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Physical and Social Activities Mediate the Associations Between Social Network Types and Ventilatory Function in Chinese Older Adults

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Objective: This study examined the associations between social network types and peak expiratory flow (PEF), and whether these associations were mediated by social and physical activities and mood. ***Method:*** Nine hundred twenty-four community-dwelling Chinese older adults, who were classified into five network types (diverse, friend-focused, family-focused, distant family, and restricted), provided data on demographics, social and physical activities, mood, smoking, chronic diseases, and instrumental activities of daily living. PEF and biological covariates, including blood lipids and glucose, blood pressure, and height and weight, were assessed. Two measures of PEF were analyzed: the raw reading in L/min and the reading expressed as percentage of predicted normal value on the basis of age, sex, and height. Diverse, friend-focused, and distant family networks were hypothesized to have better PEF values compared with restricted networks, through higher physical and/or social activities. No relative advantage was predicted for family-focused networks because such networks tend to be associated with lower physical activity. ***Results:*** Older adults with diverse, friend-focused, and distant family networks had significantly better PEF measures than those with restricted networks. The associations between diverse network and PEF measures were partially mediated by physical exercise and socializing activity. The associations between friend-focused network and PEF measures were partially mediated by socializing activity. No significant PEF differences between family-focused and restricted networks were found. ***Conclusions:*** Findings suggest that social network types are associated with PEF in older adults, and that network-type differences in physical and socializing activity is partly responsible for this relationship.

Keywords: social network types, peak expiratory flow, older persons, Chinese

It is well-established that respiratory system functioning declines with age due to a lifetime cumulation of environmental toxins (including tobacco and air pollutants) and respiratory tract infections, as well as weakened respiratory mechanics such as decreased elastic recoil of the chest wall and the lung, and decreased respiratory muscle strength (Vaz Fragoso & Gill, 2012). These declines place an older person at risk for chronic hypoxia, which is associated with vascular inflammation and insulin resistance, and leads to atherosclerosis, cardiovascular incidents, blood–brain barrier dysfunction, 19and brain ischemic lesions (e.g., Engström et al., 2002, 2003; Liao et al., 1999).

Importantly, studies have consistently demonstrated a link between ventilatory function and mortality (including deaths due to nonrespiratory diseases), as well as physical and cognitive conditions, even after controlling for age, sex, socioeconomic status, height, body mass index (BMI), apolipoprotein E ε4 allele, lipids, blood pressure, glucose, self-rated health, physical activity, smoking, history of pulmonary and cardiovascular diseases, and so on (Cheng et al., in press; Cook et al., 1991; Guo et al., 2007; Klein, Moss, Klein, & Cruickshanks, 2001; Persson et al., 1986; Schaub et al., 2000). Of the various indices of lung functioning, peak expiratory flow (PEF), a simple, inexpensive, and easily administered measure, has emerged as a powerful predictor of physical health and mental health outcomes, although in clinical practice, it is mainly used for the assessment of obstructive airway disease and the monitoring of patients with asthma. For instance, a cross-sectional study (Schaub et al., 2000) investigating the associations of dementia with different indices of ventilatory function found stronger associations with extrapulmonary, effort-dependent measures (i.e., PEF and forced expiratory volume) than with intrapulmonary, effort-independent measures (i.e., maximal expiratory flow at 25% or 50% of forced vital capacity). Between the two effort-dependent measures, PEF had a much stronger effect than forced expiratory volume; for example, compared with those per-

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forming in the top quartile, participants with the lowest quartile of PEF were 20.4 times more likely, whereas participants with the lowest quartile of forced expiratory volume were only 7.6 times more likely, to have dementia.

Furthermore, longitudinal studies have revealed rather intriguing findings pertaining to PEF. In a representative sample of Swedish women aged 38 to 60 years, PEF independently predicted incidences of myocardial infarction, ischemic heart disease, stroke, and all-cause mortality over the next 12 years (Persson et al., 1986), as well as dementia after 29 years (Guo et al., 2007), after controlling for various covariates. The likelihood of developing dementia, in general, and Alzheimer's disease, in particular, were essentially the same per one-standard-deviation decrease in PEF, forced expiratory volume, and forced vital capacity (Guo et al., 2007). Similar associations were observed between PEF and mortality over 5 to 6 years in a Boston general population of older men and women (Cook et al., 1991), as well as in those with potentially life-threatening conditions such as diabetes (Klein et al., 2001). In an attempt to explain the link between PEF and cardiovascular diseases, researchers found that PEF predicted the formation of carotid atherosclerotic plaques over a 4-year interval in French older adults free of coronary heart disease and stroke at baseline (Zureik, Kauffmann, Touboul, Courbon, & Ducimetière, 2001). Given the significance of PEF as a predictor of physical health and cognitive impairment, it is important that more research is undertaken to understand its determinants. This study examined social network predictors of PEF and the mediating role of activity participation.

Psychosocial Factors in PEF, With an Emphasis on Social Network Influence

Whereas the roles of physical factors in determining PEF performance are well known (Quanjer, Lebowitz, Gregg, Miller, & Pedersen, 1997), attention to the potential influence of psychosocial factors has been relatively lacking. One notable exception was the study by Smyth, Soefer, Hurewitz, Kliment, and Stone (1999). With ecological momentary assessments conducted in adults with asthma over 3 weeks, Smyth and colleagues studied the effects of mood, stressors, daily activities (not only physical activities), social contacts, and geographical location on PEF and asthma symptoms. This set of variables explained a massive 29% of the variance in PEF and 21% in asthma symptoms. Negative mood and stress were associated with worse PEF, whereas the reverse was true for positive mood. The diary findings on the adverse effect of negative mood corroborate experimental evidence in which negative mood induction aggravates symptoms in asthmatic individuals, possibly through vagal excitation, leading to airway restriction (see review by Ritz, 2004).[1] Negative mood may also reduce the motivation to perform PEF, which is effort dependent. Whereas the adverse effect of negative mood is well established, the effect of positive mood has not always converged (Ritz, 2004). For instance, a study found that diary reports of positive mood were associated with better lung functioning, whereas laboratory mood induction led to the reverse *in the same individuals* (von Leupoldt, Ehnes, & Dahme, 2006). The basis for these differences is not yet clear. Nevertheless, studies in real-life settings, such as those by von Leupoldt et al. and Smyth et al., generally supported the PEF enhancing effect of positive mood.

Other than mood, Smyth and colleagues (1999) found that social contacts and activities were associated with better PEF. Furthermore, the diurnal patterns of PEF were completely accounted for by the covariates; that is, the lower values of PEF in early morning (when social contacts, activity levels, and mood also tended to be lower) among the asthmatic participants disappeared after the covariates were statistically controlled. These findings raise the question of whether social network characteristics are associated with PEF, and whether activity participation and mood mediate this relationship, if it exists. Another reason why social network may improve PEF concerns its general health protection effect (Cohen, 2004) and, in particular, suppression of inflammatory processes (Loucks et al., 2006; Shankar, McMunn, Banks, & Steptoe, 2011). Social isolation may be associated with airway inflammation, whether symptomatic or not, that impairs PEF.

A closer look at the daily activities reported by Smyth and colleagues are warranted. Among the different kinds of activity, only exercise and socializing (and also a miscellaneous category) were associated with higher PEF, with exercise being a stronger factor. All other activity types, including relaxing, working, and eating and drinking, were either negatively or not associated with PEF. Although exercise, or physical activity in general, is a well-known predictor of PEF (Cook et al., 1989), due possibly to its effect on airway smooth muscle dilation via the vagal withdrawal pathway (Ritz, 2004), the potential effect of socializing activity has been overlooked in the literature. There is a reason to believe that even socializing activity may have a beneficial effect on PEF. Recent research has suggested that, *on top of physical activity*, sedentary activities (i.e., those that do not increase energy expenditure significantly above resting level, such as sitting and watching TV) are associated with inflammatory markers and predict metabolic syndrome, cardiovascular diseases, functional limitations, and mortality (Gennuso, Gangnon, Matthews, Thraen-Borowski, & Colbert, in press; Santos et al., 2012; Wilmot et al., 2012). Thus, despite engagement in physical activity, spending more time inactive still poses significant health risks, which may include respiratory impairment. Thus, having activities, whether physical or social, can have beneficial effects on PEF. In this connection, it is noteworthy that whereas socializing activities are integral to the functioning of social networks, hence being more common in people with more diverse networks, the relationship between social network and physical activity is more complex.

It is well established that social contacts can be health damaging as well as health promoting, as when social network members transmit ill-advised health practices to each other (Berkman, Glass, Brissette, & Seeman, 2000). In the Chinese culture, family activities are often centered on meals, activities that bear no relationship to PEF. Moreover, under the influence of familism and traditional family roles, particular family members, especially children and daughters-in-law, are supposed to "take care of everything" for their older family members, whether or not the assistance is truly needed (Cheng & Chan, 2006). Thus, family-focused interactions

[1] The vagus nerve is one of the cranial nerves that connect medulla in the brain stem and parasympathetic ganglia of airway smooth muscles, especially those of large airways. It plays an important role in the autonomic regulation of airway functioning. Activation of the vagal motor nerves results in bronchoconstriction through acetylcholine actions, and vice versa (Nadel & Barnes, 1984).

may tend to promote sedentary times. In fact, studies in Israel and the United States have suggested that support from the immediate family, but not friends, tend to be associated with lower physical activity (Litwin, 2003; Orsega-Smith, Payne, Mowen, Ho, & Godbey, 2007), and the same is expected to be true for Chinese/Asian societies, if not more. Because of the difference in family and friend support in encouraging physical activities, questions arise as to whether there are associations between social network types and PEF.

Social Network Types

Social support researchers are interested in how structural (e.g., network size) and functional (e.g., emotional support) characteristics of social networks impact on physical health and mental health. Whereas structural aspects are postulated to have a general health-enhancing effect, functional support offers protection when needs arise (Cohen, 2004). In addition to analyzing the independent effects of different measures of structural and functional support, researchers have found that these different aspects of social networks may covary to form what are known as social network types.

Social network types are constellations of functional and structural aspects of social support that identify patterns across a range of network characteristics. Typically, four main network types are found across cultures (see, e.g., Cheng, Lee, Chan, Leung, & Lee, 2009; Fiori, Antonucci, & Akiyama, 2008; Fiori, Antonucci, & Cortina, 2006; Fiori, Smith, & Antonucci, 2007; Litwin, 2003; Litwin & Shiovitz-Ezra, 2011; Park, Smith, & Dunkel, in press, for studies in German, Israeli, Hong Kong Chinese, South Korean, and U.S. samples). A *restricted network* is one with few social ties and activities; it is usually associated with the worst physical health and mental health outcomes. A *family-focused network* is characterized by close relationships with immediate family members, but a lack of organizational activities (e.g., volunteer work, leisure activities at social centers) and contact with nonfamily members. On the contrary, frequent contacts with friends and neighbors, but few kinship ties, characterize *friend-focused networks*; a low level of organizational participation is also common. Finally, people with a *diverse network* have a high level of involvement in organizational activities as well as interactions with family and nonfamily members. They enjoy a variety of support functions, including day-to-day practical support from family and socializing from friends, more robust substitution of support functions when the preferred support provider is not available, and the benefits of social integration (Cohen, 2004; Cohen & Janicki-Deverts, 2009). They tend to have more physical and social activities (Cheng et al., 2009; Litwin, 2003), better physical functioning (Litwin, 1998), higher well-being and lower depression (Cheng et al., 2009; Fiori et al., 2006; Litwin & Shiovitz-Ezra, 2011), and lower mortality (Litwin & Shiovitz-Ezra, 2006) than those with more restricted networks.

In addition, by distinguishing horizontally extended family (siblings, cousins, all other in-laws, etc.) from vertically extended family members (parents, spouse, children, children-in-law, grandchildren, and great grandchildren, etc.),[2] Cheng and colleagues (2009) were able to find a *distant family network* in Hong Kong Chinese older persons. People with this network type tended to be never married and without children, but they engaged in high support exchanges with distant kin and moderate levels of exchanges with friends and neighbors. The distinction between distant family and a family-focused network showed the different levels of involvement of the extended family in the lives of Chinese older adults, depending on their circumstances.

There were other interesting correlates of social network types among Hong Kong Chinese older adults (Cheng et al., 2009). Women were overrepresented in diverse and friend-focused networks, whereas men were overrepresented in family-focused, distant family, and restricted networks. Moreover, people with restricted networks reported the lowest well-being scores, whereas those with diverse networks reported the best overall, with people having friend-focused, family-focused, and distant family networks more or less equally in between.

As mentioned earlier, family support tends to be associated with lower physical activity. Indeed, a study of Israeli older adults found restricted networks and networks focused on the immediate family to be comparable in physical activity, but both were lower than the other network types (Litwin, 2003). Another study of U.S. older adults found that networks centered on close family members have even slightly lower physical activity than restricted networks (Litwin, 2012). However, these studies have measured exercise only, but one can reasonably argue that housework is a common physical activity by older adults that cannot be ignored, given its predictive validity against cardiovascular risks and functional and cognitive decline (Bowen, 2012; Stamatakis, Hillsdon, & Primatesta, 2007; Tudor-Locke, Johnson, & Katzmarzyk, 2010). Although empirical data are lacking, it is reasonable to speculate that housework is a more common physical activity among older adults with restricted and distant-family networks, as well as those relying primarily on support from friends and neighbors (i.e., friend-focused network), because they have less day-to-day practical support (usually performed by immediate family members) available to them. Hence, the differential in physical activity between family-focused and the other networks may have been underestimated in previous studies. Taken together, older persons with diverse, friend-focused, family-focused, and distant family networks tend to have better emotional well-being than persons with restricted networks. However, family-focused networks, especially those in Chinese societies, may tend to discourage physical activity. Other network types, especially the diverse network, tend to provide more opportunities for physical as well as social activities.

The Study

In a review and commentary, Cohen and Janicki-Deverts (2009) remarked that "even though the basic association [between diverse network and morbidity/mortality] was first reported 30 years ago . . . we still do not know why it happens" (p. 377). It is important that research is undertaken to investigate the connection between

[2] In family sociology and anthropology, a vertically extended family is one in which three or more generations live in the same household (or nearby). Extensions along the lines of siblings, cousins, and so on are called horizontally extended families (Glick, Bean, & Van Hook, 1997). In our work on social network, functional exchanges with these family members, rather than whether they live together, were emphasized. It was found that vertically and horizontally extended family members could be readily differentiated in terms of closeness, importance, and support exchange patterns (Cheng et al., 2009; Cheng, Li, Leung, & Chan, 2011).

social network and relevant biomarkers that predict morbidities and mortality. Given the aforementioned review, this study examined, for the first time, the associations between social network types and PEF, with physical activity (exercise and housework), social activity (social contacts and socializing), positive mood, and negative mood and depression as mediators. As mentioned, network-type differences on affective well-being and social contacts and activities have been consistently reported across cultures, with the restricted network being the most disadvantaged, the diverse network being the most advantaged, and the others somewhere in between. In general, this is also the pattern predicted for PEF. However, because physical activity is an important determinant of PEF, the potential PEF advantage of family-focused over restricted networks due to enhanced mood and social contacts (Cheng et al., 2009) may be canceled out by their relative lack of physical activity. Taken as a whole, it was postulated that those with distant family, friend-focused, and diverse networks would have better PEF than those with restricted networks, and such differences would be most obvious between diverse and restricted networks, due to the former's advantage across a range of factors with potential effects on PEF. No significant PEF difference was postulated between family-focused and restricted networks.

Method

Participants and Procedure

Community-dwelling Hong Kong Chinese adults aged 60 years or over were recruited through referrals and advertisements in social centers for older persons to participate in a study on social network and health. The study was intended to contrast individuals with immediate kin versus those without, and hence older adults who were never married, divorced, or separated were oversampled. Eventually, 1,005 older adults, roughly equally divided into the marital categories of married, never married, divorced/separated, and widowed, voluntarily enrolled in the study (Cheng et al., 2009). A research assistant explained individually the study purpose and procedures involved, and assured potential participants of data confidentiality and their rights to withdraw from participation at any time without consequences for the services they received at the agencies. Participants provided written informed consent separately to the interview section and the biological assessments (i.e., they could consent to interview without agreeing to do biological assessment). Demographic and social network data were obtained through individual interviews at social centers or at participants' homes, whereas biological and other medical data were obtained at participants' homes and assessed by a registered nurse who was assisted by an assistant, due partly to the need to carry equipment around. They were offered HKD100 (equivalent to USD12.5) for participation. Of the 1,005 participants recruited, 924 (91.9%) who provided complete biological data constitute the sample for this study. Detailed sample characteristics can be found in Table 1. Ethics approval was obtained from the Ethics Subcommittee of the Research Committee of the City University of Hong Kong and the Central Research Committee of the Hong Kong Institute of Education.

Measures

Social network types. The five types reported in Cheng et al. (2009) for this sample, namely, diverse, friend-focused, family-focused, distant family, and restricted network, were used. The network types, with mutually exclusive memberships, were derived from cluster analysis of a number of parameters, including network size, social activity, and contact frequency and support exchanges with vertical, horizontal, and nonfamily members. The social network measures were constructed on the basis of responses to the social convoy questionnaire (Kahn & Antonucci, 1980), and follow-up questions on contact frequency (one item) and support exchanges (e.g., confiding, mutual activities; 14 items) about each network member. The social convoy questionnaire is a widely adopted instrument in the social network literature (Wrzus, Hänel, Wagner, & Neyer, 2013) and has been translated into Chinese (Cheng et al., 2009; Cheng, Lam, Kwok, Ng, & Fung, in press). Participants were shown three concentric circles drawn around a center, labeled "me." Network members who were so important that it was difficult for the participant to imagine life without them were placed into the inner circle. Those very important but not as close were placed in the middle circle, whereas people who were sufficiently close and important but had not been included were placed in the outer circle. Network members were summed across the three circles to form network sizes for vertical, horizontal, and nonfamily. To avoid collinearities with network size measures, contact frequency and support exchanges were averaged across network members within the specific relationship category. More details about the items and the derivation of the network types can be found elsewhere (Cheng et al., 2009).

Physical activity. Participation in exercise was rated on a 6-point scale of 1 = *no exercise at all*, 2 = *occasionally walking*, 3 = *occasionally walking and light exercise*, 4 = *exercising (≥20 min) once or twice per week*, 5 = *exercising (≥20 min) three times or more per week*, and 6 = *exercising (≥20 min) almost daily*. Moreover, consistent with the International Physical Activity Questionnaire (Macfarlane, Lee, Ho, Chan, & Chan, 2007), participants rated housework that was more (e.g., groceries; Elsawy & Higgins, 2010) as well as less (e.g., dish washing) physically effortful on a 4-point frequency scale of 0 = *never* to 3 = *almost daily*; these two items were summed to form a total score.

Social activity. Frequency of face-to-face contact with each individual network member was rated on a 6-point scale of 1 = *occasional*, 2 = *once a month*, 3 = *several times a month*, 4 = *once a week*, 5 = *several times a week*, and 6 = *daily*. The ratings were summated across all network members who were not living with the participant to form a total score of social contacts. Twenty-six individuals without any network member were assigned a score of 0. In addition, the frequencies of participation in eight socializing activities (e.g., singing Chinese opera, handicraft classes, playing mahjong, volunteering), each rated on a 5-point scale of 1 = *never* to 5 = *almost every day*, were averaged to form a composite index of socializing activity.

Mood. The Geriatric Depression Scale (Yesavage et al., 1982–1983) is the most widely adopted measure of depressive mood in older adults. A 4-item Chinese version of the Geriatric Depression Scale (Cheng & Chan, 2004; Cheng et al., 2010), with

Table 1
Sample Characteristics

	Men (n = 437)	Women (n = 487)	All (N = 924)
Demographics			
Age (years)	72.3 (6.55)	71.9 (7.43)	72.1 (7.03)
Marital status (%)*			
Married	30	26	28
Never married	22	18	20
Divorced/separated	26	25	25
Widowed	22	31	27
Educational level (%)***			
No formal education	23	49	37
Primary	43	34	38
Secondary	28	14	21
Tertiary	6	3	5
Household income (%)[a]*			
None	13	19	16
<$3,000	30	32	31
$3,000–$5,999	44	31	37
$60,000–$14,999	7	9	8
≥$15,000	6	9	8
Medical history and functional impairment (%)			
Smoking***	49	5	26
Asthma***	7	2	5
Chronic lung disease***	5	1	3
Hypertension	47	50	49
Hypercholesterolemia***	19	32	26
Coronary heart disease***	21	12	16
Stroke**	10	5	7
Diabetes	20	19	19
IADL impairment	8	5	6
Biological data			
Height (cm)***	162.5 (7.29)	151.5 (6.71)	156.7 (8.88)
BMI (weight/height^2)**	23.4 (3.61)	24.2 (3.71)	23.8 (3.68)
Peak expiratory flow (L/min)***	340.3 (137.9)	255.8 (72.1)	295.7 (116.2)
Percent predicted peak expiratory flow[b]*	70.5 (26.9)	74.5 (19.5)	72.6 (23.4)
Systolic BP (mmHg)	127.4 (17.4)	129.0 (19.6)	128.3 (18.6)
Diastolic BP (mmHg)	78.1 (9.53)	77.2 (9.38)	77.6 (9.46)
Total cholesterol (mg/dl)***	181.0 (47.7)	215.1 (50.0)	199.0 (51.8)
HDL cholesterol (mg/dl)***	43.5 (16.3)	55.2 (16.8)	49.6 (17.6)
LDL cholesterol (mg/dl)***	116.5 (38.0)	135.0 (43.6)	126.2 (42.0)
Triglycerides (mg/dl)***	106.7 (87.7)	129.9 (93.3)	118.9 (91.4)
Blood glucose (mmol/L)	6.02 (1.53)	5.98 (1.62)	6.00 (1.58)
Activity measures			
Exercise***	4.86 (1.49)	5.21 (1.32)	5.04 (1.42)
Housework***	4.15 (1.77)	4.54 (1.65)	4.36 (1.72)
Socializing activity***	1.28 (0.35)	1.36 (0.37)	1.33 (0.37)
Social contacts***	20.5 (17.2)	26.1 (19.1)	23.5 (18.4)
Mood			
Positive affect***	3.00 (0.96)	3.21 (0.90)	3.11 (0.94)
Negative affect	1.76 (0.80)	1.77 (0.78)	1.77 (0.79)
Depression	0.89 (1.28)	0.77 (1.21)	0.83 (1.25)
Social network types (%)**			
Diverse	22	31	27
Friend-focused	25	26	25
Family-focused	17	14	16
Distant family	20	18	19
Restricted	16	11	14

Note. Values shown are means (*SD*s), unless otherwise stated. Significant sex differences based on t, χ^2, or Fisher's exact tests are denoted by asterisks. IADL = instrumental activities of daily living; BMI = body mass index; BP = blood pressure; HDL = high-density lipoprotein; LDL = low-density lipoprotein.
[a] Hong Kong dollar, pegged at 7.8 to 1 USD. [b] n = 879 (420 men and 459 women).
* $p < .05$. ** $p < .01$. *** $p < .001$.

items rated on a scale of 0 = *no* and 1 = *yes* against the past week (α = .78), was used. Positive (α = .87) and negative affect (α = .85) were measured by a short form of the Chinese Affect Scale (Cheng, 2004), each with six items rated on a 5-point scale of 1 = *rarely* to 5 = *often* against the past week.

Peak expiratory flow. PEF was measured using the Mini-Wright EN13826 peak flow meter (standard and low range models), EU scale (Clement Clarke International, Edinburgh way, Essex, United Kingdom). Participants were asked to inhale maximally in a standing position, and exhale as hard and as fast as possible. It was administered by the registered nurse in early morning (typically between 9:00 and 10:30 a.m.) before any medications were taken. Participants were asked to stand upright (with aid if necessary), take a deep breath, seal their lips around the mouthpiece, and blow as hard as they could into the mouthpiece. This was repeated three times after resetting the pointer on the device. Two values constitute the dependent variables in this study: (a) the best of three attempts, and (b) the best of three attempts expressed in terms of percentage of predicted normal value as a function of age, sex, and height (Clement Clarke International, n.d.), or percent predicted PEF. However, because predicted values are available only up to 85 years of age (Nunn & Gregg, 1989), 45 individuals above 85 years were excluded when the latter variable was analyzed.

Biological covariates. Lipids (total cholesterol, high-density lipoprotein cholesterol, and triglycerides) and glucose were assessed in early morning, after 12-hr overnight fasting and before morning medications, by the nurse using calibrated portable devices (details of the devices may be obtained from the first author). Blood pressure was measured using a mercury sphygmomanometer. Low-density lipoprotein cholesterol was estimated using the Friedewald formula (Branchi, Rovellini, Torri, & Sommariva, 1998). Height and weight, used to calculate BMI, were also measured using scales, not self-reported.

Chronic diseases. Participants indicated whether they were ever diagnosed with a list of chronic conditions (0 = *no*, 1 = *yes*). The following that may affect PEF are included in this study: asthma, chronic lung disease (other than asthma), hypertension, hypercholesterolemia, coronary heart disease, stroke, and diabetes. The medical history was also taken by the registered nurse.

Other covariates. History of smoking was scored as 0 = *no* and 1 = *yes*. Instrumental activities of daily living (IADL) were measured using the Lawton and Brody (1969) scale; eight tasks (e.g., using telephone, preparing meals, transportation) were rated on a 3-point scale of 1 = *completely dependent*, 2 = *needs help*, and 3 = *completely independent*, with a total score of 24. Because this was a relatively healthy sample, those with any impairment (i.e., $<$24) were coded as 1, and those without as 0.

Statistical Analysis

Alpha was set at .05, two-tailed. Because of moderate to high correlations between certain variables (e.g., between total and low-density lipoprotein cholesterol, between measured blood pressure and self-reported hypertension), regressions were conducted so that only covariates with independent effects on PEF and percent predicted PEF would be selected for the main analyses. Thus, the two dependent measures were each regressed on the following variables in one equation requesting stepwise entry: age, sex (0 = *men*, 1 = *women*), height, education, income, history of smoking, BMI, lipids, glucose, blood pressure, chronic diseases, and IADL impairment. Variables independently associated with either PEF or percent predicted PEF were included in subsequent analyses; these were age, sex, height, education, history of smoking, BMI, total cholesterol, asthma, stroke, and IADL impairment.

The main analyses consisted of a series of regressions to determine the associations between network types and PEF, as well as the mediating effects of activities and mood. Social network types were coded as dummy variables, with the restricted network as the reference group. Mediation is demonstrated when the relationship between the independent and the dependent variable is significantly reduced after the mediating variable is controlled, whereas the independent variable has to be a significant predictor of the mediator, and the mediator, in turn, is a significant predictor of the dependent variable (Baron & Kenny, 1986). To select mediators, one regression model was run for each of the dependent measures as follows: PEF and percent predicted PEF were regressed on exercise, housework, social contacts, socializing activity, positive affect, negative affect, and depression, together with the set of covariates. A hypothesized mediator that was not related to either dependent variable was dropped from the model. As a result, only physical activity and socializing activity were retained for further analyses. Next, the two selected mediators were regressed separately on the network types, along with the covariates (hence, two regression models), to see whether they were predicted by network types. As both mediators were predicted by network types, they were retained for the analysis of mediation effects. Finally, PEF and percent predicted PEF were each regressed, in three successive models, on (a) the covariates, (b) network types, and (c) the mediating variables. Five multivariate outliers were removed prior to regression analyses. Multicollinearity was checked by reference to the variance inflation factors.

The mediation pathways were tested by the bootstrapping method for multicategorical independent variables (Hayes & Preacher, 2013). This method has the advantage of being able to handle multiple categories of a nominal independent variable and multiple mediators simultaneously, thus yielding unbiased estimates of the indirect effects. Bootstrapping is also more powerful than conventional tests (e.g., the Sobel test) that assume normality of the sampling distribution of the mediation effect. Five thousand bootstrap samples were generated for the estimation of indirect effects; a mediation pathway was taken to be statistically significant if the 95% CI did not contain zero. For the purpose of consistency, all the regression results reported below were based on the same bootstrapped samples by specifying the same random seed.

Results

Thirty-seven percent of the participants had percent predicted PEF lower than 80%, which is generally considered to be in the low range (Vaz Fragoso, Gahbauer, Van Ness, & Gill, 2007). Being older, female, shorter, and less educated, as well as having lower BMI, IADL impairment, higher cholesterol, and a history of smoking, asthma, and stroke, were associated with lower PEF (see Model 1 in Table 2). The results were similar when it came to predicted PEF (see Model 1 in Table 3), except that older women were found to have PEF closer to the predicted normal values. The

Table 2
Regression of Peak Expiratory Flow on Social Network Types, Activity Measures, and Demographic and Health Covariates (N = 924)

	Model 1			Model 2			Model 3		
	B (*SE*)	β	*p*	B (*SE*)	β	*p*	B (*SE*)	β	*p*
Covariates									
Age	−3.41 (0.48)	−0.21	<.001	−3.15 (0.49)	−0.19	<.001	−3.06 (0.49)	−0.19	<.001
Sex	−72.48 (9.50)	−0.31	<.001	−77.17 (9.48)	−0.33	<.001	−81.89 (9.44)	−0.36	<.001
Education	13.45 (3.69)	0.11	<.001	11.20 (3.70)	0.09	.003	10.16 (3.71)	0.08	.006
Height	2.17 (0.48)	0.17	<.001	2.09 (0.47)	0.16	<.001	2.03 (0.47)	0.16	<.001
BMI	2.17 (0.89)	0.07	.015	1.94 (0.89)	0.06	.029	1.71 (0.88)	0.05	.053
IADL impairment	−19.16 (13.65)	−0.04	.161	−15.54 (13.60)	−0.03	.254	−5.12 (13.67)	−0.01	.708
Smoking	−34.43 (8.67)	−0.13	<.001	−33.43 (8.62)	−0.13	<.001	−34.13 (8.55)	−0.13	<.001
Asthma	−77.11 (15.63)	−0.14	<.001	−76.29 (15.53)	−0.14	<.001	−72.76 (15.41)	−0.13	<.001
Stroke	−43.19 (12.92)	−0.10	<.001	−43.09 (12.80)	−0.10	<.001	−38.89 (12.70)	−0.09	.002
Total cholesterol	−0.15 (0.066)	−0.07	.020	−0.16 (0.066)	−0.07	.015	−0.16 (0.066)	−0.07	.015
Social network type									
Diverse				47.61 (11.12)	0.18	<.001	38.22 (11.20)	0.15	<.001
Friend-focused				25.10 (10.93)	0.09	.022	21.28 (10.84)	0.08	.050
Family-focused				17.16 (12.08)	0.05	.156	15.89 (11.96)	0.05	.184
Distant family				29.53 (11.48)	0.10	.010	27.96 (11.37)	0.09	.014
Activity measures									
Exercise							7.64 (2.32)	0.09	.001
Socializing activity							28.99 (9.36)	0.09	.002
R^2	.293			.309			.325		

Note. BMI = body mass index; IADL = instrumental activities of daily living.

set of covariates explained a massive 29.3% of the variance in PEF and 12.6% in percent predicted PEF. The difference in explained variance between the two analyses might be attributed to the fact that the measure of percent predicted PEF had already factored in some of the effects of age, sex, and height, owing to the formula for calculating predicted values (Nunn & Gregg, 1989); yet age, sex, and height continued to be associated with percent predicted PEF, even though expected normal values have been taken into account.

When PEF or percent predicted PEF was regressed on the hypothesized mediators, only exercise and socializing activity were significant predictors after controlling for the covariates; thus, housework, social contacts, and all the mood measures were dropped from further analysis.[3] Next, exercise and socializing activity were separately regressed on the network types, along with the covariates. Older adults with diverse networks reported significantly more exercise (B = 0.46, *SE* = 0.16, β = 0.15), $t(904) = 2.94$, $p = .003$, and socializing activities (B = 0.20, *SE* = 0.04, β = 0.24), $t(904) = 5.16$, $p < .001$, than those with restricted networks. People with friend-focused networks also had more socializing activities than those with restricted networks (B = 0.08, *SE* = 0.04, β = 0.10), $t(904) = 2.08$, $p = .038$. No effects were found for the two family networks (people with distant family networks had slightly more socializing activities than those with restricted networks, but the difference was not statistically significant, $p = .078$).

Finally, PEF and percent predicted PEF were regressed on network types, exercise, and socializing activity, together with the covariates. Tables 2 and 3 show the final models and the coefficients of the predictors entered simultaneously. Older adults with diverse, friend-focused, and distant family networks had significantly better percent predicted PEF as well as PEF than those with restricted networks. No difference was found whatsoever between family-focused and restricted networks. Network types added 1.6% and 2.2% of variance explained in PEF and percent predicted PEF, respectively, beyond the effects of the covariates. The unstandardized regression coefficients (B) in Model 2 showed the difference between a particular network type and the restricted network, before the mediators were entered. Compared with people with restricted networks, those with diverse networks were 47.61 L/min and 11.40% better, those with distant family networks were 29.53 L/min and 5.85% better, and those with friend-focused networks were 25.10 L/min and 6.17% better, in PEF and percent predicted PEF, respectively. It was also noteworthy that age and sex were no longer significantly associated with percent predicted PEF after taking into account the effects of network types. Exercise and socializing activity were entered in the next step (Model 3) and were significant predictors of both PEF and percent predicted PEF, adding 1.6% and 2.0% of explained variance, respectively. Variance inflation factors associated with the set of predictors ranged from 1.03 to 2.51 across regression models, suggesting that multicollinearity was not a concern.

In light of these results, three mediation pathways were tested for each of the dependent variables, namely, from diverse network via exercise, from diverse network via socializing activity, and from friend-focused network via socializing activity. (No media-

[3] Results were the same whether the mediators were entered simultaneously or in a stepwise fashion. Moreover, when the two housework items were considered separately, the results were the same; neither item predicted PEF or percent predicted PEF. In addition, some studies suggested that contacts with friends are beneficial to health, whereas contacts with kin, especially close kin, are not (Sabin, 1993; Yasuda et al., 1997). Nevertheless, replacing the current contact measure with contacts with friends or those with distant relatives did not change the outcome of the analysis.

Table 3
Regression of Percent Predicted Peak Expiratory Flow on Social Network Types, Activity Measures, and Demographic and Health Covariates (N = 879)

	Model 1			Model 2			Model 3		
	B (*SE*)	β	*p*	B (*SE*)	β	*p*	B (*SE*)	β	*p*
Covariates									
Age	−0.34 (0.13)	−0.09	.008	−0.24 (0.13)	−0.06	.062	−0.21 (0.13)	−0.05	.110
Sex	5.14 (2.18)	0.11	.018	4.09 (2.17)	0.09	.060	2.98 (2.16)	0.06	.169
Education	3.06 (0.85)	0.13	<.001	2.56 (0.85)	0.10	.003	2.24 (0.85)	0.09	.009
Height	0.30 (0.11)	0.11	.006	0.28 (0.11)	0.10	.011	0.27 (0.11)	0.10	.013
BMI	0.47 (0.20)	0.08	.021	0.40 (0.20)	0.06	.049	0.36 (0.20)	0.06	.078
IADL impairment	−7.91 (3.26)	−0.08	.015	−6.92 (3.24)	−0.07	.033	−4.49 (3.26)	−0.05	.169
Smoking	−7.03 (1.99)	−0.13	<.001	−6.78 (1.97)	−0.13	<.001	−6.99 (1.96)	−0.13	<.001
Asthma	−15.97 (3.56)	−0.14	<.001	−15.72 (3.53)	−0.14	<.001	−14.83 (3.50)	−0.13	<.001
Stroke	−9.62 (3.09)	−0.10	.002	−9.70 (3.06)	−0.10	.002	−8.66 (3.04)	−0.09	.004
Total cholesterol	−0.044 (0.015)	−0.10	.004	−0.047 (0.015)	−0.11	.002	−0.046 (0.015)	−0.10	.002
Social network type									
Diverse				11.40 (2.55)	0.22	<.001	9.21 (2.57)	0.18	<.001
Friend-focused				6.17 (2.51)	0.11	.014	5.22 (2.49)	0.10	.037
Family-focused				4.37 (2.76)	0.07	.114	4.04 (2.73)	0.06	.139
Distant family				5.85 (2.64)	0.10	.027	5.45 (2.62)	0.09	.038
Activity measures									
Exercise							1.55 (0.53)	0.10	.004
Socializing activity							7.05 (2.13)	0.11	.001
R^2	.126			.148			.168		

Note. BMI = body mass index; IADL = instrumental activities of daily living.

tion was tested for the relationships between the distant family network and measures of PEF, because this network type did not differ from the restricted network in physical and socializing activities.) Results of the bootstrap analyses suggested that all the mediation pathways were significant. The indirect effects and their 95% confidence intervals are shown in Table 4. For example, older adults with diverse networks had a combined advantage of 9.39 (3.54 + 5.85) L/min, or 2.19% (0.74% + 1.45%) of the predicted normal value, over those with restricted networks via more exercise and socializing activities. The indirect effects of the friend-focused network were comparatively much smaller.[4] In any case, these indirect effects represented only a small proportion of the total effects due to specific network types. Even after controlling for the mediators, the direct effects of network types remained relatively strong, especially those of the diverse network. From the standardized regression coefficients (β) in Model 3 (Tables 2 and 3), it can be seen that, for the diverse network, the direct effects alone could more than offset the negative effects of specific major risk factors such as asthma or smoking.

Discussion

The literature has focused on physical determinants of PEF but has overlooked potential psychosocial factors. This study has demonstrated—for the first time—that better PEF is associated with certain network types, namely diverse, friend-focused and distant family networks. Moreover, for older persons with diverse and friend-focused networks, the advantages in PEF were partly due to increased physical and/or socializing activity over those with restricted networks. At the same time, older adults with networks centered on the immediate family had PEF values only comparable with those with restricted networks.

Previous studies have found physical activity to be a strong determinant of PEF (Cook et al., 1989). However, judging from the standardized regression coefficients in Tables 2 and 3, it appeared that socializing activity had main effects on PEF and percent predicted PEFs that were comparable with those of exercise, but its role in PEF has been relatively ignored in the literature (cf. Smyth et al., 1999). Contrary to expectation, housework, social contacts, and positive and negative mood were not independently related to PEF. Most housework is not physically demanding. However, the negative result with regard to housework was not due to combining less with more effortful housework in one measure, as neither item predicted PEF or percent predicted PEF (see Footnote 3). This appeared to contradict Western findings concerning the beneficial health effects of housework (Bowen, 2012; Stamatakis et al., 2007; Tudor-Locke et al., 2010). However, it should be noted that whereas housework may mean rather demanding physical activities for people living in houses with geographically scattered stores in other societies, it is not necessarily the case for Hong Kong people, most of whom live in small apartments in densely populated neighborhoods with a variety of supplies nearby. Thus, researchers may need to be sensitive to environmental factors when evaluating the utility of different kinds of physical activity in health promotion.

It is interesting that although socializing activity was a relatively strong predictor of PEF measures, social contacts were not. It appears that nonspecific contacts per se may not capture the health

[4] Kenny (2012) suggests that for a mediation effect involving a dichotomous independent variable (e.g., a dummy), standardized coefficients of .02, .15, and .40 may be considered small, medium, and large effect sizes, respectively. Hence, the total indirect effect via activities was moderate to large for the diverse network, and small for the friend-focused network.

Table 4
Indirect Effects, Controlling for Covariates

	Peak expiratory flow			Percent predicted peak expiratory flow		
	B	95% CI	β	B	95% CI	β
Diverse network						
via exercise	3.54	[0.96, 8.07]	0.01	0.74	[0.18, 1.71]	0.01
via socializing activity	5.85	[2.2, 10.79]	0.02	1.45	[0.57, 2.59]	0.03
Friend-focused network						
via socializing activity	2.32	[0.47, 5.39]	0.01	0.55	[0.09, 1.38]	0.01

benefits of social participation, as social contacts can promote both healthy and unhealthy behaviors (Berkman et al., 2000). Thus, the effects of social contact as measured in this study might be muted because of its inability to distinguish between healthy and unhealthy contacts. For instance, some social contacts may reinforce a sedentary lifestyle and unhealthy diet, such as family members gathering for meals, and many traditional Chinese dishes are high in cholesterol. In addition, no relationship was found between mood and peak flow. Previous studies that found a relationship (Smyth et al., 1999) had not controlled for the range of biological and health measures (some of which being related to mood) as the present study, which might account for the difference in finding.

Compared with older adults with restricted networks, those with diverse, friend-focused, and distant family networks had superior PEF values, with those having diverse networks doing best. People with family-focused networks, however, did not differ from those with restricted networks in PEF performance. Decades of research has shown consistently the benefits of social integration, in terms of meaningful roles in multiple relationships and groups. People who are high in social integration are connected to a diverse network including family members, friends, neighbors, and organizations, and have less susceptibility to diseases as well as better prognosis in those with morbidities and lower mortality compared with those with few social ties (see reviews by Cohen, 2004; Cohen & Janicki-Deverts, 2009). Cohen and Janicki-Deverts proposed two interpretations of these findings: (a) a threshold effect so that those with social ties below a certain threshold are susceptible to morbidities and mortality (i.e., the effect of social integration is actually driven by social isolation; see also Shankar et al., 2011; Steptoe, Shankar, Damakakos, & Wardle, in press), and (b) an incremental influence of social integration as a continuum. Judging from the lack of PEF difference between the family-focused network and the restricted network, the threshold effect hypothesis does not seem to fit the data well, as does the incremental effect hypothesis. This is because people with family-focused networks have more ties than those with distant family and restricted networks, but fewer ties than those with diverse and friend-focused networks (Cheng et al., 2009). The incremental effect hypothesis would predict a dose-dependent pattern on the basis of number of social ties. Moreover, if the threshold effect hypothesis was true, networks with social ties above the threshold should have performed similarly on PEF. Both were not the case.

As social network provides a platform for mutual activities, the network-type differences may very well be accounted for by their differences in activity participation. In this study, the superior PEF and percent predicted PEF of older adults with friend-focused networks were partially mediated by their higher involvement in socializing activity, whereas the PEF advantages of people with diverse networks were mediated by both socializing activity and physical exercise. For the latter group, the mediation through socializing activity was stronger than that through exercise (see Table 4), which should not be surprising, as network types were partly defined by differences in socializing activity (Cheng et al., 2009). However, activity participation could not fully account for the network-type differences, as the effect of the distant family network was not mediated by activity at all, and the mediation effects, when they occurred, were small compared with the main effects. A large proportion of network-type variations remained unexplained. As this is the first study to explore the relationship between social network type and ventilatory function as assessed by PEF, more research is needed to understand the underlying mechanism. Such underlying mechanisms might help identify modifiable processes to target in interventions.

Despite these intriguing results, the present study suffers from two limitations. First, as a cross-sectional study, causality cannot be inferred among the variables. In particular, although a lack of activity may predict poorer PEF, a less effective respiratory system might also lead to lower activity levels, as in a vicious cycle. Thus, the causal direction may very well be bidirectional, rather than one-way. Future research should disentangle the causal directions among social network, activity, and PEF. Second, physical activity (i.e., exercise and housework) was measured by three items together. Although it is not uncustomary to rely on brief or even single-item measures in large scale surveys, it would be advantageous to use established instruments with more items—such as the International Physical Activity Questionnaire (Macfarlane et al., 2007)—that assess a wide range of activities and their intensities in a more comprehensive manner. It will also be advantageous if clear definition of each type of activity (e.g., exercise) is provided to avoid varied interpretations by different individuals. Despite these limitations, the present study sheds light on another potential mechanism by which social network types predict morbidity and mortality (Cohen, 2004; Cohen & Janicki-Deverts, 2009), that is, through reduced lung function. It also confirms the general finding, one that has been found across cultures (Litwin, 2003, 2012; Orsega-Smith et al., 2007), that social networks that are more or less restricted to the immediate family may not be protective of health among older adults. Nevertheless, more research is needed to replicate the association between social network and PEF across cultures. Future research should also pay attention to the timing of PEF assessment, as PEF may vary throughout the day and to avoid the potential effect of respiratory medications.

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