated value (368), due to possible uncooperative respondents and loss of questionnaires. Hence, a total of 2300 questionnaires were distributed randomly in the selected districts. The survey was conducted in four steps. First, we calculated the sample size of each district based on population proportion of different districts. Second, according to the random sampling frame (district→subdistrict office→residents' committee→resident), we selected the surveyed households with the assistance of the residents' committee. Third, we recruited and trained the surveyors from the college students. Fourth, the surveyors contacted the selected household and conducted visits through the residents' committee. The questionnaires were distributed by these surveyors using the face-to-face interview. It should be noted that each district was investigated based on the same procedures. Finally, we collected 2032 valid questionnaires. 234 questionnaires were excluded due to subjects reporting not doing housework or doing little housework. 34 residents failed to participate in the survey due to no time, fear, health reasons, and holiday.

2.2. Structural equation modeling

A framework model was proposed based on the literature review in introduction of this paper, as illustrated in Fig. 1. The framework model involved six hypotheses, including indoor environment→housework (H_1), housework→psychosocial stress (H_2), indoor environment→psychosocial stress (H_3), housework→MSDs (H_4), indoor environment→MSDs (H_5), and psychosocial stress→MSDs (H_6).

Structural equation modeling (SEM) was used to establish complex relations between residential indoor environment, psychosocial stress, housework activity level and musculoskeletal disorders (Abbreviated as HWMSDs model). The HWMSDs model consists two parts: the measurement model and structural model (see Fig. 2), according to the measurement and structural theory (Hair et al., 2014). In the measurement model, residential indoor environment, psychosocial stress, housework activity level and musculoskeletal disorders symptoms (also called latent variables, as shown in ellipses) were operationalized into measurable indices (also called observed variables, as shown in boxes). In the structural model, complex relationships between the aforementioned latent variables (ellipses) were described.

2.2.1. Measurement model

Concerning the relationship between the latent variable and its indicators, the measurement model can be reflective (the directional arrow is pointing from the latent variable to its indicators, indicating the assumption that the latent variable causes the covariation of indicators) or formative (the direction of the arrow is from indicators to the latent variable, indicating the assumption that each indicator captures a specific aspect of the latent variable). According to the proposed criteria by Jarvis et al. (Jarvis et al., 2003), the measurement models in the HWMSDs model were formative. For example, the residential indoor environment satisfaction involves the different facets, such as satisfaction with thermal, acoustic, lighting or air quality environments. Obviously, the formative measurement model setup is more appropriate for the residential indoor environment satisfaction. Similarly, the housework consists of cooking, washing dishes, shopping for household goods and groceries, room cleaning and doing laundry. Therefore, the housework was also measured formatively.

The latent variables (LV) was formed by combining its indicators (I) in formative models of the HWMSDs model. This relationship can be expressed as follows. Note that the latent variables was assumed to be error free (Sarstedt et al., 2016).

$$LV = \Sigma\lambda I \tag{1}$$

Where λ stands for the standardized weight coefficients, indicating each indicator's relative importance to the corresponding latent variable. The range of λ is from −1 to 1.

2.2.2. Structural model

The associations between residential indoor environment ($LV_{environment}$), housework ($LV_{housework}$), psychosocial stress (LV_{stress}) and MSDs (LV_{MSD}) were described in the structural model (Fig. 2). The mathematical formula for these casual relations were shown as follows:

$$LV_{housework}k = \eta 1\ LVenvironment + \delta housework \tag{2}$$

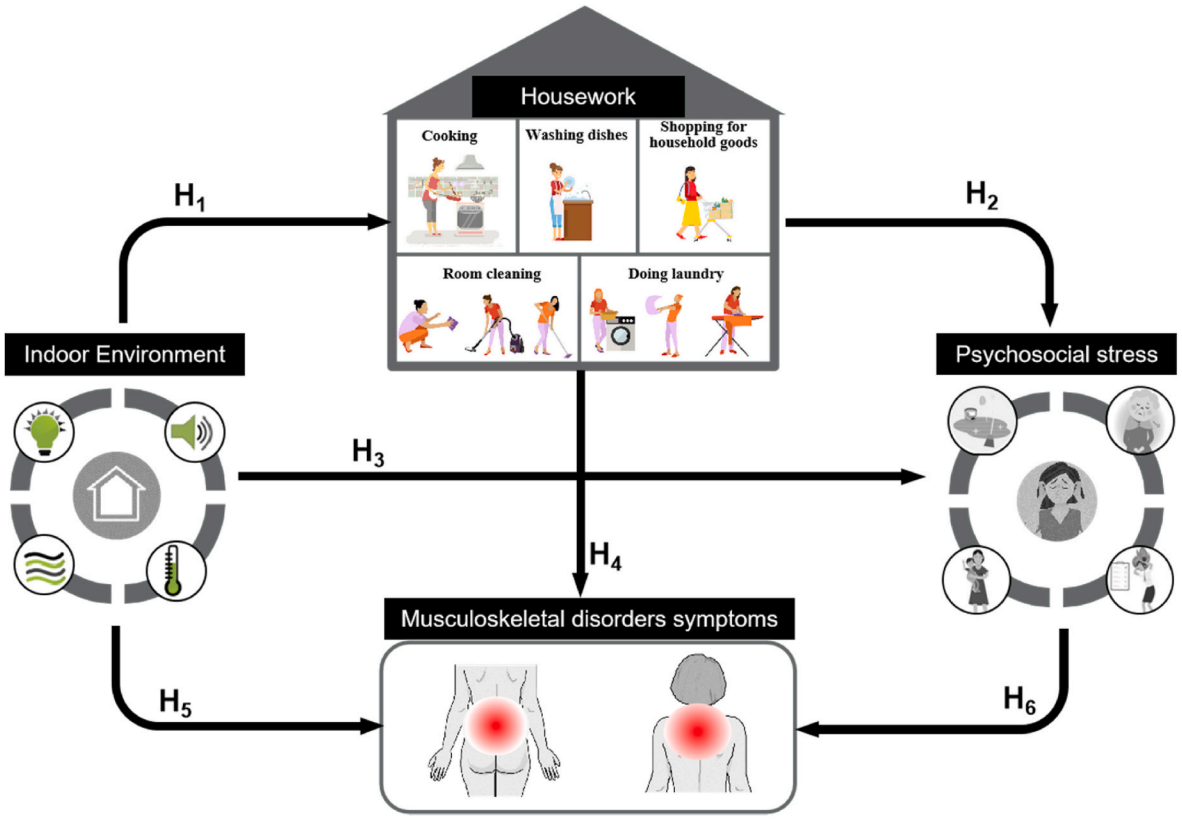

Fig. 1. The proposed framework model.

$$LVstress = \eta 2\ LVhousework + \eta 3\ LVenvironment + \delta stress \quad (3)$$

$$LVMSD = \eta 4\ LV_{\text{housework}} + \eta_5\ LV_{\text{environment}} + \eta_6\ LV_{\text{stress}} + \delta_{\text{MSD}} \quad (4)$$

Where η represents the standardized regression coefficients (also called path coefficients) and the range of η is [-1,1]. δ stands for the error term associated with endogenous latent variables.

Structural equation modeling can be estimated based on CB-SEM (Covariance-based SEM) or PLS-SEM (Partial least squares-based SEM) algorithm. The PLS-SEM algorithm often works efficiently with non-normality of data distributions, small sample sizes, model complexity and related methodological anomalies in comparison to CB-SEM algorithm (Rigdon, 2012). PLS-SEM algorithm focuses on minimizing the unexplained variance of the dependent latent variables to estimate the path coefficients (η) and weights (λ) (Tenenhausa et al., 2005). The detailed description of the PLS-SEM algorithm was provided by Henseler et al. (Henseler & Chin, 2010). Consequently, HWMSDs model was calculated based on the PLS-SEM algorithm using the SmartPLS version 3.0 (Ringle et al., 2015).

2.2.3. Model evaluation

The evaluation of HWMSDs model results involves separate assessments of the measurement models and the structural model (Ramayah et al., 2018). For the measurement models, the evaluation focuses on the reliability and validity of the latent variable measures. The specific measures include the convergent validity, collinearity among indicators (Variance Inflation Factor, $VIF < 5$) and significance and relevance of weights (P value < 0.05). Assessment of the structural model determines how well survey data support the hypothesis (Fig. 2). The procedure involves collinearity issues (Variance Inflation Factor, $VIF < 5$), predictive accuracy (Coefficients of determination R^2, >0.2), size and significance of path coefficients (P value < 0.05), and predictive relevance (Stone-Geisser's Q^2 value, >0). It should be note that there is no global goodness-of-fit criterion (such as CFI, Cronbach's alpha and RMSEA) for the PLS-SEM model.

3. Results

3.1. Characteristics of study participants and dwelling information

A total of 2032 valid questionnaires were collected and the response rate was 88.3 % in this study. Table 2 presents the Characteristics of the respondents and homes. More than half of respondents was over 40 years (52.1%) and the average age was 41.3 years (SD 12.5). 7.5% of respondents had a primary school education, while about 51% had a university, master, PhD or specialization education. Approximately 63% of the respondents resided in the surveyed buildings for more than five years, and most respondents (67.5%) spent averagely 12–15 h at home. The average household size was 3.27 persons and 52.9% of all households included two or three persons. 46.3% of the survey population were affected by some problems with weight: 37.1% are overweight (BMI>23.9) and 9.2% are underweight (BMI<18.5). Concerning the lifestyle, 86.1% and 7.1% were never and often smokers, respectively. Regular drinking was declared by 27.4% of study participants, while 54.9% drank no alcohol at all. For the dwellings, the percentage of floor area above 100 m^2 in the investigated buildings was 46.8%, and over half of floor numbers were below 3 floors. 24.8% of the respondents reported no elevators. Among the 2742 respondents surveyed, 46.6% felt that the kitchen area was small, and 22.1% felt that the counter height of kitchen was low. Similarly, 46.8% of respondents reported that the toilet area was small.

3.2. Housework activity level, residential indoor environment satisfaction, psychosocial stress and self-reported MSDs

Fig. 3 shows the percentage of respondents reporting housework

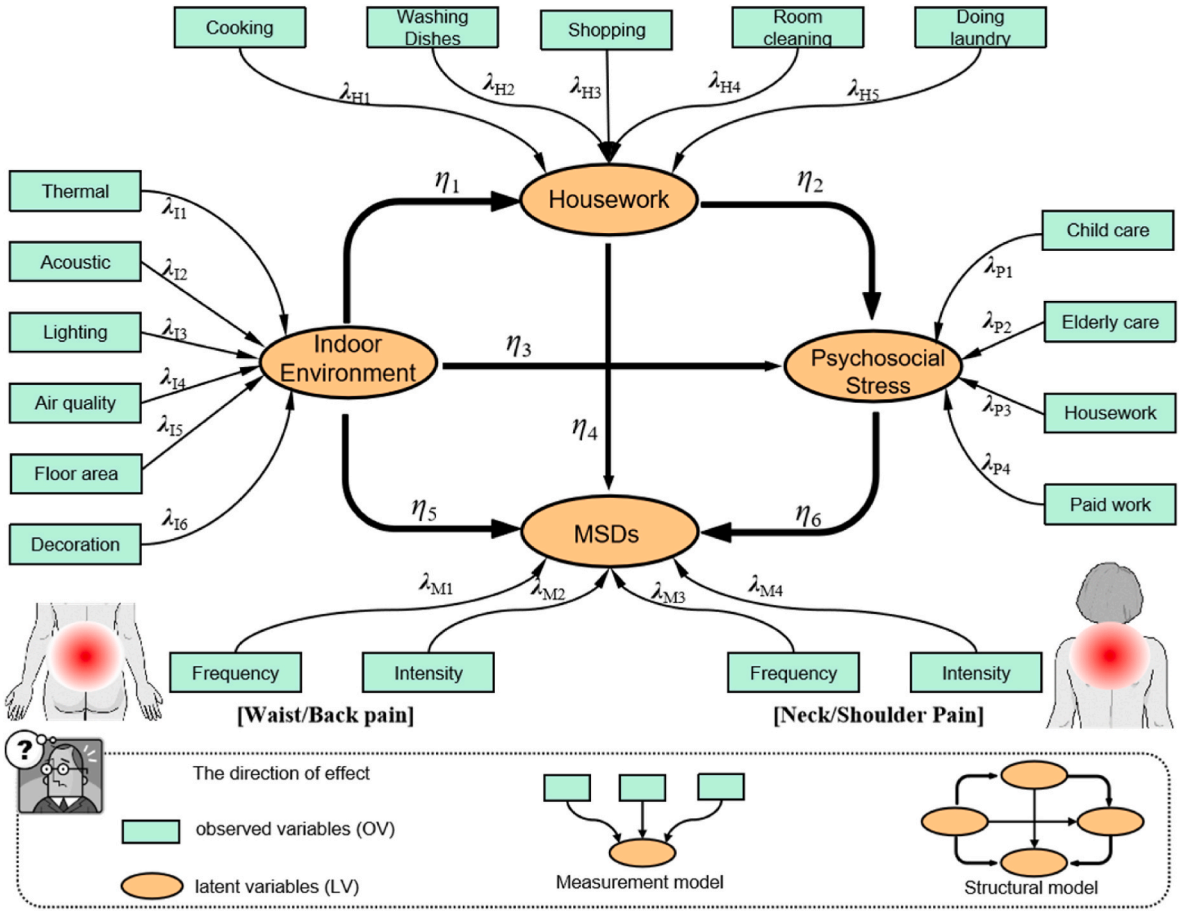

Fig. 2. Structural equation modeling of residential indoor environment, psychosocial stress, housework activity level and MSDs.

activity level, residential indoor environment satisfaction, psychosocial stress and MSDs at different frequencies. With respect to the housework activity, 46% of women indicated that they were spending >120 min in cooking every week, while 13%, 17%, 21% and 29% spending >120 min in washing dishes, shopping, room cleaning and doing laundry, respectively. Among the respondents, approximately 80% of respondents reported more than 1–2 times neck/shoulder or waist/back pain every month. More than 40% of women had moderate, severe or extreme intensity of pain. Among the most unsatisfactory with the indoor environment components was indoor air quality (26%), which was higher than decoration(15%), thermal environment (14%), floor area (13%), acoustics (12%) and lighting environments (9%). 60% of women reported always or often feeling the stress of child care work, followed paid work by (54%), housework (44%) and elderly care (24%) stress.

3.3. Model results and evaluation

Fig. 4 presents HWMSDs model results derived from all the survey data. Psychosocial stress was the greatest risk factor for the development of MSDs (0.44), followed by housework activity level (0.23), while indoor environment satisfaction showed the protective role for MSDs (−0.27). Similarly, indoor environment satisfaction also showed the negatively effect on psychosocial stress (−0.22). Housework activity level had a significant effect on psychosocial stress (0.20). In addition, indoor environment satisfaction had an relatively weak impact on housework activity level (0.14).

For measurement models, cooking had the greatest absolute contribution to housework activity level (0.81), followed by doing laundry (0.73), room cleaning (0.71), shopping (0.59) and washing dishes (0.41). Child care (0.78) delivered the greatest weight to psychosocial stress, compared with paid work (0.76), housework (0.73) and elderly care (0.47). The most important drivers of indoor environment satisfaction was floor area (0.89), followed by lighting (0.85), acoustic (0.82), air quality (0.81), thermal environments (0.66), and decoration (0.51). The frequency and intensity of neck/shoulder and waist/back showed the similar contribution to MSDs.

Table 3 displays the HMMSDs model evaluation results. The variance inflation factor (VIF) were lower than the threshold value of 5, thus suggesting that the collinearity was not an issue in the measurement model. Moreover, there were statistical significance for all the formative indicators. In the structure model, all VIF values were also lower than the threshold value of 5. Furthermore, all relationships were significant. The coefficients of determination for MSDs (0.51) and psychosocial stress (0.26) were above the threshold value of 0.2, but rather weak for housework (0.17). The predictive relevance values for housework (0.13), psychosocial stress (0.21) and MSDs (0.36) were greater than the threshold value of 0, proving the predictive relevance for the model. In summary, the model has basically met all requirements.

3.4. Multiple group analysis

Multiple group analysis was used to disclose the effect of personal characteristics (such as age, BMI, education, length of residence, household size and floor area) on path relationships in the HWMSDs model, as indicated in Table 4. These personal characteristics were selected based on two following reasons. First, studies have suggested that these variables may affect the path relationships in the HMMSDs model. For example, prevalence of MSDs generally increased with age and BMI due to loss of muscular strength, increased bone fragility and fat redistribution (Gheno et al., 2012). High education level was liked to

Table 2
Characteristics of the respondents and homes.

Characteristics	Number (%)	Characteristics	Number (%)
Age (years)		**Alcohol consumption**	
<20	234(11.5)	Often	102(5.0)
20~30	339(16.7)	Sometimes	455(22.4)
30~40	380(18.7)	Seldom	361(17.8)
40~50	784(38.6)	Never	1114(54.8)
>50	295(14.5)	**Floor area (m^2)**	
Education level		<60	518(25.5)
Master, PhD, or specialization	142(7.0)	60~80	183(9.0)
University	898(44.2)	80~100	380(18.7)
Professional	225(11.1)	100~120	384(18.9)
Middle school	614(30.2)	>120	567(27.9)
Primary school	153(7.5)	**Floor number**	
Length of residence (years)		<3	224(11.0)
<2	435(21.4)	3~8	628(30.9)
2~5	327(16.1)	9~15	660(32.5)
5~10	254(12.5)	>15	520(25.6)
10~20	360(17.7)	**Elevator**	
>20	656(32.3)	Yes	1528(75.2)
Time spent at home (hours)		No	504(24.8)
<9	47(2.3)	**Kitchen area**	
9~12	396(19.5)	Small	947(46.6)
12~15	1372(67.5)	Moderate	981(48.3)
>18	217(10.7)	Large	104(5.1)
Household size (Person)		**Counter height in the kitchen**	
1	33(1.6)	High	502(24.7)
2~3	1074(52.9)	Moderate	1081(53.2)
4~5	582(28.6)	Low	449(22.1)
>5	343(16.9)	**Toilet area**	
Body Mass Index(kg/m^2)		Small	951(46.8)
<18.5	187(9.2)	Moderate	1002(49.3)
18.5–23.9	1091(53.7)	Large	79(3.9)
>23.9	754(37.1)		
Smoking status			
Often	144(7.1)		
Sometimes	85(4.2)		
Seldom	53(2.6)		
Never	1750(86.1)		
Total	2032		

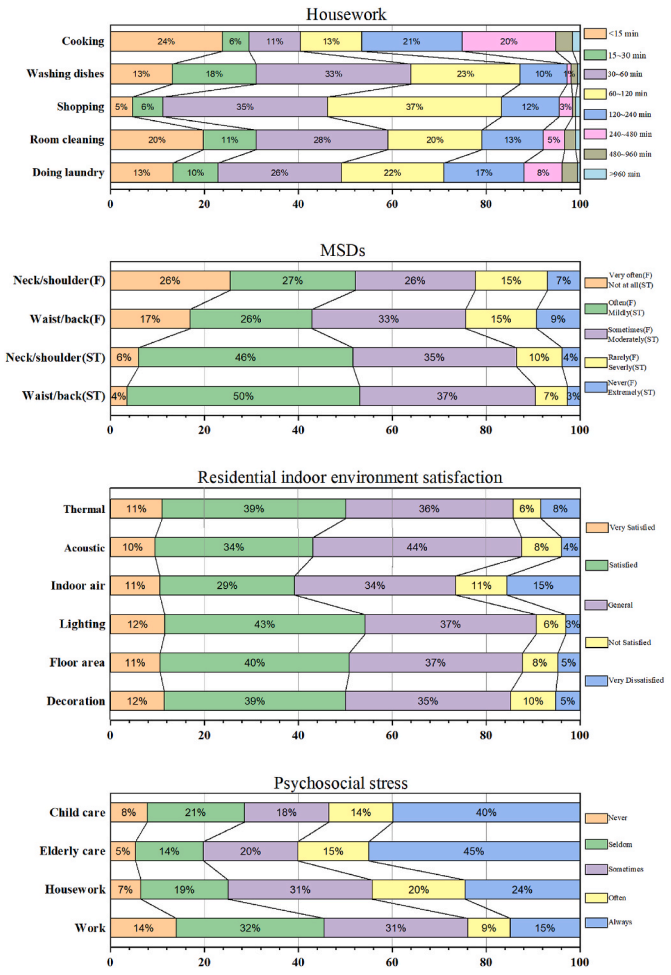

Fig. 3. The distribution of housework activity level, residential indoor environment satisfaction, psychosocial stress and MSDs at different frequencies.

less time spent on housework (Kamila et al., 2019). Floor area and household size are often associated with the housework intensity. Second, path coefficients in the HWMSDs model were statistically significant after the multiple group analysis.

As with the age, the path coefficient of housework activity level to MSDs differed significantly between <40 years and >40 years subgroup. The effect size of psychosocial stress on MSDs was significantly higher in the 30–40 years or 40–50 years subgroup than the effect size in the <30 years or >50 years subgroup. The impact of housework activity level on MSDs was significantly higher for overweight women (BMI>23.9 kg/m^2), while the impact of psychosocial stress on MSDs was higher for underweight women (BMI<18.5 kg/m^2).

The path coefficients of indoor environmental satisfaction to MSDs and housework activity level were both not significantly different across different BMI subgroups. There was a significant difference between the '< middle school' and '> professional' education level subgroup for the path coefficient of housework activity level to MSDs. Similarly, the path coefficient (psychosocial stress → MSDs) was relatively larger in the '< middle school' subgroup than the coefficient in the 'professional' subgroup. The effect of indoor environment satisfaction to psychosocial stress was found higher in the '> university' subgroup than 'primary school' subgroup. For the length of residence, the pathways for housework activity level to MSDs in the '5–10', '2–5' and '<2' subgroup were significantly lower than the '10–20' and '>20' subgroup, while the pathways for psychosocial stress to MSDs in the '5–10' and '2–5' subgroup were higher than '10–20' and '>20' subgroup. The association strength of housework activity level or psychosocial stress on MSDs for '1–3' household size was relatively larger than '4–5' and '> 5' household size. But the strength of indoor environment satisfaction on MSDs gradually increased with the raise of household size. The effect of housework activity level on psychosocial stress was not significantly different between these household size subgroups. With regard to floor area, the path coefficient of housework activity level to MSDs was significantly larger for '>120' subgroup than other subgroups. The pathways for psychosocial stress to MSDs in the '100–120' and '>120' subgroups were higher than less than '<100' subgroups. The relationship between indoor environment satisfaction and housework activity level was no significant differences across '60–80', '80–100' and '>120' subgroup. The coefficient of housework activity level to psychosocial stress in '>100' subgroups were relatively lower than other subgroups.

4. Discussion

4.1. Link between residential indoor environment, housework, psychosocial stress and MSDs

This study developed the HWMSDs model describing complex interactions among housework activity, indoor environment satisfaction, psychosocial stress and MSDs for Chinese women in the Central Plain of China. This model showed significantly risk roles of psychosocial stress (0.44) and housework activity level (0.23) on MSDs, which sharply contrast to the protective role of indoor environmental satisfaction (−0.27). Unfortunately, there were few studies that specifically indicated the relative contribution of these three types of determinant to MSDs. There was only one study revealing the effects of total hours of housework, satisfaction of living environment, stress and fatigue on

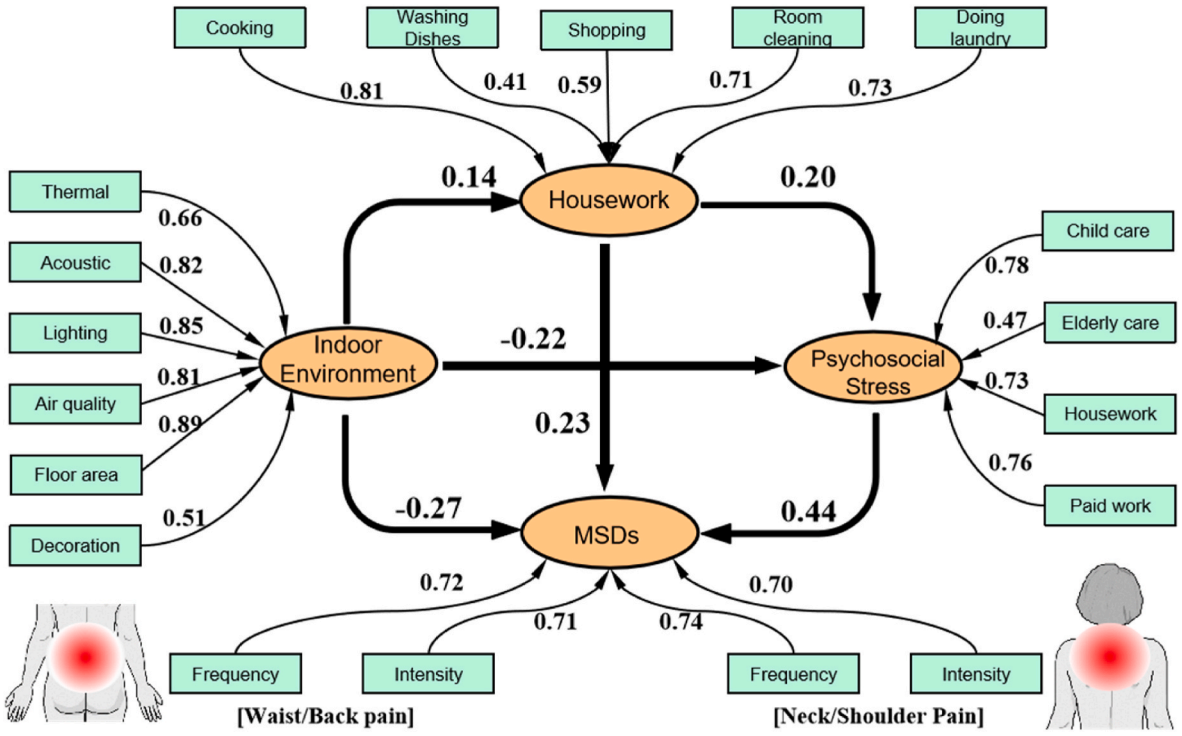

Fig. 4. The HWMSDs results based on the structural equation model using the questionnaire survey data.

Table 3
HWMSDs model evaluation results.

Formative Measurement Model							
Latent Variables	Indicators	Weight	VIF	Latent Variables	Indicators	Weight	VIF
Indoor	Thermal	0.66**	1.89	Housework	Cooking	0.81**	1.68
Environmental	Acoustic	0.82**	1.81		Washing dishes	0.41*	1.38
Satisfaction	Lighting	0.85**	1.20		Shopping	0.59*	1.17
	Air quality	0.81**	1.13		Room cleaning	0.71**	1.64
	Floor area	0.89**	1.21		Doing laundry	0.73**	1.84
	Decoration	0.51*	1.47				
MSDs	Frequency[1]	0.72**	1.28	Psychosocial stress	Child care	0.78**	1.49
	Intensity[1]	0.71**	1.97		Elderly care	0.47*	1.79
	Frequency[2]	0.74**	1.11		Housework	0.73**	1.78
	Intensity[2]	0.70**	1.82		Paid work	0.768	1.90

Structural Model				
Relations	Path Coefficient	VIF	Coefficient of Determination	Predictive Relevance
$LV_{environment} \rightarrow LV_{housework}$	0.14*	1.51	0.17	0.13
$LV_{housework} \rightarrow LV_{stress}$	0.20*	1.26	0.26	0.21
$LV_{environment} \rightarrow LV_{stress}$	−0.22*	1.77	0.26	0.21
$LV_{environment} \rightarrow LV_{MSD}$	−0.27*	1.63	0.51	0.36
$LV_{housework} \rightarrow LV_{MSD}$	0.23*	1.83	0.51	0.36
$LV_{stress} \rightarrow LV_{MSD}$	0.44*	1.43	0.51	0.36

Note: *P < 0.05; **P < 0.01; [1]waist/back pain; [2]Neck/shoulder pain.

chronic pain for 5000 Japanese women. In their research, Nagasawa et al. (Nagasawa et al., 2013) found that total hours of housework (−0.04) was the protective factor for chronic pain, while stress (0.92) or satisfaction of living environment (0.13) was the risk factor. Their findings on the statistical significance of housework was rather different from our study. This can be explained by the fact that approximately 83% of investigated Japanese women were full-time housewives, but the figure was only 5% in our study. Moreover, it has been reported that more than 65% of women bear most of housework load (Women of China, 2018). This indicated that most Chinese women in the survey sacrificed their own resting time to serve the family even after the paid work, which may further strengthen the effect of housework on MSDs. It was important to note that our study (−0.27) demonstrated the protective role of indoor environment satisfaction on MSDs in contrast to the risk role in the study (0.13) of Nagasawa et al. Previous studies have shown indoor environmental stressors, such as temperature, humidity, noise and vibration, can cause musculoskeletal tension and increase the risk of MSDs (Magnavita et al., 2011; Pienimaki, 2002; Pirmoradi et al., 2018; Telfer & Obradovich, 2017). In fact, indoor environmental satisfaction reflected individuals' subjective judgement scales for indoor environment quality, and good indoor environmental quality can reduce the risk of MSDs. That is, indoor environment satisfaction should be the protective factor for the development of MSDs. Furthermore, the HWMSDs model also showed the negative effect of indoor environment satisfaction on psychosocial stress (−0.22), which further provided support for this reverse effect. Interestingly, a positive association (0.14) was found between indoor environment satisfaction and housework, implying that indoor environment satisfaction may promote the

Table 4
Multiple group analysis results for HWMSDs model.

Characteristics		Path relationship					
		HW →MSDs	PS→MSDs	IE →MSDs	IE →HW	HW→PS	IE →PS
Age (years)	<30	0.14^{b}	0.33^{b}	-0.34^{a}	0.14^{a}	0.16^{b}	-0.31^{a}
	30~40	0.11^{b}	0.49^{a}	$-0.26^{a,b}$	0.13^{a}	0.24^{a}	$-0.24^{a,b}$
	40~50	0.32^{a}	0.41^{a}	$-0.27^{a,b}$	0.14^{a}	$0.19^{a,b}$	-0.19^{b}
	>50	0.28^{a}	0.27^{b}	-0.23^{b}	0.10^{a}	$0.20^{a,b}$	$-0.23^{a,b}$
BMI	<18.5	0.17^{b}	0.50^{a}	-0.26^{a}	0.13^{a}	0.24^{a}	0.35^{a}
(kg/m^2)	18.5–23.9	0.19^{b}	0.24^{c}	-0.23^{a}	0.17^{a}	0.22^{a}	0.14^{b}
	>23.9	0.29^{a}	0.33^{b}	-0.27^{a}	0.12^{a}	-0.07^{NS}	-0.08^{NS}
Education	Master, PhD, or specialization	0.13^{b}	0.26^{c}	-0.35^{a}	0.18^{a}	0.11^{a}	-0.28^{a}
	University	0.10^{b}	0.15^{d}	-0.25^{b}	0.22^{a}	0.12^{a}	-0.26^{a}
	Professional	0.14^{b}	0.25^{c}	-0.38^{a}	0.16^{a}	0.15^{a}	-0.17^{b}
	Middle school	0.36^{a}	0.49^{a}	-0.24^{b}	0.22^{a}	0.02^{NS}	-0.03^{NS}
	Primary school	0.29^{a}	0.37^{b}	-0.03^{NS}	0.01^{NS}	0.14^{a}	-0.16^{b}
Length of residence (years)	<2	0.18^{b}	0.09^{NS}	-0.41^{a}	0.22^{a}	0.34^{a}	-0.32^{a}
	2~5	0.13^{b}	0.42^{a}	-0.06^{NS}	$0.13^{a,b}$	0.20^{b}	0.08^{NS}
	5~10	0.16^{b}	0.50^{a}	-0.20^{b}	0.11^{b}	$0.24^{a,b}$	-0.15^{b}
	10~20	0.27^{a}	0.33^{b}	-0.33^{a}	0.18^{a}	0.11^{b}	0.02^{NS}
	>20	0.31^{a}	0.29^{b}	-0.27^{b}	0.19^{a}	0.21^{b}	-0.13^{b}
Household size (Person)	1~3	0.33^{a}	0.47^{a}	-0.10^{c}	$0.18^{a,b}$	0.23^{a}	-0.21^{b}
	4~5	0.11^{b}	0.31^{b}	-0.21^{b}	0.22^{a}	0.18^{a}	-0.20^{b}
	>5	0.17^{b}	0.31^{b}	-0.39^{a}	0.12^{b}	0.22^{a}	-0.33^{a}
Floor area (m^2)	<60	0.10^{c}	0.32^{b}	-0.34^{b}	0.02^{NS}	0.29^{a}	-0.26^{a}
	60~80	0.21^{b}	0.35^{b}	-0.46^{a}	0.28^{a}	0.22^{a}	-0.17^{b}
	80~100	0.21^{b}	0.31^{b}	$-0.41^{a,b}$	0.25^{a}	0.24^{a}	-0.14^{b}
	100~120	0.23^{b}	0.51^{a}	0.06^{NS}	0.06^{NS}	0.10^{b}	0.02^{NS}
	>120	0.34^{a}	0.46^{a}	-0.20^{c}	0.21^{a}	0.09^{b}	$-0.20^{a,b}$
Initial Model		0.23	0.44	−0.27	0.14	0.20	−0.22

Note: HW-housework activity level; PS-psychosocial stress; IE-indoor environmental satisfaction; a, b, c-multiple comparisons: the appearance/repetition of the same letter means that there is no marked difference among the groups under the condition of $P > 0.05$.

enthusiasm of housework activities. Although there was no literature that specifically the relationship between them, relevant literature has clearly established the positive relationship between environmental satisfaction and paid work (Clements-Croome, 2006). Additionally, it should be noted that the direct impact of housework (0.23) on MSDs was rather weaker than psychosoical stress (0.44), but housework on psychosocial stress turn out to be significant (0.20). Thus, housework not only play facilitating roles on MSDs but also moderating roles by enhancing other paths.

The HWMSDs model further showed that cooking (0.81) was assigned greatest weights to the housework, followed by doing laundry (0.73) and room cleaning (0.71), then by shopping (0.59) and washing dishes (0.41). Perhaps this was due to the fact that participants averagely spent 181 min in cooking, 112 min in doing laundry, 108 min in room cleaning, 96 min in shopping and 82 min in washing dishes every week. That is, each of the five housework tasks was weighted based on an assessment of its relative activity level. Moreover, child care was the most psychosocial stress for the investigated women.

4.2. Modification effect of personal factors

Multiple group analysis results highlighted that moderators (age, BMI, education, length of residence, household size and floor area) could change the strength of relationships in the HWMSDs model. Specifically, the association strength of housework to MSDs showed upward trend with age, length of residence, BMI and floor area. Previous research has consistently indicated that prevalence of MSDs generally increased with age (Bodin et al., 2012). As a result, the influence of housework on MSDs can be enhanced by age. The explanation for length of residence may be that there was significant positive association (0.48, $P < 0.05$) between age and length of residence. Being overweight (BMI>23.9) has been shown to increase the risk of MSDs, because overweight can add to the burden on the joints (Onyemaechi et al., 2016). Thus, overweight (high BMI) may extend the impact of housework on MSDs. It was relatively easy to understand the reasons for floor area. Because larger floor area means greater work intensity, such as sweeping, window cleaning and vacuuming. On the contrary, the path coefficient of housework to MSDs was trending downward with education level and household size. This reason may be that the education level is an important composite of socioeconomic status, and high socioeconomic status has been found to be associated with less time spent on housework (Gaston, 2016). The effect of household size might be due to other family members' share of housework with housewives.

The relationship between psychosocial stress and MSDs was also affected by age. The effect size for ages 30–50 years was higher than the ages <30 years or >50 years. Probably the main reason was that women ages 30–50 years received more work press, according to the survey data (Nagasawa et al., 2013). Moreover, the average length of residence for this group was 12.8 years. This can explain the phenomenon that the effect sizes of psychosocial stress on MSDs for length of residence in the 2–5 years and 5–10 years subgroups were larger than the 10–20 years and >20 years subgroups. High education levels have been proved to be associated with the decreased psychosocial stress by previous studies (Kamila et al., 2019), thus diminishing the extent to which MSDs was affected by psychosocial stress. Household size was inversely related to the association strength of psychosocial stress on MSDs. This finding cast doubt on claims that household size served as a stressor to increase housework time (Geist & Cohen, 2011). In similar, the pathway of indoor environmental satisfaction to MSDs was influenced by household size. However, the impact of indoor environmental satisfaction on housework has been invariant across different groups of respondents, which was not affected by these moderators. In fact, some literature reviews suggested that there were too few studies to provide convincing evidence regarding the impact of personal characteristics on the satisfaction with indoor environment (Frontczak & Wargocki, 2011). The effects of housework or indoor environment satisfaction on psychosocial stress were both moderated by age, education level, length of residence, household size and floor area. But the mechanisms underlying and influencing the psychosocial stress still remained unclear.

4.3. Strengths and limitations

This study contributed to the research field by developing the HWMSDs model to disentangle complex interactions between residential indoor environment, housework, psychosocial stress and MSDs for women. Furthermore, it also provided some information regarding the influence of personal characteristics on path relationships of HWMSDs model.

However, there may be some possible limitations in this study. Firstly, the HWMSDs model results can not be considered representatives for all women in the Central Plain of China due to the potential of selection bias. The sample size should continue to expand in future. Secondly, MSDs was measured by self-report. Although self-reported health has been widely used to measure health outcomes, more detailed information should be obtained by objective measurements. Thirdly, there are some potential pathways underlying the association between residential indoor environment, housework, psychosocial stress and MSDs. This is an area that needs to be further explored to provide a more comprehensive picture of housework and MSDs. In addition, male samples need to be included in future studies. Occupation needs to be considered as a confounding factor.

5. Conclusions

This article identified the relationship between housework, residential indoor environment, psychosocial stress and MSDs based on the survey data in the Central Plain of China. The key findings are as follows.

1) Housework and psychosocial stress were risk factors for the development of MSDs, whereas indoor environment satisfaction showed the protective role for MSDs.
2) Cooking had the greatest absolute contribution to housework activity level, followed by doing laundry, room cleaning, shopping and washing dishes. Child care delivered the greatest weight to psychosocial stress.
3) Relationships between housework, residential indoor environment, psychosocial stress and MSDs were moderated by age, BMI, education, length of residence, household size and floor area.

Declaration of competing interest

The authors declare that they have no competing interests.

Author statement

Jifu Lu-Writing-review & editing, project administration, resources and supervision; Yu Chen-Writing-original draft, Writing-review & editing, conceptualization, data curation, formal analysis, methodology, software, project administration, validation and visualization; Yapeng Lv- Writing-original draft, methodology and software.

Ethical statement

This study was approved by the Ethics Committee of Zhengzhou University. All respondents consented to participate in the study and written informed consent was obtained.

Data availability

The authors are unable or have chosen not to specify which data has been used.

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Appendix

I. Personal characteristics

1	Sex ☐Female ☐Male	Age: Height: Weight: Occupation:
	Education Level	☐Primary School ☐Junior high school ☐High school ☐Junior college school ☐Undergraduate school ☐Master's degree ☐Doctor of Medicine
2	Current place of residence	province town county
3	Number of years of residence in current place	☐Less than a year ☐2–5 years ☐5–10 years ☐10–20 years ☐More than 20 years
4	Number of co-occupants	☐0 people ☐1 people ☐2 people ☐3 people ☐4 people ☐5 or more people
5	Average time spent at home on weekdays (including sleep)	☐Less than 6 h ☐6–9 h ☐9–12 h ☐12–15 h ☐15–18 h ☐18–21 h ☐Over 21 h
6	Housework habits	☐often ☐Occasionally ☐Very few ☐Never
7	Habit of smoking	☐often ☐Occasionally ☐Very few ☐Never
8	Drinking habits	☐often ☐Occasionally ☐Very few ☐Never

II. Residence

1	How many floors do you live in?	Floor
2	How many floors is your house on?	Floor
3	Does your house have an elevator in the building?	☐Yes ☐No
4	What is the area of your house in square meters?	☐40 ☐40–60 ☐60–80 ☐80~100 ☐100–120 ☐Above 120

(*continued on next page*)

(*continued*)

1	How many floors do you live in?	Floor
5	Do you think the hob is the right height in the kitchen?	□Very high □A little high □Appropriate □A little low □Very low
6	Do you think the kitchen is the right size?	□Very high □A little high □Appropriate □A little low □Very low
7	Do you think the size of the bathroom is appropriate?	□Very high □A little high □Appropriate □A little low □Very low

III. Habits of life

1). The number of times per week you perform the following lifestyle behaviors ?

	Once a day	Once every 5–6 days	Once every 3–4 days	Once every 1–2 days	1 to 3 times per month	Less than once a month	No
Go out	□	□	□	□	□	□	□
Exercise	□	□	□	□	□	□	□
Use a computer	□	□	□	□	□	□	□
Bathing (Winter)	□	□	□	□	□	□	□
Bathing (summer)	□	□	□	□	□	□	□
Cooking	□	□	□	□	□	□	□
Do the laundry	□	□	□	□	□	□	□
Clean the toilet	□	□	□	□	□	□	□
Clean the room	□	□	□	□	□	□	□

2). How long do you spend on the following life behaviors?

	Within 5 min	5–10 min	10–20 min	20–30 min	30–60 min	1–3 h	3–5 h	More than 5 h
Use a computer	□	□	□	□	□	□	□	□
Bathing (Winter)	□	□	□	□	□	□	□	□
Bathing (summer)	□	□	□	□	□	□	□	□
Cooking	□	□	□	□	□	□	□	□
Do the laundry	□	□	□	□	□	□	□	□
Clean the toilet	□	□	□	□	□	□	□	□
Clean the room	□	□	□	□	□	□	□	□

3). Do you like to do the following housework?

	Like it very much	like	General	dislike	Dislike very much	Don't know
Cooking	□	□	□	□	□	□
Do the laundry	□	□	□	□	□	□
Clean the toilet	□	□	□	□	□	□
Clean the room	□	□	□	□	□	□

4). Are you satisfied with the following facilities?

	Very satisfied	Satisfied	Generally	dissatisfied	Very dissatisfied	Don't know
Interior decoration	□	□	□	□	□	□
Illumination	□	□	□	□	□	□
Heating system	□	□	□	□	□	□
Air conditioning (air conditioning)	□	□	□	□	□	□
Area of residence	□	□	□	□	□	□
Residential indoor environment	□	□	□	□	□	□

5). In the past 3 months, have you ever felt tired or stressed due to the following reasons?

	A lot of it	Have	Generally	Very few	Never
Take care of children	□	□	□	□	□
Care for the elderly	□	□	□	□	□
Do the housework	□	□	□	□	□
Work	□	□	□	□	□

IV. Chronic pain symptoms

1) Back pain	
1. Do you often suffer from back pain?	☐Yes ☐No
2. Have you had any back pain lasting more than two days in the last 3 months?	☐Almost every day ☐1–2 times per week ☐1–2 times per month ☐1–2 times in 3 months ☐Never
3. In the past 3 months, have you had back pain for more than two days that affected your life?	☐Yes ☐Slightly ☐Rarely ☐Never
4. The most painful intensity of your back pain in the last 3 months	☐Painless ☐Mild ☐Moderate ☐Severe ☐Serious
5. Have you felt any improvement in your back pain in the last 3 months?	☐Improvement in progress ☐No change ☐Deterioration ☐No back pain
2) Shoulder pain (or stiffness)	
1. Do you often suffer from shoulder pain?	☐Yes ☐No
2. Have you had shoulder pain lasting more than two days in the last 3 months?	☐Almost every day ☐1–2 times per week ☐1–2 times per month ☐1–2 times in 3 months ☐Never
3. In the last 3 months, have you had any shoulder pain that has affected your life for more than 2 days?	☐Yes ☐Slightly ☐Rarely ☐Never
4. The intensity of the most painful episode of your shoulder pain in the last 3 months	☐Painless ☐Mild ☐Moderate ☐Severe ☐Serious
5. Have you felt any improvement in your shoulder pain in the last 3 months?	☐Improvement in progress ☐No change ☐Deterioration ☐No shoulder pain
3) Have you felt physically tired for more than two days in the last 3 months?	☐Almost every day ☐1–2 times per week ☐1–2 times per month ☐1–2 times in 3 months ☐Never
4) Do you consider yourself healthy?	☐Healthy ☐General ☐Bad ☐Very bad
5) How is your sleep?	☐Sleeps well ☐Sometimes insomnia ☐Frequent insomnia

V. *Low back, shoulder or general symptoms with specific lifestyle behaviour*

1) Do you feel tired all over when you finish your daily chores?	☐Always feeling ☐Sometimes feeling ☐Rarely feels ☐No feeling
2) Do you feel discomfort in your lower back when you finish your daily chores?	☐Always feeling ☐Sometimes feeling ☐Rarely feels ☐No feeling
3) Do you feel discomfort in your shoulders when you finish your daily chores?	☐Always feeling ☐Sometimes feeling ☐Rarely feels ☐No feeling

4) In the last 3 months, have you felt discomfort in your lower back when performing any of the following acts of living?

	Always feeling uncomfortable	Sometimes feeling uncomfortable	Rarely feels uncomfortable	No Discomfort	Avoid this behaviour	No chance of This act occurred
Get up	☐	☐	☐	☐	☐	☐
Wash your face	☐	☐	☐	☐	☐	☐
Hand washing	☐	☐	☐	☐	☐	☐
Getting up from a chair (sofa, toilet, etc.)	☐	☐	☐	☐	☐	☐
Sitting on a chair (sofa, toilet, etc.)	☐	☐	☐	☐	☐	☐
Going up and down the stairs	☐	☐	☐	☐	☐	☐
Take something from a high or low place	☐	☐	☐	☐	☐	☐
Washing dishes by hand	☐	☐	☐	☐	☐	☐
Use a hoover or mop	☐	☐	☐	☐	☐	☐

5) In the last 3 months, have you felt discomfort in your shoulder when performing any of the following acts of living?

Going up and down the stairs	☐	☐	☐	☐	☐	☐
Take something from a high or low place	☐	☐	☐	☐	☐	☐
Washing dishes by hand	☐	☐	☐	☐	☐	☐
Use a hoover or mop	☐	☐	☐	☐	☐	☐

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