Body mass index and depressive symptoms among Chinese older couples: A longitudinal actor–partner interdependence model analysis

Introduction

Obesity and depression are becoming widespread conditions among older adults. According to WHO, the number of obese people in the world has tripled between 1975 and 2016 (WHO, 2020). The prevalence of obesity in older adults has been on the rise both in developed and developing countries (Malenfant & Batsis, 2019). In the United States, the prevalence of obesity was even over 40% among older adults aged 60 and over in 2017-2018 (Hales et al., 2020). The prevalence of depression is also growing increasingly and is expected to become the second-largest disease burden by 2030 (Mathers & Loncar, 2006). Obesity or depression in older adults is the leading cause of poorer quality of life (Mannan et al., 2016), severer chronic diseases (Romain et al., 2018), more medical expenses (Withrow & Alter, 2011), and higher mortality (Kohler et al., 2018). Moreover, obesity and depression will be closely interconnected and interact causing more serious health consequences for older adults (Romain et al., 2018).

Many previous studies have investigated the relationship between body weight and depressive symptoms in older adults, but the results are quite controversial. Some studies suggested that the causality run from body weight to depressive symptoms and found the positive (Ohayon, 2007; Roberts et al., 2003; Sachs-Ericsson et al., 2007), negative (Chang & Yen, 2012; Luo et al., 2018; Qian et al., 2017; Zhou et al., 2018), and U-shape relationships (Hajek & Konig, 2018; Noh et al., 2015). The reverse temporal sequence has also been proposed by many studies, with the positive (de Wit et al., 2010; Singh et al., 2014; Simon et al., 2008), and negative associations (Forman-Hoffman et al., 2007; Kuo et al., 2011) reported. A bidirectional relationship between body weight and depressive symptoms was also confirmed by some studies (Emery et al., 2020; Kim et al., 2014; Luppino et al., 2010). However, there are still some studies that did not detect a significant relationship between them (Murphy et al., 2009).

The mixed results may be that most of the previous studies only used the individual data as the unit of analysis, without examining the body weight-depressive symptoms association in a dyadic context. In other words, the majority of previous studies provide little information about the impact that one's spouse's body weight and depressive symptoms have on this association.

However, the marital dyad is considered to be one of the most important family relationships affecting individuals in later life (Thomas et al., 2017). A robust body of literature suggests that there are health benefits to being married, including greater happiness (Clark et al., 2008), better health (Simon, 2002), and lower mortality (Mete, 2005). In addition, the health conditions of individuals in marital dyads are also known to be concordant (Meyler et al., 2007). Owing to the shared environment and similar lifestyle habits such as diet and physical activity (Lee et al., 2005; Jackson et al., 2015), prior studies show that spouses' BMIs are positively associated (Chiappori et al., 2012; Jeffery & Rick, 2002), and one's risk of being obese nearly doubles if his or her partner becomes obese (Cobb et al., 2016). Couples also pass on negative feelings to one another, which increases their risk of being depressed. There is evidence suggests that one's higher levels of depressive symptoms are associated with higher levels of depressive symptoms in his/her partner (Kiecolt-Glaser & Wilson, 2017; Siegel et al., 2004).

The Actor–Partner Independence Model (APIM), an innovative dyadic analysis approach, can be utilized to analyze the cross-partner effects in couples. APIM uses the paired data instead of individual data to simultaneously estimate the association between one's predictor variable and his/her outcome variable (called actor effects), and the association between his/her partner's predictor variable and one's own outcome variable (called partner effects) (Kenny et al., 2006). It controls the non-independence of data by setting the correlations between predictor variables, and the correlations between residual items of outcome variables (Cook & Kenny, 2005). Many prior studies have used the APIM to examine the dyadic relationship in couples, such as the physical activity–BMI association (Burns et al., 2020), the depressive symptoms–quality of life association (Guo, 2019), and the depressive symptoms–marital satisfaction association (Wang et al., 2014). Only one study to date has used APIM to investigate the dyadic association between BMI and depressive symptoms in African American couples, but only cross-sectional data was used (Wickrama & Bryant, 2012). However, employing APIM to the longitudinal data can enable us to examine the temporal dynamics of the association we focused in couples.

Besides, the association between BMI and depressive symptoms could differ for Chinese older adults relative to their Western counterparts. The negative relationship between BMI and depressive symptoms in older adults was reported by many previous studies conducted in China (Luo et al., 2018; Qian et al., 2017; Zhou et al., 2018), which is contrary to the findings from many Western countries (Forman-Hoffman et al., 2007; Luppino et al., 2010). The different findings between Western countries and China may lie in the cultural differences in the viewpoint on body weight. Excessive body weight is a sign of unhealthy and stigma, and frequently associated with discrimination in Western countries (Spahlholz et al., 2016).

However, in China society, excessive body weight is often viewed as a symbol of wealth and health, and obese people are more likely to be welcomed by others, and get more respect and higher self-esteem (Li et al., 2004; Zhu et al., 2015). The association between happiness and body weight is best described in the well-known idiom of "happy mind and fat body" (Li et al., 2004). This traditional concept of body weight is related to the long-term food scarcity experience of the Chinese before the rapid economic development of China, especially the experience of great famine in the 1950s. From the late 1950s to the early 1960s, China suffered a great famine, which lasted for a long time and caused 30 million deaths with 662 million people affected (Wang et al., 2018). Therefore, people in China believe that only rich people can afford to eat more and gain more weight (Chang & Yen, 2012; Li et al., 2004). And the most negative association between body weight and depressive symptoms was found in older adults because the experience of food shortage in their childhood strengthened the traditional concept of body weight (Zhou et al., 2018). Thus, Chinese older adults with a high body mass index are less likely to experience negative emotions in China.

China has a large proportion of older adults aged 60 or above, with the number increasing from 76.64 million (7.43 percent) in 1982 to 178 million (13.26 percent) in 2010 and further to 254 million (18.13 percent) at the end of 2019 (DPES, 2020). With the improved living standards, Chinese older adults' average BMI increased by 1.3 kg/m^2, and the prevalence of overweight/obesity among them has increased from 25.8% in 1993 to 40.8% in 2015 (Song et al., 2018; Xi et al., 2012). Meanwhile, the prevalence of depression in older adults has increased as well, with the prevalence varies from 13% to 41% in different samples (Zhou et al., 2018). Given the inconsistent findings in previous studies and the increased prevalence of obesity and depression among Chinese older adults, it is important to further investigate the body weight–depressive symptoms association among Chinse older couples in the long run.

Therefore, the purpose of the present study was to extend the previous findings by looking at the association between BMI and depressive symptoms among Chinese older couples using the longitudinal APIM, which allows for simultaneously estimating the actor and partner effects across multiple time points. Specifically, using three waves (2011, 2013, 2015) of CHARLS (Chinese Health and Retirement Longitudinal Survey) and APIM, this study aimed to (1) examine the temporal dynamics of the association between BMI and depressive symptoms; (2) examine whether actor and partner effects exist in the association between BMI and depressive symptoms among Chinese older couples.

To the best of our knowledge, this is the first study examining the association between BMI and depressive symptoms among Chinese older couples from the longitudinal dyadic

perspective. It contributes to the literature by examining the temporal dynamics in older adults' BMI–depressive symptoms association. It is also estimated the cross-partner effects in the association between BMI and depressive symptoms in Chinese older couples. Furthermore, given the increased prevalence of obesity and depression among Chines older adults, the findings of the present study may highlight the couple-based intervention programs to promote healthy body weight and positive emotions in older adults. Below, we first introduced the data and method, followed by the results. Then we discussed our findings and the conclusion was introduced in the last section.

Data and Method

Data

The data used in this study were drawn from the Chinese Health and Retirement Longitudinal Survey (CHARLS), which is a nationally representative sample of Chinese residents aged 45 and older. Using a multistage stratified Probability Proportional to Size sampling, the baseline survey in 2011 randomly selected 150 county-level units, 450 community-level units, 10257 households, and a total of 17708 people from the country. All data were collected by face-to-face computer-assisted personal interviews with a response rate of over 80% at the baseline. Three follow-up surveys were carried out in 2013, 2015, and 2018 respectively, with follow-up progress rates over 86% (Zhao et al., 2020). The data collection was approved by the Ethics Committee of Peking University, and each participant was informed of the purpose of this survey. The participation of each participant in the study was voluntary, and they were assured that their privacy would be strictly protected.

Since there was no information on participants' height and weight in the 2018 wave, we used 2011, 2013, and 2015 waves of CHARLS to investigate the association between body mass index (BMI) and depressive symptoms among Chinese older couples. After excluding those who under 60, those who died or lost to follow-up between 2011 and 2015 waves, and those who have no living heterosexual spouse, the analytic sample included 3420 individuals, a total of 1710 older couples. Those respondents who died or lost to follow-up between waves were older, had worse Instrumental Activities of Daily Living (IADL) and higher levels of depressive symptoms compared with those who remained in the sample.

Measures

Body mass index (BMI) was defined as weight in kilograms divided by the height in meters squared (kg/m^2). Height and weight were measured by the trained investigators.

Depressive symptoms were measured by a 10-item short form of the Center for Epidemiologic Studies Depression scale (CES-D) (Andresen et al., 1994). Among them, eight items measured the negative emotions, two items measured the positive emotions. Four options from "rarely or none of the time" (0) to "most or all of the time" (3) were available for each item. The coding was reversed for the two positive items. Depressive symptoms score was obtained by calculating the total score of the ten items, which ranged from 0 to 30, with a higher score indicating higher levels of depressive symptoms (Cronbach's alpha ranged from 0.75 to 0.80 across three waves).

Covariates Referring to previous studies examining the reciprocal effects in couples (e.g. Guo, 2019; Wang et al., 2014; Wickrama & Bryant, 2012), some potential confounders, including age, education, annual income (in Chinese yuan, logarithm), IADL (Instrumental Activities of Daily Living), length of marriage (years), and place of residence (0 = rural, 1 = urban) at the baseline were controlled as time-invariant covariates in this study. Education was measured by the question "What's the highest level of education you have now?". Eleven options were available ranging from "Illiterate" (1) to "Doctoral degree" (11), with a higher score indicating higher educational attainment. IADL was assessed by five basic activities in CHARLS, including doing household chores, preparing hot meals, shopping for groceries, taking medications, and managing money. Four options were available for each activity ranging from "No, I don't have any difficulty" (0) to "I can not do it" (4). IADL score was obtained by computing a total sum score, with higher scores indicated worse IADL (Cronbach's alpha was 0.77 at the baseline). Sample descriptive statistics were presented in Table 1.

Method

We used the Actor-Partner Interdependence Model (APIM) to examine the association between BMI and depressive symptoms among Chinese older couples. APIM can simultaneously estimate the actor effects and the partner effects (Kenny et al., 2006). For example (see Figure 1), in the BMI-to-CES-D association from T1 to T2, husbands' actor effects refer to the influence of husbands' BMI at T1 on their CES-D at T2, while husbands' partner effects refer to the influence of their wives' BMI at T1 on their CES-D at T2; wives' actor effects refer to the influence of wives' BMI at T1 on their CES-D at T2, while wives' partner effects refer to the influence of their husbands' BMI at T1 on their CES-D at T2.

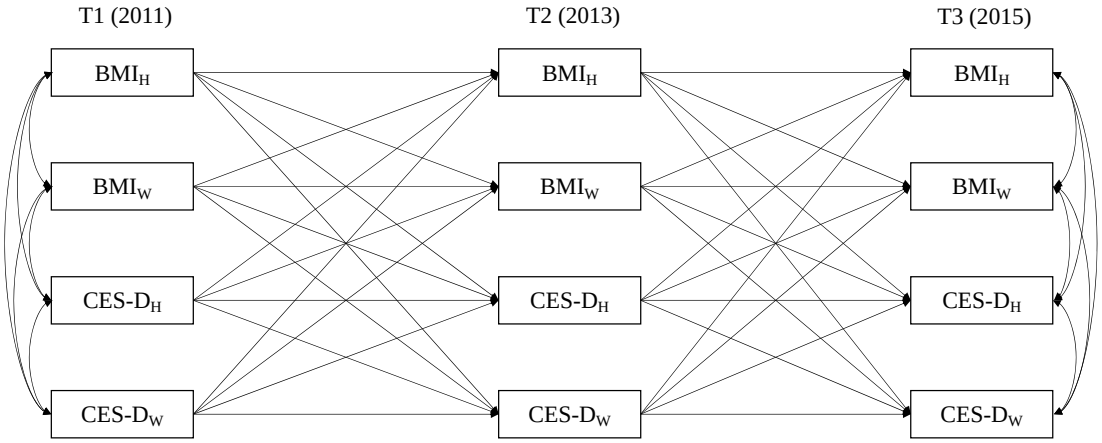

Figure 1. Path of Actor-Partner Interdependence Model (APIM) in the current study.

Notes. H = Husbands; W = Wives; BMI = Body Mass Index; CES-D = the Center for Epidemiologic Studies of Depression; The correlations among all variables at T2 were estimated in the same way as those among variables at T1 and T3 were estimated, but for clarity, these correlation lines were not depicted.

Analytic strategy

To test the reciprocal relationship between BMI and depressive symptoms among Chinese older couples, we employed the APIM to three waves (2011, 2013, 2015) of CHARLS. In the following analysis, after described the characteristics of the variables used in this study, Pearson correlation analysis was conducted among couples' BMI and depressive symptoms; then APIM were employed to examine the association between BMI and depressive symptoms among Chinese older couples. All preliminary analyses were carried out using Stata Version 15, and APIM analysis was carried out using Mplus Version 7.4. Missing data were estimated using the Full Information Maximum Likelihood (FIML) in Mplus. Root Mean Square Error of Approximation (RMSEA), Comparative Fit Index (CFI), and SRMR (Standardized Root Mean Square Residual) were used as the evaluation indicators for model fitting, with RMSEA values < 0.08, CFI values > 0.90, and SRMR values < 0.09 indicating a good model fit (Kline, 2011).

Results

Descriptive results

Table 1 shows the characteristics of the variables used in this study. The average BMI and CES-D of older adults experienced an opposite change from T1 to T3. The average BMI of older adults increased from 23.10 kg/m^2 at T1 to 23.28 kg/m^2 at T2 and further decreased to 23.23 kg/m^2 at T3, whereas the average CES-D of older adults decreased from 8.21 at T1 to 7.28 at T2 and further increased to 7.75 at T3. Husbands' BMI and CES-D were consistently lower than their wives' BMI and CES-D from T1 to T3.

Table 1. Descriptive analysis of the sample, CHARLS, 2011-2015 (1710 dyads).

Variable	Total Mean (SD)/%	Husbands Mean (SD)/%	Wives Mean (SD)/%	Husbands-Wives Differences
T1 (2011 baseline)				
Age	67.08 (5.61)	68.22 (5.74)	65.94 (5.24)	***
Education	2.89 (1.87)	3.53 (1.89)	2.26 (1.63)	***
Income	11226.14 (37996.08)	14384.35 (40892.03)	8075.38 (34594.07)	***
IADL	6.16 (2.63)	6.03 (2.63)	6.29 (2.62)	**
Length of marriage	44.61 (7.46)			
Urban household	18.89			
BMI	23.10 (3.53)	22.51 (3.32)	23.69 (3.64)	***
CES-D	8.21 (6.38)	7.20 (5.83)	9.21 (6.75)	***
T2 (2013 follow-up)				
BMI	23.28 (3.48)	22.76 (3.28)	23.82 (3.59)	***
CES-D	7.28 (5.83)	6.48 (5.30)	8.09 (6.21)	***
T3 (2015 follow-up)				
BMI	23.23 (3.54)	22.78 (3.41)	23.69 (3.60)	***
CES-D	7.75 (6.59)	6.69 (6.03)	8.80 (6.94)	***

Notes. BMI = Body Mass Index; CES-D = the Center for Epidemiologic Studies of Depression; The significance of the husbands-wives difference in the last column is determined by t-test or Chi-square test; * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Table 2 shows the results of Pearson correlation analysis among husbands' and wives' BMI and CES-D from T1 to T3. One's BMI was positively correlated with his/her own and partner's BMI, and one's CES-D was positively correlated with his/her own and partner's CES-D. Husbands' BMI was negatively correlated with their own and wives' CES-D apart from husbands' BMI at T2 with their own and wives' CES-D at T3. Wives' BMI was negatively correlated with their husbands' CES-D, whereas rarely significantly correlated with their own CES-D.

Table 2. Pearson correlations coefficients among husbands' and wives' BMI and CES-D, CHARLS, 2011-2015.

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
(1) BMI_H T1	1.00											
(2) BMI_W T1	0.25***	1.00										
(3) BMI_H T2	0.89***	0.23***	1.00									
(4) BMI_W T2	0.25***	0.90***	0.23***	1.00								
(5) BMI_H T3	0.88***	0.21***	0.89***	0.23***	1.00							
(6) BMI_W T3	0.19***	0.88***	0.20***	0.90***	0.19***	1.00						
(7) CES-D_H T1	-0.12***	-0.10***	-0.11***	-0.08**	-0.13***	-0.06*	1.00					
(8) CES-D_W T1	-0.09***	-0.06*	-0.09***	-0.07*	-0.08**	-0.03	0.38***	1.00				
(9) CES-D_H T2	-0.11***	-0.09***	-0.08**	-0.12***	-0.11***	-0.09***	0.42***	0.23***	1.00			
(10) CES-D_W T2	-0.12***	-0.03	-0.07*	-0.04	-0.10***	-0.03	0.25***	0.46***	0.29***	1.00		
(11) CES-D_H T3	-0.07**	-0.09***	-0.03	-0.07*	-0.07**	-0.06*	0.40***	0.22***	0.48***	0.22***	1.00	
(12) CES-D_W T3	-0.08**	-0.03	-0.05	-0.02	-0.08**	-0.03	0.24***	0.45***	0.17***	0.45***	0.27***	1.00

Notes. H = Husbands; W = Wives; BMI = Body Mass Index; CES-D = the Center for Epidemiologic Studies of Depression; T1 = 2011, T2 = 2013, T3 = 2015; * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

APIM results

Figure 2 illustrates the APIM results of the association between BMI and depressive symptoms among Chinese older couples. The longitudinal APIM demonstrated good fit to the data: RMSEA = 0.063, CFI = 0.952, SRMR = 0.027.

Actor effects. Actor effects were estimated to investigate the impact of one's earlier BMI or CES-D on his/her own subsequent BMI and CES-D. The results showed that prior BMI was a significant predictor of subsequent BMI, and prior CES-D was a significant predictor of subsequent CES-D for both husbands and wives. BMI at T1 was a significant predictor of their CES-D at T2 for husbands in that greater BMI predicted lower levels of CES-D ($\beta = -0.051$, $p < 0.05$). However, the same was not true for wives. One's BMI at T2 was not a significant predictor of his/her CES-D at T3 for both husbands and wives. One's earlier CES-D was not a significant predictor of his/her own subsequent BMI from T1 to T3 for both husbands and wives.

Partner effects. Partner effects were estimated to explore the impact of one's earlier BMI on his/her partner's subsequent BMI and CES-D, and the impact of one's earlier CES-D on his/her partner's subsequent BMI and CES-D. BMI at T1 was not a significant predictor of their partners' BMI at T2 for both husbands and wives. However, wives' BMI at T2 was a significant predictor of husbands' BMI at T3 such that wives' greater BMI predicted greater levels of BMI in their husbands ($\beta = 0.035$, $p < 0.05$). The same was not true for husbands' BMI at T2 to their wives' BMI at T3. CES-D at T1 was a significant predictor of their partner's CES-D at T2, such that greater CES-D predicted greater CES-D in their partners (Husbands: $\beta = 0.080$, $p < 0.001$; Wives: $\beta = 0.076$, $p < 0.01$). Wives' CES-D at T2 was a significant predictor of their husbands' CES-D at T3 such that wives' greater CES-D predicted greater levels of CES-D in their husbands ($\beta = 0.092$, $p < 0.001$). However, husbands' CES-D at T2 was not a significant predictor of their wives' CES-D at T3. One's BMI at T1 was a significant predictor of his/her partner's CES-D at T2 such that greater BMI predicted lower levels of CES-D in his/her partner (Husbands: $\beta = -0.065$, $p < 0.01$; Wives: $\beta = -0.058$, $p < 0.05$). However, one's BMI at T2 was not a significant predictor of his/her partner's CES-D at T3 for both husbands and wives. One's earlier CES-D was not a significant predictor of his/her partner's subsequent BMI from T1 to T3 for both husbands and wives.

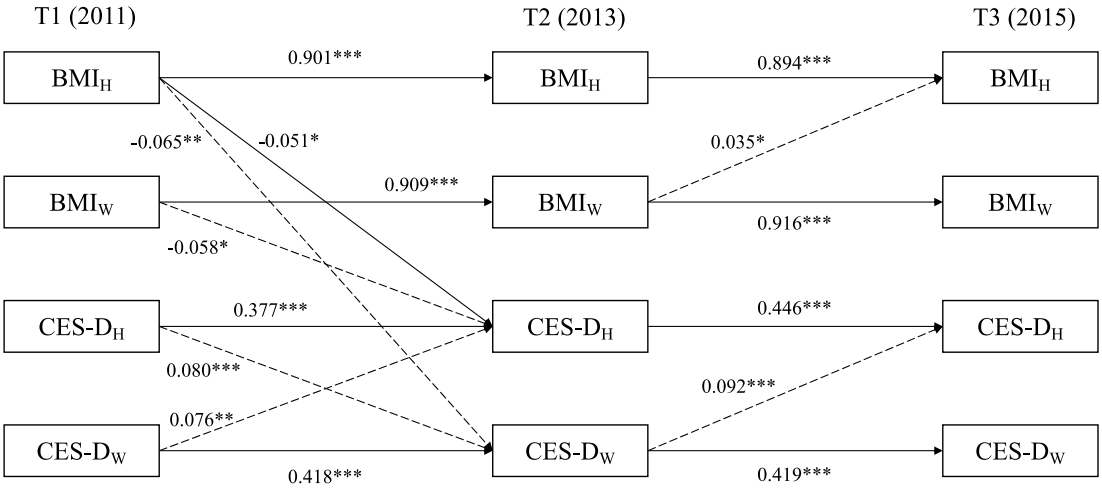

Figure 2. The APIM results of the association between BMI and depressive symptoms among Chinese older couples.

Notes. H = Husbands; W = Wives; BMI = Body Mass Index; CES-D = the Center for Epidemiologic Studies of Depression; Covariates including age, education, income, IADL, length of marriage, and place of residence were controlled; For ease of presentation, only significant paths linking BMI and depressive symptoms were shown; Standardized coefficients were shown; The significant actor effects were in solid lines, significant partner effects were in dotted lines. RMSEA = 0.063; CFI = 0.952; SRMR = 0.027; * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Discussion

Employing Actor-Partner Interdependence Model (APIM) to three waves (2011, 2013, 2015) of the Chinese Health and Retirement Longitudinal Survey (CHARLS), the current study examined the association between body mass index (BMI) and depressive symptoms among Chinese older couples. This study found many actors and partner effects among Chinese older couples with the longitudinal dyadic study design.

Actor effects

We found that, across three waves, husbands' and wives' earlier BMI and depressive symptoms consistently positively predicted their later BMI and depressive symptoms, respectively. These significant actor effects indicated that Chinese older adults' earlier levels of BMI and depressive symptoms have long-lasting effects on their subsequent scores on BMI and depressive symptoms. Besides, in contrast with depressive symptoms, older adults' BMI seems to be more influenced by their previous status.

The current study showed that husbands' BMI at T1 predicted their depressive symptoms at T2, with higher levels of BMI predicted lower levels of depressive symptoms, whereas no significant association between wives' BMI and their depressive symptoms from T1 to T2. Such

gender differences in the associations between BMI and depressive symptoms were in line with many previous studies conducted in China. For example, using multiple waves of CHARLS, the same sample used in the current study, Luo et al. (2018) and Zhou et al. (2018) found the relationship between body weight and depression was only significant in male older adults, but not in female older adults. Other studies, either conducted in China or western countries, have also reached this conclusion (Dong et al., 2013; Vogelzangs et al., 2009).

Some biological, behavioral, and cultural mechanisms have been proposed to explain the negative BMI-to-depressive symptoms association among older adults. Firstly, some studies suggested that older adults with a greater BMI have a higher reserve of muscle mass and thus are more likely to have a better physical functional ability which is believed to contribute to lowering depressive symptoms (Ho et al., 2008). Secondly, compared to non-obese people, obese older adults have a higher consumption of certain nutrients, such as carbohydrates and folate/B12, which are beneficial to relieve depressive symptoms (Li et al., 2004; Petridou et al., 2016). Finally, in Chinese cultures, only those who are carefree will have a larger body shape, and being fat is also believed to be a symbol of wealth and health, and could help an individual earn more self-esteem and respect in China society (Li et al., 2004; Zhu et al., 2015). Therefore, it is reasonable to expect that a higher level of BMI will reduce depressive symptoms.

For the gendered BMI–depressive symptoms associations, previous research suggested that male older adults are prone to judge the low body weight as less preferable and regard it as a poor body image compared to large body shape (Luo et al., 2018). However, for female older adults, the psychological improvement brought about by the weight gain may be neutralized by their excessive focus on external images (Zhou et al., 2018). Besides, female older adults' BMI and depressive symptoms are higher than male older adults, so changing in the same unit of BMI may significantly decrease men's depressive symptoms, but not women's, which is the so-called floor effects. Another explanation for the non-significant associations in wives may be that after controlled the influence of the husbands' BMI and depressive symptoms, the relationship between wives' BMI and depressive symptoms was no longer significant. However, we found that husbands' earlier BMI predicted their later depressive symptoms only from T1 to T2, and no significant association linking their BMI to depressive symptoms was found from T2 to T3. It may be that the effect of husbands' BMI on their depressive symptoms cannot last a long time because of their lower levels of BMI and depressive symptoms.

Inconsistent with previous studies (Emery et al., 2020; Kim et al., 2014), this study did not find a bidirectional association between BMI and depressive symptoms in Chinese older adults. We found that BMI was a significant predictor of depressive symptoms for both husbands and

wives, whereas depressive symptoms had no significant effect on BMI, which is consistent with many previous studies (Roberts et al., 2003; Yu et al., 2020). Apart from the dyadic study design applied in the current study, another possible explanation may be that it may need a longer time for depressive symptoms to affect BMI, while the current is a relatively short-term longitudinal study. Therefore, future research is needed to ascertain whether depressive symptoms is a predictor of BMI in Chinese older couples by utilizing a longer-term longitudinal design.

Partner effects

We found that wives' BMI at T2 predicted husbands' BMI at T3, with wives' greater BMI predicted husbands' greater BMI, which is inconsistent with previous research suggesting cross-partner effects in couple's BMI (Chiappori et al., 2012; Jeffery & Rick, 2002). One possible explanation for the unidirectional predictive effect from wives' BMI to husbands' BMI may be related to the gender division of household labor in China. In China society, husbands are mainly responsible for family livelihoods, while wives are responsible for the housework, especially cooking (Luo & Chui, 2018; Zang, 2020). The decision-making power in cooking allows wives' BMI to have a significant impact on the husbands' BMI. Furthermore, prior study has indicated that wives experienced greater increases in BMI than husbands after marriage (Shafer, 2010). A greater BMI in wives makes it more possible to affect their husband's BMI than the other way around. However, it may take a longer time for wives' BMI to effect, because the association linking wives' BMI and husbands' BMI only emerged from T2 to T3.

In line with previous research, the current study found that from T1 to T2, one's earlier depressive symptoms positively predicted their partners' depressive symptoms later, and one's earlier BMI negatively predicted their partners' depressive symptoms later for both husbands and wives. Theories of emotional transmission and contagion (Kiecolt-Glaser & Newton, 2001; Larson & Almeida, 1999) suggested that the emotions of spouses, either negative or positive emotions, are dependent and causally linked. For the transmission of negative emotions in couples, several studies found that higher levels of depressive symptoms in one spouse are associated with higher levels of depressive symptoms in their partners (Hippisley-Cox et al., 2002; Kiecolt-Glaser & Wilson, 2017). For the transmission of positive emotions, limited research suggested that there are significant spillover effects of positive emotions in older couples (King et al., 2018).

However, this study found that one's BMI had no significant effect on their partners' BMI from T2 to T3, whereas wives' depressive symptoms at T2 still had a significant influence on their husbands' depressive symptoms at T3. These results were consistent with previous research suggesting that the contagion effects for negative emotions are greater than for positive

emotions (Larson & Almeida, 1999), and wives' depressive symptoms predicted their husbands' subsequent depressive symptoms than the other way around in the long run (King et al., 2018). One explanation is that women usually have a higher level of depressive symptoms than men because of the hormonal fluctuations and higher levels of inflammation (Kiecolt-Glaser & Wilson, 2017; Qian et al., 2017), which allows wives' depressive symptoms to have a long-term effect on their husbands' depressive symptoms. Another explanation is that compared with women, men are more likely to rely on their spouses for social support in later life. It is difficult for a husband to cultivate interests and relationships in later life, and therefore are more dependent on their wives emotionally and physically (King et al., 2018). However, once wives become depressed, the social support husbands receive would be severely affected, which may lead to an increase in husbands' depressive symptoms. Also, compared with men, women have a greater emotional expressivity, particularly the greater expression of negative emotions (Carstensen et al., 1995), which may also contribute to the long-term impact of wives' depressive symptoms.

Strengths and limitations

This study has the following strengths: first, we investigated temporal dynamics of the association between older adults' BMI and depressive symptoms by utilizing the longitudinal data. Secondly, applying the Actor-Partner Interdependence Model, we simultaneously estimated the actor and partner effects in the association between BMI and depressive symptoms in older couples. Finally, we explored the relationship between BMI and depressive symptoms in Chinese older adults. Many previous studies focused on this association were mainly conducted in Western countries. However, the differences between Chinese and Western cultures may lead to a very different relationship between BMI and depressive symptoms in older adults.

However, this article still has some limitations. First, this study did not control some confounders due to the data limitations, such as marital quality and couples' behavioral closeness, which may moderate the dynamic links between couples' BMI and depressive symptoms. Secondly, compare with those who died or lost to follow-up between waves, participants who remained in the current sample were younger, had better IADL and lower levels of depressive symptoms, which may affect the generalization of the findings in this study. Thirdly, we did not explore the mechanism of the association linking BMI and depressive symptoms. Many studies postulated that sleep, including sleep quality and sleep duration, may be one of the underlying mechanisms of the transmission and contagion of BMI and depressive symptoms in couples (Mannan et al., 2016; Romain et al., 2018). Finally, the current study only

utilized three waves of data with a four-year span. However, it may take a longer time for some associations to emerge. Future research with longer assessment periods is needed to address these limitations.

Conclusion

In conclusion, this study found the unidirectional association between BMI and depressive symptoms in Chinese older adults, with the causality runs from BMI to depressive symptoms. The cross-partner association between BMI and depressive symptoms in Chinese older couples were also found, with wives were the 'sender' of negative emotions and higher body weight was more protective for husbands' mental health. Given the increased prevalence of obesity and depression in Chinese older adults and the current findings, couple-based interventions and programs should be taken to improve older adults' physical and mental health conditions.

References

Andresen, E. M., Malmgren, J. A., Carter, W. B., & Patrick, D. L. (1994). Screening for depression in well older adults: Evaluation of a short form of the CES-D. *American Journal of Preventive Medicine*, 10(2), 77-84.

Burns, R. J., Fillo, J., Deschênes, S. S., & Schmitz, N. (2020). Dyadic associations between physical activity and body mass index in couples in which one partner has diabetes: Results from the Lifelines cohort study. *Journal of Behavioral Medicine*, 43(1), 143-149.

Carstensen, L. L., Gottman, J. M., & Levenson, R. W. (1995). Emotional behavior in long-term marriage. *Psychology and Aging*, 10, 140-149.

Chang, H., & Yen, S. (2012). Association between obesity and depression: Evidence from a longitudinal sample of the elderly in Taiwan. *Aging and Mental Health*, 16(2), 173-180.

Chiappori, P. A., Oreffice, S., & Quintana, D. C. (2012). Fatter attraction: Anthropometric and socioeconomic matching on the marriage market. *Journal of Political Economy*, 120(4), 659-695.

Clark, A. E., Diener, E., Georgellis, Y., & Lucas, R. E. (2008). Lags and leads in life satisfaction: A test of the baseline hypothesis. *The Economic Journal*, 118(529), 222-243.

Cobb, L. K., McAdams-DeMarco, M. A., Gudzune, K. A., Anderson, C. A., Demerath, E., Woodward, M., Selvin, E., & Coresh, J. (2016). Changes in body mass index and obesity risk in married couples over 25 years: The ARIC cohort study. *American Journal of Epidemiology*, 183(5), 435-443.

Cook, W. L., & Kenny, D. A. (2005). The actor-partner interdependence model: A model of bidirectional effects in developmental studies. *International Journal of Behavioral Development*, 29(2), 101-109.

De Wit, L., Luppino, F., van Straten, A., Penninx, B., Zitman, F., & Cuijpers, P. (2010). Depression and obesity: A meta-analysis of community-based studies. *Psychiatry Research*, 178(2), 230-235.

Department of Population and Employment Statistics, National Bureau of Statistics (DPES). (2020). *China Population and Employment Statistics Yearbook*. Beijing: China Statistic Press.

Dong, Q., Liu, J. J., Zheng, R. Z., Dong, Y. H., Feng, X. M., Li, J., & Huang, F. (2013). Obesity and depressive symptoms in the elderly: A survey in the rural area of Chizhou, Anhui province. *International Journal of Geriatric Psychiatry*, 28(3), 227-232.

Emery, C. F., Finkel, D., Gatz, M., & Dahl Aslan, A. K. (2020). Evidence of bidirectional associations between depressive symptoms and body mass among older adults. *The Journals of Gerontology: Series B*, 75(8), 1689-1698.

Forman-Hoffman, V. L., Yankey, J. W., Hillis, S. L., Wallace, R. B., & Wolinsky, F. D. (2007). Weight and depressive symptoms in older adults: Direction of influence?. *The Journals of Gerontology: Series B*, 62(1), S43-S51.

Guo, X. (2019). Reciprocal effects of depressive symptoms and life satisfaction among Chinese older married couples from 2010 to 2014: Evidence from the China Family Panel Studies. *Aging and Mental Health*, 24(8), 1216-1224.

Hajek, A., & Konig, H. H. (2018). The association between obesity and social exclusion in middle-aged and older adults: Findings from a nationally representative study in Germany. *BMC Geriatrics*, 18(1), 1-7.

Hales, C. M., Carroll, M. D., Fryar, C. D., & Ogden, C. L. (2020). Prevalence of obesity and severe obesity among adults: United States, 2017-2018. https://www.cdc.gov/nchs/products/databriefs/db360.htm. Accessed April 6, 2021.

Hippisley-Cox, J., Coupland, C., Pringle, M., Crown, N., & Hammersley, V. (2002). Married couples' risk of same disease: Cross sectional study. *BMJ*, 325(7365), 1-5.

Ho, R. C., Niti, M., Kua, E. H., & Ng, T. P. (2008). Body mass index, waist circumference, waist–hip ratio and depressive symptoms in Chinese elderly: A population-based study. *International Journal of Geriatric Psychiatry*, 23(4), 401-408.

Jackson, S. E., Steptoe, A., & Wardle, J. (2015). The influence of partner's behavior on health behavior change: The English Longitudinal Study of Ageing. *JAMA Internal Medicine*, 175(3), 385-392.

Jeffery, R. W., & Rick, A. M. (2002). Cross-sectional and longitudinal associations between body mass index and marriage-related factors. *Obesity Research*, 10, 809-815.

Kenny, D. A., Kashy, D. A., & Cook, W. L. (2006). *Dyadic data analysis*. New York: Guilford Press.

Kiecolt-Glaser, J. K., & Newton, T. (2001). Marriage and health: His and hers. *Psychological Bulletin*, 127, 472-503.

Kiecolt-Glaser, J. K., & Wilson, S. J. (2017). Lovesick: How couples' relationships influence health. *Annual Review of Clinical Psychology*, 13, 421-443.

Kim, J., Noh, J. W., Park, J., & Kwon, Y. D. (2014). Body mass index and depressive symptoms in older adults: A cross-lagged panel analysis. *PloS One*, 9(12), 1-9.

King, D. B., Canham, S. L., Cobb, R. J., & O'Rourke, N. (2018). Reciprocal effects of life satisfaction and depressive symptoms within long-wed couples over time. *The Journals of Gerontology: Series B*, 73(3), 363-371.

Kline, R. B. (2011). *Principles and Practice of Structural Equation Modeling*. New York: The Guilford Press.

Kohler, C. A., Evangelou, E., Stubbs, B., Solmi, M., Veronese, N., Belbasis, L., Bortolato, B., Melo, M. C. A., Coelho, C. A., Fernandes, B. S., Olfson, M., Ioannidis, J. P. A., & Carvalho, A. F. (2018). Mapping risk factors for depression across the lifespan: An umbrella review of evidence from meta-analyses and Mendelian randomization studies. *Journal of Psychiatric Research*, 103, 189-207.

Kuo, S., Lin, K., Chen, C., Chuang, Y., & Chen, W. (2011). Depression trajectories and obesity among the elderly in Taiwan. *Psychological medicine*, 41(8), 1665-1676.

Larson, R. W., & Almeida, D. M. (1999). Emotional transmission in the daily lives of families: A new paradigm for studying family process. *Journal of Marriage and the Family*, 61, 5-20.

Lee, S., Cho, E., Grodstein, F., Kawachi, I., Hu, F. B., & Colditz, G. A. (2005). Effects of marital transitions on changes in dietary and other health behaviours in U.S. women. *International Journal of Epidemiology*, 34, 69-78.

Li, Z., Ho, S., Chan, W., Ho, K., Li, M., Leung, G. M., & Lam, T. H. (2004). Obesity and depressive symptoms in Chinese elderly. *International Journal of Geriatric Psychiatry*, 19(1), 68-74.

Luo, H., Li, J., Zhang, Q., Cao, P., Ren, X., Fang, A., Liao, H., & Liu, L. (2018). Obesity and the onset of depressive symptoms among middle-aged and older adults in China: Evidence from the CHARLS. *BMC Public Health*, 18(1), 909-918.

Luo, M. S., & Chui, E. W. T. (2018). Gender division of household labor in China: Cohort analysis in life course patterns. *Journal of Family Issues*, 39(12), 3153-3176.

Luppino, F. S., de Wit, L. M., Bouvy, P. F., Stijnen, T., Cuijpers, P., Penninx, B. W., & Zitman, F. G. (2010). Overweight, obesity, and depression: A systematic review and meta-analysis of longitudinal studies. *Archives of General Psychiatry*, 67(3), 220-229.

Malenfant, J. H., & Batsis, J. A. (2019). Obesity in the geriatric population–A global health perspective. *Journal of Global Health Reports*, 3, 1-7.

Mannan, M., Mamun, A., Doi, S., & Clavarino, A. (2016). Is there a bi-directional relationship between depression and obesity among adult men and women? Systematic review and bias-adjusted meta analysis. *Asian Journal of Psychiatry*, 21, 51-66.

Mathers, C. D., & Loncar, D. (2006). Projections of global mortality and burden of disease from 2002 to 2030. *PLoS Medicine*, 3(11), 2011-2030.

Mete, C. (2005). Predictors of elderly mortality: Health status, socioeconomic characteristics and social determinants of health. *Health Economics*, 14, 135-148.

Meyler, D., Stimpson, J. P., & Peek, M. K. (2007). Health concordance within couples: A systematic review. *Social Science and Medicine*, 64(11), 2297-2310.

Murphy, J. M., Horton, N. J., Burke, J. D., Monson, R. R., Laird, N. M., Lesage, A., & Sobol, A. M. (2009). Obesity and weight gain in relation to depression: Findings from the Stirling County Study. *International Journal of Obesity*, 33(3), 335-341.

Noh, J. W., Kwon, Y. D., Park, J., & Kim, J. (2015). Body mass index and depressive symptoms in middle aged and older adults. *BMC Public Health*, 15(1), 1-7.

Ohayon, M. M. (2007). Epidemiology of depression and its treatment in the general population. *Journal of Psychiatric Research*, 41, 207-213.

Petridou, E. T., Kousoulis, A. A., Michelakos, T., Papathoma, P., Dessypris, N., Papadopoulos, F. C., & Stefanadis, C. (2016). Folate and B12 serum levels in association with depression in the aged: A systematic review and meta-analysis. *Aging and Mental Health*, 20(9), 965-973.

Qian, J., Li, N., & Ren, X. (2017). Obesity and depressive symptoms among Chinese people aged 45 and over. *Scientific Reports*, 7, 1-7.

Roberts, R. E., Deleger, S., Strawbridge, W. J., & Kaplan, G. A. (2003). Prospective association between obesity and depression: evidence from the Alameda County Study. *International Journal of Obesity*, 27(4), 514-521.

Romain, K., Webb, T., & Kumar, M. (2018). Depression and obesity: Can the cycle be broken?. *BJPsych Advances*, 24(2), 132-140.

Sachs-Ericsson, N., Burns, A. B., Gordon, K. H., Eckel, L. A., Wonderlich, S. A., Crosby, R. D., & Blazer, D. G. (2007). Body mass index and depressive symptoms in older adults: The moderating roles of race, sex, and socioeconomic status. *The American Journal of Geriatric Psychiatry*, 15(9), 815-825.

Shafer, E. (2010). The effect of marriage on weight gain and propensity to become obese in the African American community. *Journal of Family Issues*, 31, 1166-1182.

Siegel, M. J., Bradley, E. H., Gallo, W. T., & Kasl, S. V. (2004). The effect of spousal mental and physical health on husbands' and wives' depressive symptoms, among older adults: Longitudinal evidence from the health and retirement survey. *Journal of Aging and Health*, 16, 398-425.

Simon, G. E., Ludman, E. J., Linde, J. A., Operskalski, B. H., Ichikawa, L., Rohde, P., Finch, E. A., & Jeffery, R. W. (2008). Association between obesity and depression in middle-aged women. *General Hospital Psychiatry*, 30(1), 32-39.

Simon, R. W. (2002). Revisiting the relationships among gender, marital status and mental health. *American Journal of Sociology*, 107, 1065-1096.

Singh, G., Jackson, C. A., Dobson, A., & Mishra, G. D. (2014). Bidirectional association between weight change and depression in mid-aged women: A population-based longitudinal study. *International Journal of Obesity*, 38(4), 591-596.

Song, M., Cheng, X., Kong, J., & Wang, H. (2018). Prevalence and influencing factors of overweight and obesity among middle-aged and elderly people in China. *Chinese Journal of Disease Control Prevention*, 22(8), 804-808.

Spahlholz, J., Baer, N., König, H. H., Riedel-Heller, S. G., & Luck-Sikorski, C. (2016). Obesity and discrimination–A systematic review and meta-analysis of observational studies. *Obesity Reviews*, 17(1), 43-55.

Thomas, P. A., Liu, H., & Umberson, D. (2017). Family relationships and well-being. *Innovation in Aging*, 1(3), 1-11.

Vogelzangs, N., Kritchevsky, S. B., Beekman, A. T., Brenes, G. A., Newman, A. B., Satterfield, S., Yaffe, K., Harris, T. B., & Penninx, B. W. (2009). Obesity and onset of significant depressive symptoms: Results from a prospective community-based cohort study of older men and women. *The Journal of Clinical Psychiatry*, 71(4), 391-399.

Wang, Q., Wang, D., Li, C., & Miller, R. B. (2014). Marital satisfaction and depressive symptoms among Chinese older couples. *Aging and Mental Health*, 18(1), 11-18.

Wang, Z., Zou, Z., Dong, B., Ma, J., & Arnold, L. (2018). Association between the Great China Famine exposure in early life and risk of arthritis in adulthood. *Journal of Epidemiol Community Health*, 72(9), 790-795.

Wickrama, T., & Bryant, C. M. (2012). Association between body mass index and depressive symptoms of African American married couples: Mediating and moderating roles of couples' behavioral closeness. *Journal of Family Issues*, 33(5), 613-638.

Withrow, D., & Alter, D. A. (2011). The economic burden of obesity worldwide: A systematic review of the direct costs of obesity. *Obesity Reviews*, 12(2), 131-141.

World Health Organization (WHO). (2020). Obesity and overweight. https://www.who.int/news-room/fact-sheets/detail/obesity-and-overweight. Accessed April 6, 2021.

Xi, B., Liang, Y., He, T., Reilly, K. H., Hu, Y., Wang, Q., Yan, Y., & Mi, J. (2012). Secular trends in the prevalence of general and abdominal obesity among Chinese adults, 1993-2009. *Obesity Reviews*, 13(3), 287-296.

Yu, M., Shi, Y., Gu, L., & Wang, W. (2020). "Jolly fat" or "sad fat": A systematic review and meta-analysis of the association between obesity and depression among community-dwelling older adults. *Aging and Mental Health*, 1-10.

Zang, E. (2020). Spillover effects of a husband's retirement on a woman's health: Evidence from urban China. *Social Science and Medicine*, 245, 1-10.

Zhao, Y., Strauss, J., Chen, X., Wang, Y., Gong, J., Meng, Q., Wang, G., & Wang, H. (2020). China Health and Retirement Longitudinal Study Wave 4 User's Guide. National School of Development, Peking University.

Zhou, Q., Wang, T., & Basu, K. (2018). Negative association between BMI and depressive symptoms in middle aged and elderly Chinese: Results from a national household survey. *Psychiatry Research*, 269, 571-578.

Zhu, Y., Wang, Q., Pang, G., Lin, L., Origasa, H., Wang, Y., Di, J., Shi, M., Fan, C., & Shi, H. (2015). Association between body mass index and health-related quality of life: The "obesity paradox" in 21218 adults of the Chinese general population. *PloS One*, 10(6), 1-13.