

Research Article

Motivation to Cultivate Social Ties and Diurnal Cortisol: Testing the Mediating Effect of Social Embeddedness in Chinese Older Adults

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Abstract

Based on a framework derived from theories of social integration and health, this study examined the relationships between motivation to cultivate social ties or network cultivation, and diurnal salivary cortisol in Chinese older adults. The main objective was to determine the behavioral mechanism that translated a higher motivation to cultivate social ties into healthier diurnal cortisol rhythms in 82 community-dwelling elders in Shanghai. Participants were provided four saliva samples immediately, 30 minutes, and 3 hours after waking and at bedtime on two consecutive days to determine their cortisol range. Participants completed a questionnaire measuring (1) network cultivation, (2) social contacts and behaviors, (3) loneliness, and (4) subjective socioeconomic status. Cortisol concentrations were analyzed using an enzyme-linked immunosorbent assay. Mediation analysis using the PROCESS macro v4.2 showed that a composite measure of social integration or embeddedness, created by combining social behaviors and loneliness, partially mediated the relationship between network cultivation and cortisol dynamic range. Given the relevance of diurnal cortisol to well-



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being in older adults, the empirical findings on the mediating effect of social integration could inform the formulation of effective psychosocial interventions to promote well-being and health in older adults, which will have important implications for public health in aging societies.

Keywords

Social network cultivation; social integration; cortisol dynamic range; salivary cortisol; Chinese elders

1. Introduction

Recent studies on healthy Chinese elders have shown that the motivation to strengthen social ties significantly affects diurnal cortisol profiles [1-3]. Elders with a higher motivation to develop and strengthen (i.e., cultivate) their social ties exhibit an accentuated cortisol awakening response and a steeper decline in cortisol over the day. This diurnal rhythm indicates a more effective activation and deactivation of the hypothalamic-pituitary-adrenal (HPA) axis, which is more commonly observed in younger age groups or older individuals who are better adjusted [4]. The cultivation of social ties, or network cultivation (NC), refers to a behavioral tendency to strengthen one's social ties and has been operationalized by the cultivation dimension of the Support Network Scale (SN Scale) [5, 6], which identifies the time and effort invested in cultivating social bonds with family, relatives, friends, and neighbors, respectively. The other two dimensions of the SN Scale are *network size* and *network use* in relation to family, relatives, friends, and neighbors. Network cultivation has been demonstrated to be the strongest predictor of successful aging in a large-scale longitudinal study of Chinese elders in Hong Kong [6]. A more recent study has also shown that the diurnal rhythm of salivary cortisol observed among Chinese elders with high scores on network cultivation was similar to that of young and healthy college students [2]. Although ample evidence has demonstrated the beneficial health effects of social support in the older adults [7] and its contributions to successful aging [8], the construct of network cultivation is different from that of social support which is commonly operationalized as "perceived" or subjective social support in the literature [9]. Network cultivation refers to the proactive investment of time and efforts to strengthen existing relationships with others, and thus differs from conventional measures of perceived or received social support that construe the older adults as passive recipients of emotional or instrumental support provided by others. The focus on this proactive strengthening of social ties was based on the socioemotional selectivity theory [10] predicting that older people tend to receive the support that they need from the relationships in which they invest most of their time and efforts to maintain and cultivate. As people grow old and perceive limited time, they are motivated to adjust their social behaviors to maximize emotional pay-offs. As a consequence, their social networks decrease in size, and satisfaction of their psychosocial needs may derive mainly from the smaller number of capital-rich, emotionally close relationships that they have been cultivating. This is in line with evidence showing that the quality of relationships is more important than the number of social relationships in predicting mental health [11] and longevity [12] in old age. This implies that network size and even network use may not be reliable predictors of well-being or

functional status in older adults. An increase in received network support could indicate age-associated declines or a need for protection against the same decreases. This may explain why network cultivation, a proactive behavioral tendency has emerged as an important factor contributing to successful aging in Chinese elders [6].

Despite demonstrating the importance of network cultivation to successful aging in Chinese older adults, the behavioral mechanisms leading from a high score of network cultivation to endocrine outcomes such as the diurnal cortisol profile are still poorly understood. To fill this gap, the present study was designed to examine the relationships of various constructs associated with network cultivation with a specific component of the diurnal cortisol profile (e.g., diurnal cortisol dynamic range, CDR, which is operationalized as the difference between the minimum and maximum level of cortisol over the day) [13]. The focus on cortisol is motivated by extensive evidence showing that the loss of diurnal regulation of this hormone is critical to the aging process and the onset of frailty [8, 14]. The present study looked explicitly at CDR because a larger CDR is highly correlated with a steeper diurnal slope (e.g., $r = -0.899$ [13]), suggesting that it is a reliable index of effective negative feedback of the HPA axis [15]. The central hypothesis was that (1) higher NC scores would be associated with a larger CDR, and (2) this would be mediated by an increase in an index of social embeddedness (SEB), which was operationalized by the sum of the standardized scores for social activities and loneliness. The focus on SEB is based on the well-documented association between social integration and reduced morbidity in the literature [16]. Moreover, the relevance of SEB to health outcomes and cortisol has been further accentuated by (1) the observation of a longitudinal association between social integration and health outcomes [7, 17, 18], and (2) the observation of an association between reduced social network activity [19] or emotional support [20] and higher cortisol levels. The hypothesis of the present study can be subsumed within the conceptual model linking social networks with health outcomes proposed by Berkman et al. [21], which can be appropriately applied to understand the health impact of the social contextual changes confronting the aging population. According to this model, social-structural constraints shape the structure and characteristics of the social networks that determine the kind and level of social support, social engagement, and social contacts available to individuals. These psychosocial mechanisms are then translated into health outcomes via health-behavioral pathways (e.g., diet, exercise, help-seeking behavior) and physiological pathways (e.g., HPA axis, immune system). The central hypotheses mentioned earlier is directly relevant to this model.

2. Materials and Methods

2.1 Participants and Procedure

The study participants were 82 healthy community-dwelling elders (55-85 years of age) recruited through the School of Public Health of Shanghai Jiao Tong University in collaboration with a community health center in Jing'an district, Shanghai. Medical workers on site were briefed about the research background and recruitment criteria. Participants were recruited through three channels: 1) older adults seeking medical consultation were invited to participate if eligible; 2) medical workers contacted eligible older adults via phone or social media platforms such as WeChat, based on their previous health records; 3) referrals from older adults who had already participated in the study were also accepted if the referred individuals met the eligibility criteria. The participants were free of heart disease, cancer, and psychiatric illness. They were not on medication such as

estrogen, synthetic glucocorticoids, anti-steroid drugs, or anti-seizure drugs that would potentially affect their cortisol concentrations. After providing informed consent, the participants were briefed about the procedural details of the study. They were asked to provide four salivary samples immediately upon waking, 30 min and 3 hours after waking, and before bedtime over two consecutive days. Saliva samples were collected using the Salivette (Sarstedt AG & Co., Nümbrecht, Germany, <https://www.sarstedt.com/en/products/diagnostic/salivasputum/product/51.1534.500/>), and sampling times were monitored using an electronic medical event monitoring (MEM) device (MEMS® 6 TrackCap, WestRock). In particular, the required number of synthetic swabs for eight saliva samples were placed in the vial with the MEMS® 6 TrackCap. Participants were required to put one swab into their mouths for 2 minutes or until it was saturated with saliva. The swab was then placed into the Salivette with labels of designated time and date, and put into the freezer of participants' home refrigerator as promptly as possible. Participants were shown how to use the Salivette to collect saliva samples in combination with the MEMS® 6 TrackCap in a self-administered way by the experimenter. They were given a study pack containing fully standardized written instructions, questionnaires, saliva sampling tubes (Salivettes), a vial with the MEMS® 6 TrackCap used to monitor the timing of saliva collection, and a comprehensive description of the procedure of the study, including instructions for using the Salivettes and the MEMS® 6 TrackCap. Saliva samples were kept in the freezer of the participants' home refrigerator until they were returned to the laboratory within one week. The returned saliva samples were stored in the laboratory at -20°C until thawed for biochemical analysis. Compliance with the saliva sampling protocol was low in this sample, although the participants were given detailed instructions on the procedure and how to use the MEMS® 6 TrackCap. A total of 30 participants failed to use the MEMS® 6 TrackCap on either one day or two days. In addition, among those who used the TrackCap, 24 participants could not comply with the protocol on both days, and 10 did not comply on one of the two days. The reason for the non-compliance was not immediately apparent. Data collection was conducted soon after the lifting of public health measures after the second wave of the COVID-19 outbreak in Shanghai in 2022. Problems associated with adjustment to the subsequent change in lifestyle may be one reason for the relatively low compliance rate.

2.2 Cortisol Assays

Cortisol concentrations were analyzed with an enzyme-linked immunosorbent assay (Enzo Life Sciences, Inc.), as used in previous studies conducted by the author [4]. The saliva samples were thawed and centrifuged at 3500 rpm for 10 min at room temperature, and the clear supernatant was used for analysis. The sensitivity of the assays was 0.2 nmol/L. The intra- and inter-assay coefficients of variation were lower than 12%, comparable to similar assays used in previous studies among Hong Kong Chinese participants [22].

2.3 Measures

In addition to providing salivary samples, the participants were asked to fill in a questionnaire consisting mainly of scales measuring network cultivation (NC), social embeddedness (SEB), and subjective socioeconomic status (SSES). As mentioned earlier, network cultivation or NC denotes a "proactive" behavioral tendency to maintain or strengthen existing networks to enhance resilience

in old age. This construct was measured by the Support Network Scale developed by Chong et al. [6] to assess the size, use, and cultivation of social networks. Only the four items examining the cultivation of social networks were used in this study for reasons mentioned earlier. Participants indicated the time and efforts invested in cultivating social ties with (1) the family, (2) relatives, (3) friends, and (4) neighbors, respectively using a 5-point scale (1 = not at all, 5 = very much). The Cronbach's alpha of NC in the present sample was 0.71. Social embeddedness (SEB) was operationalized by the composite of two components: social activities/participation and loneliness. This measure was adapted from two similar measures of social embeddedness [10, 23]. The first one is based on a measure of social embeddedness used in the 1987 National Medical Expenditure Survey (NMES), in which the construct was operationalized by (1) the frequency of "visits by friends, visits to friends, and telephone conversations with friend or relatives", (2) the frequency of attending church, club meetings, or other voluntary groups, and (3) the availability of a confidant to share private feelings and concerns [23]. The second one is used based on a measure of the feeling of social embeddedness, which is a composite of (1) social satisfaction, (2) exchange of tenderness in social relationships, and (3) loneliness [10]. The measure used in the present study was a combination of the frequency of social activities taken from the former and the feeling of loneliness from the latter. Loneliness was included because it is a risk factor for various health-related outcomes [24] and is one of the most prevalent risk factors for Chinese people aged 65 or older [25]. The social activities index is a composite of multiple indicators, including the frequency of (1) face-to-face and nonvisual contact with family, relatives, and friends and (2) community or organizational participation (1 = never, 2 = rarely, 3 = sometimes, 4 = often). Higher scores for social activities indicate a higher level of social contact and participation; similar measures are reliable predictors of mortality [20]. The loneliness component was assessed using a Chinese adaptation of a 3-item scale derived from the Revised UCLA Loneliness Scale [26], where the participants rated how often they felt lonely using a 4-point scale: 1 = never, 2 = rarely, 3 = sometimes, and 4 = often. The ratings of the loneliness items were reversed before scoring so that higher loneliness scores indicated a lower level or absence of loneliness. To improve the internal consistency of this measure, the second item (about how often participants felt they were left out of life) was removed from the scoring, resulting in a Cronbach alpha of .60. The scores of the social activities and loneliness components were standardized and summed to form an index of social embeddedness (SEB). These two components of social embeddedness were positively correlated, $r = 0.253$, $p = 0.28$. Subjective Socioeconomic Status (SSES) was assessed using a measure adopted in a recent study [27] that asked the participants to indicate their social standing on a drawing of a ladder with 10 rungs, where the top rung (10) represents people who are best off. The bottom rung represents those who are worst off (1).

2.4 Statistical Analyses

For the cortisol parameters, the analysis focused explicitly on CDR, which was operationalized as the difference between the highest and lowest cortisol levels over a day [28], for three reasons. First, a recent study showed that a larger CDR indicates more efficacious negative feedback of the HPA axis [15], consistent with the more significant deactivation of cortisol observed in better-adjusted elders or younger populations [22, 29]. Second, a larger CDR has been recently associated with better cognitive and physiological functioning in a representative US sample [13]. Third, CDR is, in

principle, less affected by non-compliance than other cortisol parameters, such as the cortisol awakening response [30]. The hypothesis that social integration mediates the association between NS and CDR, with a higher network cultivation score leading to higher social embeddedness and, in turn, to a larger CDR (Figure 1), was tested using the PROCESS macro v4.2 in SPSS v28.

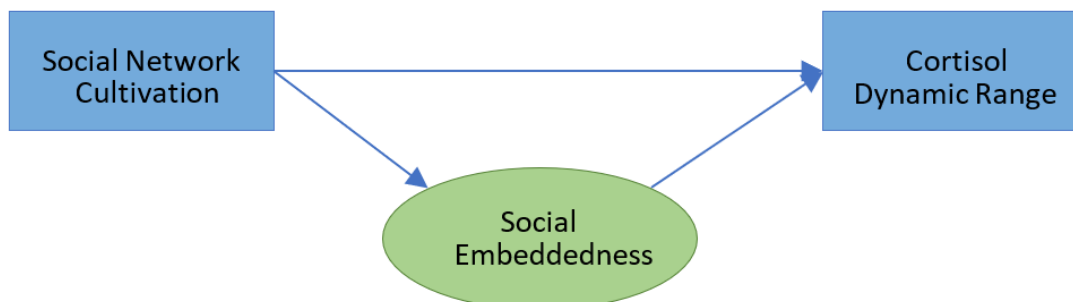


Figure 1 Mediation of social embeddedness in the relationship between social network cultivation and cortisol dynamic range.

2.5 Ethics Statement

The study was conducted by the Declaration of Helsinki and approved by the Institutional Review Board of the City University of Hong Kong and the School of Public Health of Shanghai Jiaotong University School of Medicine (protocol code 11614919 approved on 18 March 2019).

3. Results

82 community-dwelling elders were recruited from Shanghai, 79 of whom provided both saliva samples and filled in the questionnaire. After removing 3 smokers from the sample, the sample size for subsequent analyses was 76 (22.4% males). Socio-demographic characteristics are shown in Table 1. The mean age of the male participants was 66.47 yrs. and that of the female participants was 66.44 yrs. As one participant did not provide accurate information about their age, the sample size for analyses involving age was 75. Regarding education, 9.2% had primary education, 36.8% had junior secondary education, 26.3% had senior secondary education, 13.2% had post-secondary vocational education, 6.3% had undergraduate education, and 7.6% had post-graduate education.

Table 1 Socio-demographic characteristics of participants (N = 76).

Characteristics	Mean (SD)	Range	n	Percentage
Age	66.44 (5.88)	57-84	75	
Gender				
Male	66.47 (5.56)	58-80	17	22.4
Female	66.44 (6.02)	57-84	59	77.6
Education				
Primary			7	9.2
Junior Secondary			28	36.8
Senior Secondary			20	26.3
Post-secondary			10	13.2

Undergraduate	5	6.3
Post-graduate	6	7.6

The cortisol levels for the two days were winsorized at two standard deviations, and then log₁₀ transformed to reduce skewness. The mean logged cortisol levels (SDs) over the two days are summarized in Table 2.

Table 2 Mean cortisol concentrations (log nmol/L) across two days (N = 76).

	Waking	30 min	3 hours	Bedtime
Day 1	0.82 (0.39)	0.85 (0.40)	0.52 (0.37)	0.39 (0.34)
Day 2	0.75 (0.46)	0.76 (0.46)	0.52 (0.40)	0.38 (0.38)

Results of a two-way ANOVA with repeated measures with day and sampling time as the two within-subject factors showed that only the effect of sampling time was significant, $F(2.13, 159.75) = 61.83, p < 0.001$. The effect of day, $F(1, 225) = 2.08, p = 0.153$ and the interaction between day and time, $F(3, 225) = 1.36, p = 0.255$ were not significant. Table 3 summarizes the correlations between the key variables and covariates.

Table 3 Correlations between the key variables and covariates.

	Mean (SD)	Sex	Age	Edu	SSES	Comp	NC	SEB	CDR ^b
Sex	N/A	--							
Age	66.44 (5.88)	-0.002	--						
Edu	N/A	-0.021	-0.134	--					
SSES	7.89 (0.99)	-0.025	0.104	0.066	--				
Comp	N/A	-0.148	-0.099	0.045	0.057	--			
NC ^a	14.91 (2.80)	-0.086	0.196	0.211	0.204	0.181	--		
SEB	N/A	-0.075	0.002	0.206	0.261*	0.153	0.438***	--	
CDR ^b	0.65 (0.33)	-0.362**	-0.080	0.352**	0.129	0.334**	0.463***	0.427***	--

Sex (male = 1, female = 2), Edu = education (college or higher = 1, others = 0), Comp = compliance (use of trackcaps = 1, non-use of trackcaps = 0), SSES = socio-economic status, NC = network cultivation, SEB = social embeddedness. *, $p < 0.05$; **, $p < 0.01$. ^a, Cronbach's alpha = 0.71. ^b, Log₁₀ CDR.

3.1 Hypothesis Testing

The results of the hypothesis testing, summarized in Table 4, clearly show that the association between NC and CDR was partially mediated by SEB because both the mediating/indirect effect and the direct effect of NC on CDR were significant. This pattern of associations was replicated when the effects of sex, age, SSES, and compliance (use v. non-use of the MEMS® 6 TrackCap) were included in Model 2 as covariates. Table 4 summarizes the main effects of the models. The mediation effect of SEB was significant in both models, as zero was not included in the confidence intervals. NC was significantly associated with SEB, $B = 0.227, p < 0.001, [95\% \text{ CI}: 0.106, 0.348]$. In Model 2, sex was found to be significantly associated with CDR, $B = -0.231, p = -0.002, [95\% \text{ CI}: -0.372, -0.090]$, with

the male participants exhibiting a larger CDR, which has not been reported in previous studies in nonChinese samples [13, 29]. The participants who used the MEMS® 6 TrackCap exhibited a larger CDR than those who did not, $B = 0.126$, $p = 0.048$, [95% CI: 0.001, 0.251]. In addition, having a college education was associated with a larger CDR, $B = 0.168$, $p = 0.016$, [95% CI: 0.032, 0.304].

Table 4 Results of the mediation analysis of social embeddedness on the relationship between network cultivation and CDR.

	B	p	LLCI	ULCI
Model 1: No covariates (N =76)				
Direct effect	0.040	0.003	0.014	0.066
Indirect effect	0.014	N/A	0.003	0.025
Model 2: Sex, Age, Edu, SSES, and Compliance as covariates (N = 75)				
Direct effect	0.033	0.009	0.008	0.057
Indirect effect	0.009	N/A	0.001	0.021

Direct effect = NC → CDR (impact of social embeddedness included), Indirect effect = mediation effect of social embeddedness.

4. Discussion

4.1 Conclusions

The findings of this study highlight the importance of SEB in determining the aging process in Chinese elders. Using CDR as the primary outcome variable, this study demonstrated the beneficial effect of an indigenous psychosocial construct, social network cultivation, on Chinese elders from Shanghai. Although the construct of network cultivation was tested and validated in Hong Kong, we expected the applicability of this construct to Shanghai, given the similarities between Hong Kong and Shanghai in the current financial markets and exposure to Western cultures [31]. Elders with a higher motivation to cultivate their social ties exhibited a larger CDR, as hypothesized. This result can be taken to imply that those with higher NC scores might age more successfully, consistent with recent evidence showing that elders who exhibit a steeper diurnal cortisol slope [32] or more effective deactivation of cortisol [33] fare better than their peers with a flatter slope or a less effective deactivation of cortisol, given that a steeper diurnal slope is highly correlated with a larger CDR. The findings of this study reiterate the importance of maintaining cortisol rhythmicity to health [9]. The results also demonstrate that psychosocial mechanisms translate a stronger motivation to cultivate social ties to healthier cortisol profiles in older adults. Participants with higher NC scores had more frequent contact with their family and friends and were more likely to participate in community activities. These participants also felt less lonely than their peers with lower NC scores. NC led to higher social integration and a larger CDR. The public health implications of these findings on aging populations should not be underestimated, given that the health benefits of social participation interventions for older adults have been shown clearly in recent reviews [34, 35].

4.2 Limitations

This study has several limitations that would be worthwhile for future studies to address. First, the low level of compliance with the sampling protocol may have affected the interpretability of the findings on cortisol levels. However, this effect may be smaller for CDR than for other cortisol parameters, such as the cortisol awakening response, the reliability of which depends much more heavily on the accurate timing of saliva sampling. Second, the current findings do not address whether participants who are more socially integrated or embedded and exhibit a younger diurnal cortisol rhythm are biologically younger because direct measures of biological aging were not examined. However, this lack of data should not be taken to imply that social integration has no significant health implications for older adults. There is ample evidence showing that social integration can affect health via other physiological pathways, such as inflammation and cardiovascular reactivity [12]. As contact with and support from family may be more important in Asian cultures [36], especially a collective culture like China [37], and the computation of NC scores does not differentiate between family and other sources of support, future research could examine this critical issue. Third, as the findings of this study were generated using a cross-sectional design, no valid causal conclusions can be derived. Future research using a longitudinal design with larger representative samples is warranted to illuminate the temporal features and complexity of the identified pattern of relationships. Interventions targeting SEB in older adults could be conducted to substantiate the possible causal relationships between SEB and health outcomes in older adults, especially in a Chinese context. Last, social embeddedness was measured using a composite of social participation and loneliness, which was not validated in prior studies with Chinese older adults. Although the measurement has theoretical and empirical support, future research should look at the validity of this novel construct of social embeddedness more closely.

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Author Contributions

Conceptualization, formal analysis, original draft preparation, review and editing, data curation, funding acquisition, Julian LAI; methodology, cortisol assays, resources, project administration, Jianwei SHI.; investigation, editing, data collection, fieldwork, Wei YIN. All authors have read and agreed to the published version of the manuscript.

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Competing Interests

The authors have declared that no competing interests exist.

Data Availability Statement

Data leading to the findings reported in this paper are available at the following: LAI, Julian (2024), "Social Integration and Salivary Cortisol in Chinese Older Adults in Shanghai", Mendeley Data, V1, doi: [10.17632/f2jg98mn4x.1](https://doi.org/10.17632/f2jg98mn4x.1).

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