Social networks and patterns of health risk behaviours over two decades: A multi-cohort study

Maarit Kauppi[i],[*], Marko Elovainio[a],[b], Sari Stenholm[b],[c], Marianna Virtanen[d], Ville Aalto[d], Markku Koskenvuo[e], Mika Kivimäki[d],[f],[g], Jussi Vahtera[c],[h]

[a] IBS, University of Helsinki, Helsinki, Finland
[b] National Institute for Health and Welfare, Helsinki, Finland
[c] Department of Public Health, University of Turku, Turku, Finland
[d] Finnish Institute of Occupational Health, Turku and Helsinki, Finland
[e] Department of Public Health, University of Helsinki, Helsinki, Finland
[f] Department of Epidemiology and Public Health, University College London Medical School, London, UK
[g] Clinicum, Faculty of Medicine, University of Helsinki, Finland
[h] Turku University Hospital, Turku, Finland
[i] Finnish Institute of Occupational Health, Lemminkäisenkatu 14-18 B (DataCity), 20520 Turku, Finland

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ABSTRACT

Objective: To determine the associations between social network size and subsequent long-term health behaviour patterns, as indicated by alcohol use, smoking, and physical activity.

Methods: Repeat data from up to six surveys over a 15- or 20-year follow-up were drawn from the Finnish Public Sector study (Raisio-Turku cohort, n = 986; Hospital cohort, n = 7307), and the Health and Social Support study (n = 20,115). Social network size was determined at baseline, and health risk behaviours were assessed using repeated data from baseline and follow-up. We pooled cohort-specific results from repeated-measures log-binomial regression with the generalized estimating equations (GEE) method using fixed-effects meta-analysis.

Results: Participants with up to 10 members in their social network at baseline had an unhealthy risk factor profile throughout the follow-up. The pooled relative risks adjusted for age, gender, survey year, chronic conditions and education were 1.15 for heavy alcohol use (95% CI: 1.06–1.24), 1.19 for smoking (95% CI: 1.12–1.27), and 1.25 for low physical activity (95% CI: 1.21–1.29), as compared with those with > 20 members in their social network. These associations appeared to be similar in subgroups stratified according to gender, age and education.

Conclusions: Social network size predicted persistent behaviour-related health risk patterns up to at least two decades.

1. Introduction

Several studies suggest that individuals with more social connections tend to live longer and healthier lives than those with less social connections [1–4]. Several plausible pathways link social relations to health [5]. For example, supportive social relations may buffer the impact of stress, by promoting less threatening interpretations of adverse events and providing cues for better coping strategies and emotional and instrumental social support [6]. Moreover, it has been suggested that social relations affect physiological outcomes, such as resting blood pressure, heart rate, stress hormone levels, and immune function [7]. Social relations may also affect health risk behaviours, such as heavy alcohol use, smoking and low physical activity [8,9].

An individual's personal social network may affect their health behaviour by shaping norms and enforcing patterns of social control, by providing health-related information, and by improving an individual's sense of responsibility for their own, as well as others' health and well-being [8]. Although not all social relations are beneficial, and some can even lead to risky health behaviour, compared to small social networks, larger social networks may have the potential to offer more diverse social relations with relatively more positive influences on health behaviours [10,11]. Previous studies among American middle-aged and older adults, for example, have found that a higher number of social ties, being married [12,13] and participation in religious activities [14] are all associated with healthier lifestyles, such as higher levels of physical activity, non-smoking and low levels of alcohol use. A cross-

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sectional study among patients in cardiac rehabilitation showed a positive association between the number of most important members in a social network and healthy life style as well as coping efficacy [15]. Similarly, cross-sectional studies among low-income adults [16] and adults at a higher risk of diabetes and cardiovascular disease [17] have found larger social networks to be positively associated with physical activity. However, prospective evidence on the role of social network size in predicting long-term health behaviour among adult populations remains scarce. Thus, little is known about how persistent the associations between social network size and health risk behaviours are.

In the present study, based on two occupational cohorts and one population-based cohort of working-aged adults, we used repeated measurements on health risk behaviours over a 15–20-year follow-up to examine whether the size of social network at baseline was associated with persistent differences in health risk behaviours over time. We hypothesized that compared to participants with large social networks, those with smaller social networks would be more likely to have unfavourable patterns of health behaviours over time, as indicated by heavy alcohol use, smoking, and low physical activity. We also hypothesized that health risk behaviours would accumulate among those with a small social network. Since sociodemographic factors are also associated with both social networks and health behaviour, we also examined the association of network size with health risk behaviours by gender, age-group and educational level [5,18–20].

2. Methods

2.1. Participants

We used data from three cohort studies: the Raisio-Turku cohort and the Hospital cohort from the Finnish Public Sector study (FPS) [21] and the Health and Social Support Study (HeSSup) [22]. The Raisio-Turku cohort was established in 1990 to investigate the impact of the psychosocial work environment on health in full-time municipal employees of the towns of Raisio and Turku. Repeat survey data was collected in 1990–92 and 1993. In 1997 the study was extended to include all public sector employees with at least six months job contract in any year from 1991/1996 to 2005 in 10 towns and 5 hospital districts in Finland (the Finnish Public Sector study (FPS)), from whom repeated survey data have been collected from 1997 onward, with 2–4 years intervals. Those participants of the Raisio-Turku cohort who responded to questions about their social network size and health risk behaviours in the baseline survey in 1992 or 1993, and to questions about health risk behaviours at least once at follow-up, in 1997, 2000, 2004/5, 2008/9 or 2012/3 (mean 4.6 repeat measurements) were included in the analyses (n = 986, 83.6% of eligible baseline respondents). Similarly, in the Hospital cohort of FPS, personnel from participating hospital districts who provided information on their social network size and health risk behaviours at the baseline survey in 1998, and on health risk behaviours at one time point at least in the follow-up (2000, 2004/5, 2008/9 and 2012/3, mean 3.9 repeat measurements) were included in the study population (n = 7307, 82.6% of eligible baseline respondents). The HeSSup cohort was based on a prospective cohort study of a representative sample of the Finnish population aged 20–24, 30–34, 40–44, and 50–54 years at baseline. Those participants who provided data on their social network size and health risk behaviours in the baseline survey in 1998, and also provided data on health risk behaviours at least once during the follow-up (2003 and 2012, mean 2.6 repeat measurements) were included in the analyses (n = 20,115, 77.7% of eligible baseline respondents).

The studies were conducted according to the principles of the Declaration of Helsinki. The Raisio-Turku and the HeSSup studies were approved by the Turku University Hospital Ethics Committee and the Hospital study by the ethics committee of the Finnish Institute of Occupational Health.

2.2. Measurement of social network size

Social network size was assessed in all cohorts at baseline using the social convoy model described by Antonucci [23]. Participants were asked to write the initials of their social network members on three concentric circles. The people who were closest and most important to the respondent, without whom life would be hard to imagine, were placed in the innermost circle. The people who were not quite that close but still important were placed in the middle circle, and those not already mentioned, but who were close and important enough to belong to their personal network were placed in the outer circle. The total number of members in these circles was calculated and classified into three categories, based on the data distribution; 0–10 (corresponding to the threshold at the lowest quartile), 11–20, and at least 21 members (corresponding to the threshold at the highest quartile). Similar categorization of social network size has been used previously [24]. The convoy model has been used successfully among people of different age ranges and from different countries [18], and has been shown to have relatively good test-retest reliability over time [24].

2.3. Measurement of health risk behaviours

Baseline and follow-up information on health risk behaviours – heavy alcohol consumption, smoking and low physical activity – was drawn from the questionnaires. Three dichotomous variables of health risk behaviours were created on the basis of similar questions used in all cohorts and over time. Alcohol use, expressed as absolute ethanol in grams/week, was estimated on the basis of the reported average consumption of beer, wine and/or spirits. The cut-off point of heavy alcohol use was set at 288 g/week for men and 192 g/week for women as proposed by the Finnish guidelines [25]. These limits also correspond with the medium risk levels of daily consumption presented by the World Health Organization [26].

Smoking status was categorized into non-smokers (including former smokers) and current smokers. Information regarding average time spent in physical activities with different intensities was used to estimate average metabolic equivalent (MET) hours/week [27]. Participants whose physical activity corresponded to < 14 MET hours/week were regarded as having a low level of physical activity [27]. In addition, a summary variable (overall unhealthy lifestyle score) was created at each wave by summing up the total number of each participant's health risk behaviours (heavy alcohol use, smoking and low physical activity) into a measure of none to three risk behaviours.

2.4. Measurement of potential confounders

Age, gender, education and chronic conditions at baseline were selected as potential confounders on the basis of an a priori assumption that these factors are associated with both social relations and health behaviours [5,18–20,28]. Information on education was based on the highest self-reported vocational education classified into three categories: basic, intermediate and high. Information regarding chronic conditions at baseline (diabetes, rheumatoid arthritis, asthma, coronary heart disease) was obtained from the National Drug Reimbursement Register and diagnosis of cancer (within five years) from the Finnish Cancer Registry. The total number of these conditions was calculated and classified into no chronic conditions and at least one chronic condition.

2.5. Statistical analyses

Descriptive statistics were calculated to evaluate baseline characteristics of all study participants in each cohort, and by social network size. Differences in these characteristics by social network size were assessed using the Kruskall-Wallis Test for continuous variables and the chi-square test for categorical variables.

Relative risks (RR) with 95% confidence intervals (CI) of health risk

behaviours across the follow-up periods were calculated in each cohort by means of repeated-measures log-binomial regression analysis using the generalized estimating equations (GEE) method [29].The GEE method enables the analysis of correlated data arising from a longitudinal study with repeated measurements on the same subject. Those with at least 21 members in their social network at baseline were used as a reference group. Three types of models were performed in each cohort; 1) age, gender and survey year -adjusted models with each health risk behaviour (heavy alcohol use, smoking and low physical activity) as a dependent variable, 2) models further adjusted for education and chronic conditions, and 3) cumulative logistic regression models with the total number of health risk behaviours (overall unhealthy lifestyle score ranging between 0 and 3) as the dependent variable, adjusted for age, gender, survey year, education and chronic conditions. Trends in health risk behaviours according to baseline social network size were examined over the 10-year period, treating year as a continuous variable, to assess whether the potential changes in risk differed between the groups.

After separate analyses in each cohort, fixed-effects meta-analysis [30] was used to pool the cohort-specific results into summary estimates. Fixed-effect analysis was chosen because the number of studies was small, which results in poor precision of the between-studies variance estimate. In such cases, the random-effect model may not be applied correctly [31]. However, random-effect models were also performed in order to verify the consistency of the results with both of these methods. Finally, stratified analyses of the associations between baseline social network size and health risk behaviours over time were performed by gender, age group (< 50 vs. ≥ 50 years) and education (basic and intermediate vs. high). In order to test whether the selective drop-out during the follow-up affected the results, we performed sensitivity analysis including only those participants who had answered both to the first and the last questionnaires. Statistical analyses were performed with the use of SAS software, version 9.4 (SAS Institute Inc., Cary NC) and the R statistical package (R version 3.2.3).

3. Results

Table 1 shows the baseline characteristics of the three cohorts (for

descriptive statistics according to social network size, see Appendix A, Tables A.1–A.3). The follow-up period extended up to 20 years, including on average, 3–5 repeat measurements depending on the cohort (range 2 to 6). Fig. 1 shows the results from meta-analyses of each health risk behaviour separately and a summary variable of overall unhealthy lifestyle score (total number of health risk behaviours ranging between 0 and 3), with summary estimates for pooled results of the three cohorts adjusted for age, gender, survey year, chronic conditions, and education. Compared with participants with at least 21 network members, those with 0–10 members in their social network were at a significantly higher risk of heavy alcohol use (RR = 1.15, 95% CI: 1.06, 1.24), smoking (RR = 1.19, 95% CI: 1.12, 1.27) and low physical activity (RR = 1.25, 95% CI: 1.21, 1.29) over time. The corresponding figures for those with 11–20 members in their social network were also higher than that for those with at least 21 network members (risk of heavy alcohol use: RR = 1.08, 95% CI: 1.00, 1.16; smoking: RR = 1.10, 95% CI: 1.04, 1.16; low physical activity: RR = 1.12, 95% CI: 1.09, 1.16). The cumulative odds ratios (cOR) of overall unhealthy lifestyle score for those with 0–10 and 11–20 members in their social network were 1.40 (95% CI: 1.33, 1.48) and 1.19 (95% CI: 1.14, 1.25), respectively, compared with participants with at least 21 members. Analyses performed with random-effects models yielded similar results (Appendix B, Figs. B.1–B.4).

There was no clear difference in trends of health risk behaviours over time between those with 0–10 members and those with at least 21 members in their total social network (Appendix C, Figs. C.1–C.3). If anything, the risk of heavy alcohol use increased slightly more among those with at least 21 members in their social network as compared with those with the smallest social network examined over the ten-year period (Table 2). On the other hand, additional analyses of participants with healthy lifestyle at baseline (none of the studied health risk behaviours) showed that health risk behaviours accumulated differently according to the size of social network. Compared with participants with at least 21 members in their social network, those with 0–10 members were at a higher risk of overall unhealthy lifestyle over the follow-up period (cOR = 1.26, 95% CI: 1.16, 1.38) (data not shown).

Stratified meta-analyses showed few differences between the results in terms of gender, age-groups or educational levels (Table 3). The only

Table 1
Baseline characteristics of participants in Raisio-Turku, Hospital and HeSSup cohorts.

Baseline characteristics	Raisio–Turku (n = 986)		Hospital (N = 7307)		HeSSup (n = 20,115)	
Age (years), mean (SD)	41.5	(8.1)	43.4	(9.2)	37.4	(11.4)
Gender, n (%)						
Women	752	(76.3)	6485	(88.8)	12,499	(62.1)
Men	234	(23.7)	822	(11.2)	7616	(37.9)
Members in the social network, mean (SD)						
Innermost circle	4.6	(3.1)	4.6	(2.7)	4.3	(2.9)
Middle circle	5.6	(4.2)	6.1	(4.4)	5.3	(4.3)
Outer circle	7.0	(6.1)	8.7	(7.9)	6.4	(5.9)
Total	17.1	(10.2)	19.4	(11.9)	16.0	(10.0)
Chronic conditions, ≥ 1[a], n (%)	36	(3.7)	489	(6.7)	1208	(6.2)
Education, n (%)						
Basic	261	(27.0)	758	(10.9)	5820	(29.2)
Intermediate	461	(47.7)	5501	(76.5)	10,660	(53.5)
High	245	(25.3)	904	(12.6)	3436	(17.3)
Heavy alcohol use[b], n (%)	84	(8.6)	364	(5.0)	1984	(9.9)
Current smoking, n (%)	189	(19.2)	1037	(14.6)	4731	(25.6)
Low physical activity[c], n (%)	332	(39.5)	2408	(33.3)	5988	(30.0)
Overall unhealthy lifestyle score[d]						
0	378	(45.2)	3881	(55.3)	9032	(49.1)
1	354	(42.3)	2614	(37.2)	6980	(38.0)
2	96	(11.5)	488	(7.0)	2092	(11.4)
3	8	(1.0)	36	(0.5)	273	(1.5)

SD: standard deviation.
[a] Includes information on diabetes, rheumatoid arthritis, asthma, coronary heart disease, cancer.
[b] Heavy alcohol use defined as weekly consumption of absolute ethanol exceeding 192 g among women and 288 g among men.
[c] Low physical activity defined as metabolic equivalent (MET) hours < 14/week.
[d] Total number of health risk behaviours (heavy alcohol use, smoking and low physical activity).
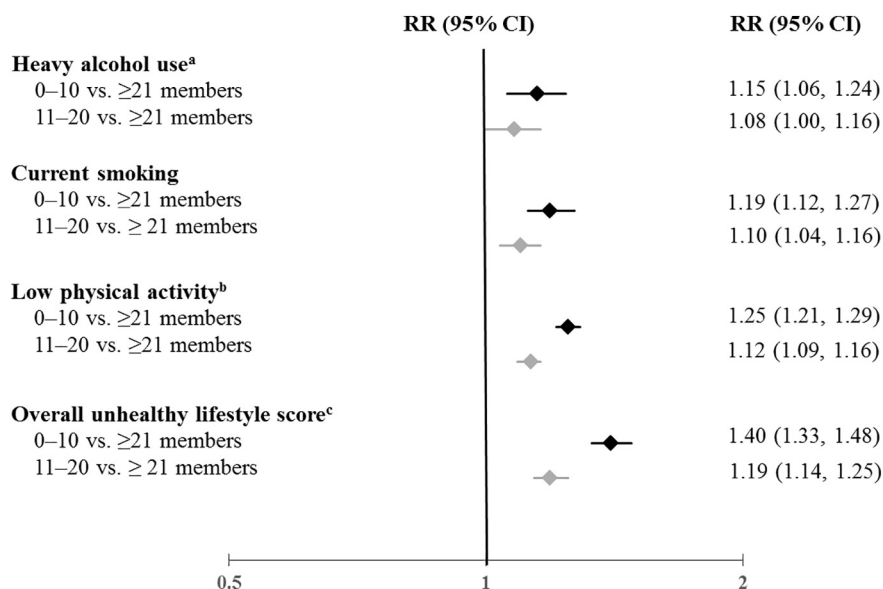
Fig. 1. Social network size and health risk behaviours. Relative risks (RR) with 95% confidence intervals (CI) are derived from repeated-measures log-binomial regression analysis using the generalized estimating equations (GEE) method. Summary estimates pooled from cohort-specific (Raisio-Turku, Hospital and HeSSup cohorts) results adjusted for age, gender, survey year, chronic conditions and education. Participants with 0–10 members and 11–20 members are compared with those with at least 21 members in the total social network.
[a] Heavy alcohol use defined as weekly consumption of absolute ethanol exceeding 192 g among women and 288 g among men.
[b] Low physical activity as metabolic equivalent (MET) hours < 14/week.
[c] Cumulative odds ratio (OR) for overall unhealthy lifestyle score (total number of health risk behaviours ranging from 0 to 3).

exceptions were that among participants with the least number of members in their social network, the association with heavy alcohol use appeared slightly stronger among women (RR 1.16 compared to RR 1.03 in men), among participants younger than 50 (RR 1.16 compared to RR 1.13 among those aged at least 50 years), and those with basic or intermediate education (RR 1.18 compared to RR 0.99 among those with high education). In addition, the association with smoking appeared slightly stronger among participants with basic or intermediate education (RR 1.23 compared to RR 0.99 among those with high education). However, none of these differences reached statistical significance at conventional levels.

The results of the sensitivity analysis adjusted for age, gender and survey year including only those participants with maximal follow-up time (i.e., those who had answered both the first and the last questionnaire), did not differ from the results drawn from the analyses performed on the whole study population (Appendix D, Fig. D.1).

The results were relatively consistent among the three cohorts. Significant heterogeneity between the cohorts were only observed for the association of social network size with heavy alcohol use (P value for I^2 0.01 Appendix B, Fig. B.1). Smaller network size tended to be associated with a lower risk of heavy alcohol use in the Raisio-Turku cohort and a higher risk in the HeSSup cohort.

4. Discussion

Our findings from two occupational cohorts and one population-based cohort from Finland suggest that smaller social networks are associated with persistently more unhealthy behaviours over the adult life course. Compared with individuals with at least 21 members in

their social network at baseline, those with up to 10 members were at a significantly higher risk of being heavy alcohol users, smokers or physically inactive over the follow-up period extending up to 15–20 years. In addition, these individuals were at a higher risk of having multiple risk factors as part of an overall unhealthy lifestyle score.

Our findings are consistent with previous, mainly cross-sectional studies on the association between social networks and health risk behaviours [12,13,15–17,20,32–34]. Previous studies have shown, for example, that individuals who drink heavily report decreased levels of social activities, worse social anchorage and low contact frequency [32]. Our results are also in line with those reporting a significant association between smoking and social isolation, low levels of social support, participation and network heterogeneity [33,34]. It has been suggested that for some people smoking provides a means of managing negative moods and stress that might result from having inadequate social relations [35]. None of these studies, however, have addressed the question of the persistency of the associations between social network size and smoking or heavy drinking.

An association with physical inactivity has previously been reported for various measures of low social engagement, such as low social integration and a small number of friends and close network members [12,13,16,17,20]. Similarly, our results highlight the importance of social network size on physical activity, the strongest and most robust association observed in the present study. Potential mechanisms linking social network and physical activity include the higher levels of social support offered by a larger network, the establishment of social norms, the provision of resources, and encouragement for activity [36]. On the other hand, it could be speculated that those who are more physically active obtain more social contacts through their participation in leisure activities. However, as the

Table 2
Trends in health risk behaviours according to social network size examined over the 10-year period, treating year as a continuous variable. Relative Risks (RR) with 95% confidence intervals (CI) are derived from repeated-measures log-binomial regression analysis using the generalized estimating equations (GEE) method. Summary estimates pooled from cohort-specific (Raisio-Turku, Hospital and HeSSup cohorts) results.

Social network size	Heavy alcohol use[a]		Current smoking		Low physical activity[b]		Overall unhealthy lifestyle score[c]	
	RR	95% CI	RR	95% CI	RR	95% CI	RR	95% CI
0–10 members	1.10	1.04, 1.16	0.75	0.73, 0.77	1.09	1.06, 1.12	0.95	0.91, 0.99
11–20 members	1.18	1.13, 1.23	0.73	0.71, 0.74	1.11	1.08, 1.13	0.95	0.93, 0.98
≥ 21 members	1.30	1.22, 1.38	0.72	0.69, 0.75	1.12	1.09, 1.16	1.00	0.96, 1.04

RR: relative risk; CI: confidence interval.
[a] Heavy alcohol use defined as weekly consumption of absolute ethanol exceeding 192 g among women and 288 g among men.
[b] Low physical activity defined as metabolic equivalent (MET) hours < 14/week.
[c] Total number of health risk behaviours ranging from 0 to 3.

Table 3

Longitudinal association of social network size with health risk behaviours, stratified by gender, age and education. Summary estimates pooled from cohort-specific (Raisio-Turku, Hospital and HeSSup cohorts) results derived from repeated-measures log-binomial regression analysis using the generalized estimating equations (GEE) method adjusted for age, gender and survey year, as appropriate. Participants with 0–10 and 11–20 members are compared with those with at least 21 members in the total social network.

		Heavy alcohol use[a]		Current smoking		Low physical activity[b]		Overall unhealthy lifestyle score[c]	
		RR	95% CI	RR	95% CI	RR	95% CI	RR	95% CI
Women	0–10 members	1.16	1.05, 1.28	1.25	1.16, 1.35	1.25	1.20, 1.30	1.43	1.34, 1.52
	11–20 members	1.15	1.05, 1.25	1.13	1.06, 1.21	1.14	1.10, 1.18	1.24	1.18, 1.30
Men	0–10 members	1.03	0.90, 1.17	1.22	1.11, 1.34	1.28	1.20, 1.36	1.41	1.28, 1.56
	11–20 members	0.91	0.80, 1.04	1.07	0.97, 1.18	1.10	1.03, 1.17	1.09	0.99, 1.20
Age < 50 years	0–10 members	1.16	1.05, 1.27	1.22	1.14, 1.31	1.31	1.25, 1.36	1.46	1.37, 1.55
	11–20 members	1.06	0.98, 1.15	1.11	1.05, 1.18	1.14	1.10, 1.18	1.20	1.14, 1.27
Age ≥ 50 years	0–10 members	1.13	0.97, 1.31	1.31	1.15, 1.49	1.22	1.16, 1.29	1.43	1.30, 1.57
	11–20 members	1.09	0.94, 1.26	1.11	0.97, 1.27	1.10	1.05, 1.16	1.19	1.09, 1.30
Basic/intermediate education	0–10 members	1.18	1.08, 1.29	1.23	1.15, 1.31	1.26	1.21, 1.30	1.44	1.36, 1.52
	11–20 members	1.05	0.97, 1.14	1.13	1.06, 1.19	1.12	1.09, 1.16	1.20	1.14, 1.26
High education	0–10 members	0.99	0.83, 1.18	0.99	0.80, 1.23	1.23	1.13, 1.35	1.27	1.12, 1.45
	11–20 members	1.16	1.00, 1.34	0.94	0.78, 1.13	1.14	1.05, 1.23	1.20	1.07, 1.34

RR: relative risk; CI: confidence interval.

RRs are adjusted for age, gender and survey year, as appropriate.

[a] Heavy alcohol use defined as weekly consumption of absolute ethanol exceeding 192 g among women and 288 g among men.

[b] Low physical activity defined as metabolic equivalent (MET) hours < 14/week.

[c] Cumulative odds ratio (cOR) for overall unhealthy lifestyle score (total number of health risk behaviours ranging from 0 to 3).

difference in the risk of being physically inactive according to social network size persisted over the follow-up period, it is also possible that having a larger social network promotes a physically active lifestyle over time.

It is noteworthy that social relations may also discourage a healthy lifestyle. For example, those who are closely connected to smokers are more likely to smoke themselves, and conversely, a decision to quit smoking is affected by the choices made in groups of inter-connected people [34]. Drinking habit is also largely influenced by the drinking habit of a social network [37]. In the present study, no information regarding the attitudes or health risk behaviours of social network members was available. Yet, the social network size at baseline was a robust predictor of these health risk behaviours over time.

Women tend to have larger social networks than men, as do better educated people compared with the less-educated and to a lesser extent, younger adults compared with the elderly [5]. Some studies have reported the associations between social relations and health behaviour to be stronger among people with lower as compared to those with higher socio-economic positions [20]. In line with this observation, we found a tendency toward a stronger association between social network size and health risk behaviours among participants with basic or intermediate education compared with those with high education. Yet, these differences could not be proven statistically.

The effects of social relations are likely to accumulate and create a growing advantage or disadvantage for health [5]. However, with respect to health risk behaviours, we found no evidence of accumulation according to social network size over time. The change in the prevalence of separate health risk behaviours did not differ significantly between participants with small networks and those with larger networks. It is possible that the age phase of the study members of the present study (ranging from 20 to 63 years) is relatively stable with respect to social relations, potentially diminishing the likelihood of clear differences in separate health risk behaviours between the groups. Follow-up periods extending over critical life transitions, such as changes in marital status or retirement, might provide more specific information regarding the contribution of social relations to trajectories of separate health risk behaviours. In addition, more detailed information on the various dimensions of social networks might be more efficient in predicting separate health risk behaviours.

4.1. Strengths and limitations

The strengths of this study were that we were able to use data from three large cohorts of working-aged adults with long follow-up periods and

repeated measurements of health risk behaviours. Information regarding sociodemographic factors and chronic conditions was also readily available. However, some limitations should be considered. First, behavioural outcomes were assessed by self-reporting, which may be subject to bias and under-reporting in some (e.g. smoking, alcohol use) and over-reporting in other (e.g. physical activity) health behaviours. The information regarding social network size was similarly based on self-reporting, and may thus not correspond to the actual number of members in the social network, but depend on the person's willingness to provide details of their social network. On the other hand, the importance (and closeness) of social relationships is always more or less based on subjective assessment, and may be difficult to evaluate objectively. Another limitation was that social network size was only assessed at baseline, and therefore it was not possible to evaluate how changes in network size may have contributed to the changes in health risk behaviours over the follow-up period. However, previous studies have shown that social relations are relatively stable across adulthood [38], which is also likely to be the case among the working-aged study population of the present study. Selective drop out during the follow-up was also a possible important limitation of the study. However, our sensitivity analyses, including only those participants who provided information about their health risk behaviours in both the first and last questionnaire showed unchanged results compared to the whole study population. Further, although we controlled for major potential confounders, e.g. chronic conditions and education, confounding can never be ruled out in observational studies such as ours. Finally, clustering of participants in geographic regions could potentially affect the results if the participants remain in the same regions. However, during the two decades of follow-up of health behaviours, many cohort members moved from their baseline residential regions. The fact that the same pattern was found in the occupational cohorts and the population cohort which was not drawn from geographic regions further suggest that clustering of participants in geographic regions is an unlikely source of major bias.

5. Conclusion

In conclusion, the data from three longitudinal cohort studies of working-aged adults suggest a sustained association between small social networks at baseline and an increased likelihood of persistent risky alcohol use, smoking, and low physical activity over a follow-up of up to 15–20 years, as compared with those who had large networks. The findings of the present study may serve as a rationale for designing public health interventions that focus on strengthening social networks in order

to support beneficial health behaviour patterns. However, further follow-up studies are needed to assess the specific factors (e.g. size of total social network, closeness or other qualities of the relations) of social networks that have the most affect, and whether the changes in these factors have an impact on the trajectories of health risk behaviours, and ultimately on health outcomes.

Competing interest

The authors have no competing interests to report.

Acknowledgements

Appendix A

Table A.1
Baseline characteristics of study participants in the Raisio-Turku cohort according to social network size.

Baseline characteristics	0–10 members (n = 253)		11–20 members (n = 472)		≥ 21 members (n = 261)		P value[a]
Age (years), mean (SD)	42.7	(8.1)	41.2	(8.1)	41.0	(8.1)	0.01
Gender, n (%)							0.001
Women	173	(68.4)	365	(77.3)	214	(82.0)	
Men	80	(31.6)	107	(22.7)	47	(18.0)	
Members in social network, mean (SD)							< 0.0001
Innermost circle	2.8	(1.3)	4.3	(1.8)	6.7	(4.6)	
Middle circle	2.3	(1.3)	4.9	(2.1)	10.0	(5.0)	
Outer circle	2.8	(1.8)	5.6	(2.5)	13.5	(7.9)	
Chronic conditions, ≥ 1[b], n (%)	6	(2.4)	19	(4.0)	11	(4.2)	0.45
Education, n (%)							0.03
Basic	76	(31.1)	134	(28.9)	51	(19.7)	
Intermediate	113	(46.3)	217	(46.8)	131	(50.6)	
High	55	(22.5)	113	(24.4)	77	(29.7)	
Heavy alcohol use[c], n (%)	18	(7.1)	40	(8.5)	26	(10.0)	0.50
Current smoking, n (%)	54	(21.3)	88	(18.7)	47	(18.1)	0.59
Low physical activity[d], n (%)	97	(45.3)	166	(40.6)	69	(31.7)	0.01

SD: standard deviation.
[a] Differences between three groups categorized according to the total number of social relations.
[b] Includes information on diabetes, rheumatoid arthritis, asthma, coronary heart disease, cancer.
[c] Heavy alcohol use defined as weekly consumption of absolute ethanol exceeding 192 g among women and 288 g among men.
[d] Low physical activity defined as metabolic equivalent (MET) hours < 14/week.

Table A.2
Baseline characteristics of study participants in the hospital cohort according to social network size.

Baseline characteristics	0–10 members (n = 1467)		11–20 members (n = 3287)		≥ 21 members (n = 2553)		P value[a]
Age (years), mean (SD)	45.0	(9.1)	43.1	(9.2)	43.0	(9.1)	< 0.0001
Gender, n (%)							< 0.0001
Women	1224	(83.4)	2948	(89.7)	2313	(90.6)	
Men	243	(16.6)	339	(10.3)	240	(9.4)	
Members in social network, mean (SD)							< 0.0001
Innermost circle	2.8	(1.4)	4.2	(1.8)	6.1	(3.4)	
Middle circle	2.5	(1.3)	4.9	(2.1)	9.7	(5.1)	
Outer circle	2.4	(1.6)	6.1	(2.6)	15.8	(9.2)	
Chronic conditions, ≥ 1[b], n (%)	109	(7.4)	220	(6.7)	160	(6.3)	0.36
Education, n (%)							< 0.0001
Basic	226	(15.8)	343	(10.6)	216	(8.6)	
Intermediate	1024	(71.4)	2478	(76.4)	1999	(79.6)	
High	184	(12.8)	424	(13.1)	296	(11.8)	
Heavy alcohol use[c], n (%)	77	(5.3)	169	(5.2)	118	(4.6)	0.56
Current smoking, n (%)	223	(15.7)	487	(15.2)	327	(13.1)	0.03
Low physical activity[d], n (%)	533	(36.9)	1134	(34.8)	741	(29.3)	< 0.0001

SD: standard deviation.
[a] Differences between three groups categorized according to the total number of social relations.
[b] Includes information on diabetes, rheumatoid arthritis, asthma, coronary heart disease, cancer.
[c] Heavy alcohol use defined as weekly consumption of absolute ethanol exceeding 192 g among women and 288 g among men.
[d] Low physical activity defined as metabolic equivalent (MET) hours < 14/week.

Table A.3

Baseline characteristics of study participants in the HeSSup cohort according to social network size.

Baseline characteristics	0–10 members (n = 6243)		11–20 members (n = 9163)		≥ 21 members (n = 4709)		P value[a]
Age (years), mean (SD)	39.0	(11.4)	36.6	(11.4)	36.7	(11.4)	< 0.0001
Gender, n (%)							< 0.0001
Women	3183	(51.0)	6052	(66.0)	3264	(69.3)	
Men	3060	(49.0)	3111	(34.0)	1445	(30.7)	
Members in social network, mean (SD)							< 0.0001
Innermost circle	2.6	(1.5)	4.3	(2.0)	6.5	(4.0)	
Middle circle	2.3	(1.4)	4.9	(2.2)	10.1	(5.5)	
Outer circle	2.2	(1.6)	5.7	(2.7)	13.3	(7.7)	
Chronic conditions, ≥ 1[b], n (%)	385	(6.4)	545	(6.1)	278	(6.1)	0.75
Education, n (%)							< 0.0001
Basic	2078	(33.6)	2553	(28.1)	1189	(25.6)	
Intermediate	3254	(52.5)	4859	(53.5)	2547	(54.8)	
High	861	(13.9)	1663	(18.3)	912	(19.6)	
Heavy alcohol use[c], n (%)	710	(11.4)	884	(9.7)	390	(8.3)	< 0.0001
Current smoking, n (%)	1631	(28.5)	2132	(25.1)	968	(22.4)	< 0.0001
Low physical activity[d], n (%)	2189	(35.4)	2619	(28.7)	1180	(25.2)	< 0.0001

SD: standard deviation.

[a] Differences between three groups categorized according to the total number of social relations.

[b] Includes information on diabetes, rheumatoid arthritis, asthma, coronary heart disease, cancer.

[c] Heavy alcohol use defined as weekly consumption of absolute ethanol exceeding 192 g among women and 288 g among men.

[d] Low physical activity defined as metabolic equivalent (MET) hours < 14/week.
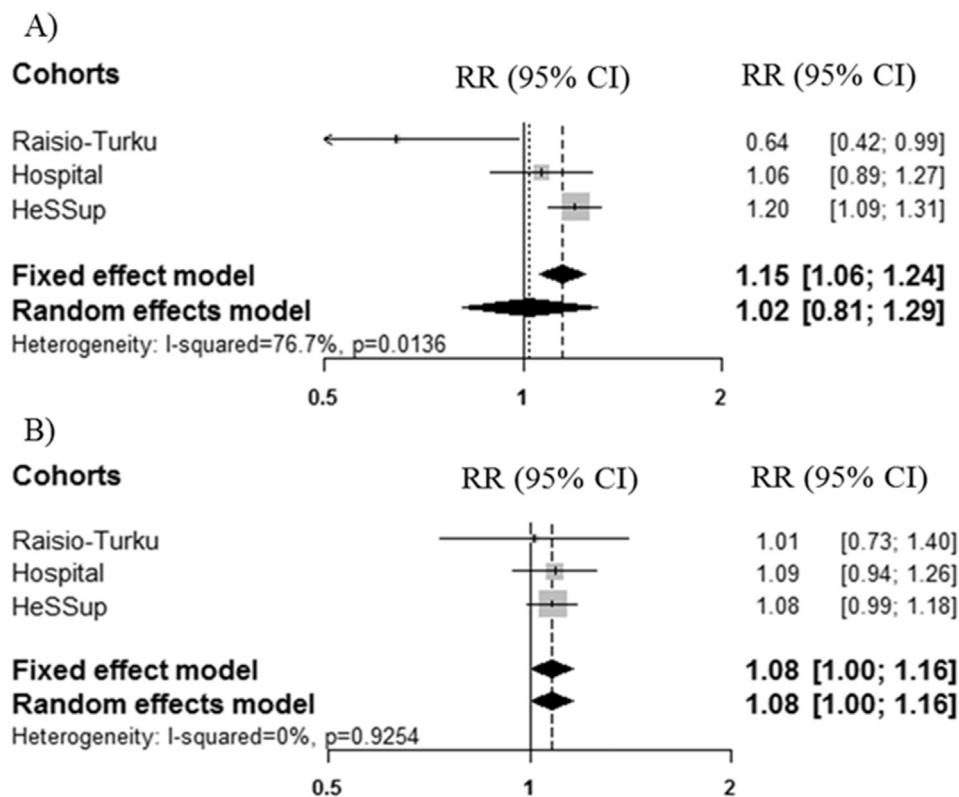
Appendix B

Fig. B.1. Social network size and heavy alcohol use (weekly consumption of absolute ethanol exceeding 192 g among women and 288 g among men). Relative risks (RRs) with 95% confidence intervals (CI) are derived from repeated-measures log-binomial regression analysis using the generalized estimating equations (GEE) method. Summary estimates pooled from cohort-specific (Raisio-Turku, Hospital and HeSSup cohorts) results adjusted for age, gender, survey year, chronic conditions and education. Participants with A) 0–10 members and B) 11–20 members are compared with those with at least 21 members in their total social network.
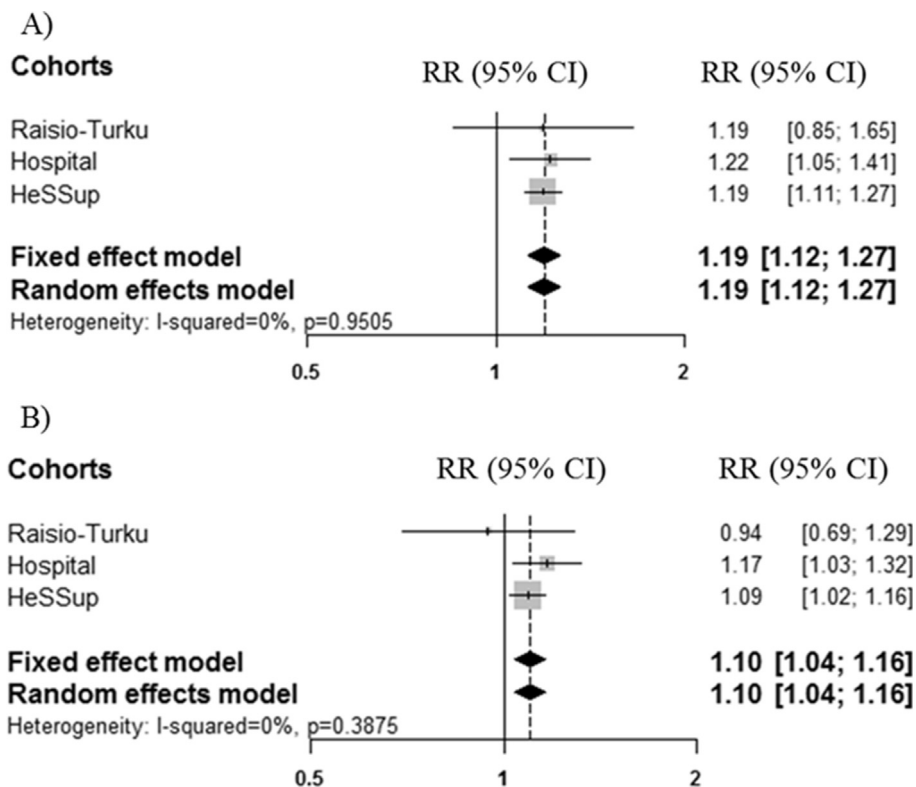
A)

Cohorts	RR (95% CI)	RR	(95% CI)
Raisio-Turku		1.19	[0.85; 1.65]
Hospital		1.22	[1.05; 1.41]
HeSSup		1.19	[1.11; 1.27]
Fixed effect model		**1.19**	**[1.12; 1.27]**
Random effects model		**1.19**	**[1.12; 1.27]**
Heterogeneity: I-squared=0%, p=0.9505			

0.5   1   2

B)

Cohorts	RR (95% CI)	RR	(95% CI)
Raisio-Turku		0.94	[0.69; 1.29]
Hospital		1.17	[1.03; 1.32]
HeSSup		1.09	[1.02; 1.16]
Fixed effect model		**1.10**	**[1.04; 1.16]**
Random effects model		**1.10**	**[1.04; 1.16]**
Heterogeneity: I-squared=0%, p=0.3875			

0.5   1   2

Fig. B.2. Social network size and smoking. Relative risks (RRs) with 95% confidence intervals (CI) are derived from repeated-measures log-binomial regression analysis using the generalized estimating equations (GEE) method. Summary estimates pooled from cohort-specific (Raisio-Turku, Hospital and HeSSup cohorts) results adjusted for age, gender, survey year, chronic conditions and education. Participants with A) 0–10 members and B) 11–20 members are compared with those with at least 21 members in their total social network.
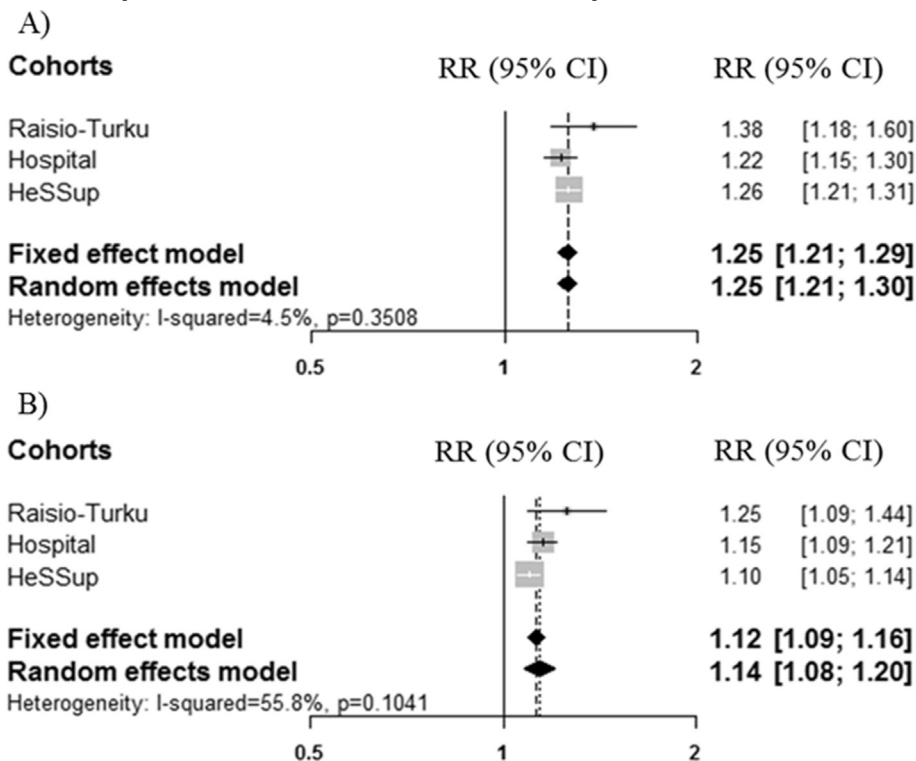
A)

Cohorts	RR (95% CI)	RR	(95% CI)
Raisio-Turku		1.38	[1.18; 1.60]
Hospital		1.22	[1.15; 1.30]
HeSSup		1.26	[1.21; 1.31]
Fixed effect model		**1.25**	**[1.21; 1.29]**
Random effects model		**1.25**	**[1.21; 1.30]**
Heterogeneity: I-squared=4.5%, p=0.3508			

0.5   1   2

B)

Cohorts	RR (95% CI)	RR	(95% CI)
Raisio-Turku		1.25	[1.09; 1.44]
Hospital		1.15	[1.09; 1.21]
HeSSup		1.10	[1.05; 1.14]
Fixed effect model		**1.12**	**[1.09; 1.16]**
Random effects model		**1.14**	**[1.08; 1.20]**
Heterogeneity: I-squared=55.8%, p=0.1041			

0.5   1   2

Fig. B.3. Social network size and low physical activity (MET hours < 14/week). Relative risks (RRs) with 95% confidence intervals (CI) are derived from repeated-measures log-binomial regression analysis using the generalized estimating equations (GEE) method. Summary estimates pooled from cohort-specific (Raisio-Turku, Hospital and HeSSup cohorts) results adjusted for age, gender, survey year, chronic conditions and education. Participants with A) 0–10 members and B) 11–20 members are compared with those with at least 21 members in their total social network.
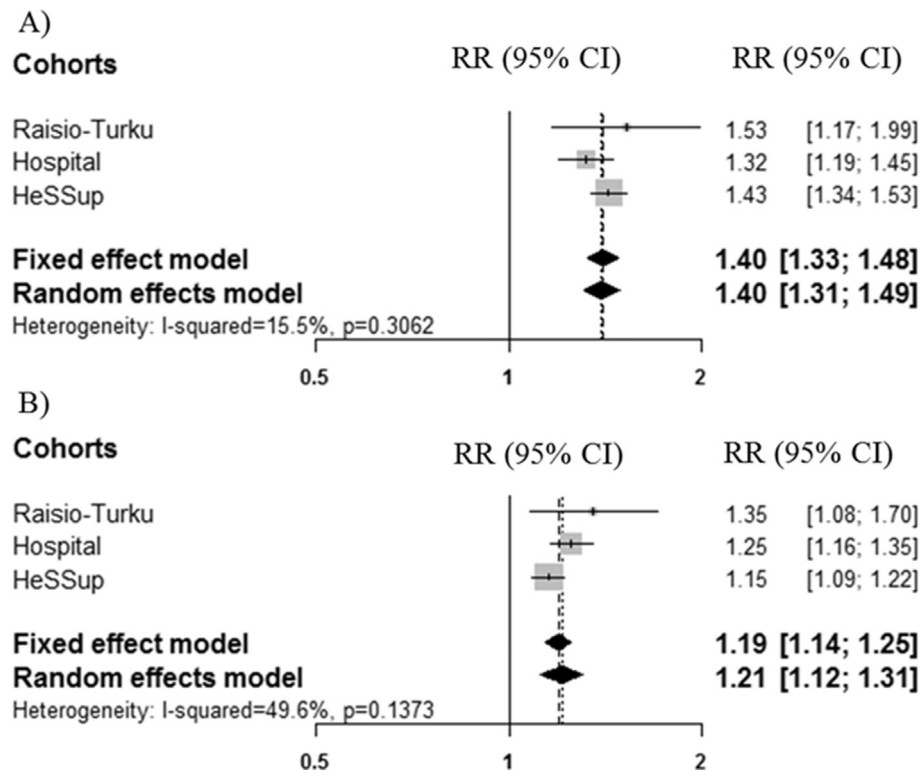
Fig. B.4. Social network size and overall unhealthy lifestyle score (total number of health risk behaviours ranging from 0 to 3). Relative risks (RRs) with 95% confidence intervals (CI) are derived from repeated-measures log-binomial regression analysis using the generalized estimating equations (GEE) method. Summary estimates pooled from cohort-specific (Raisio-Turku, Hospital and HeSSup cohorts) results adjusted for age, gender, survey year, chronic conditions and education. Participants with A) 0–10 members and B) 11–20 members are compared with those with at least 21 members in their total social network.
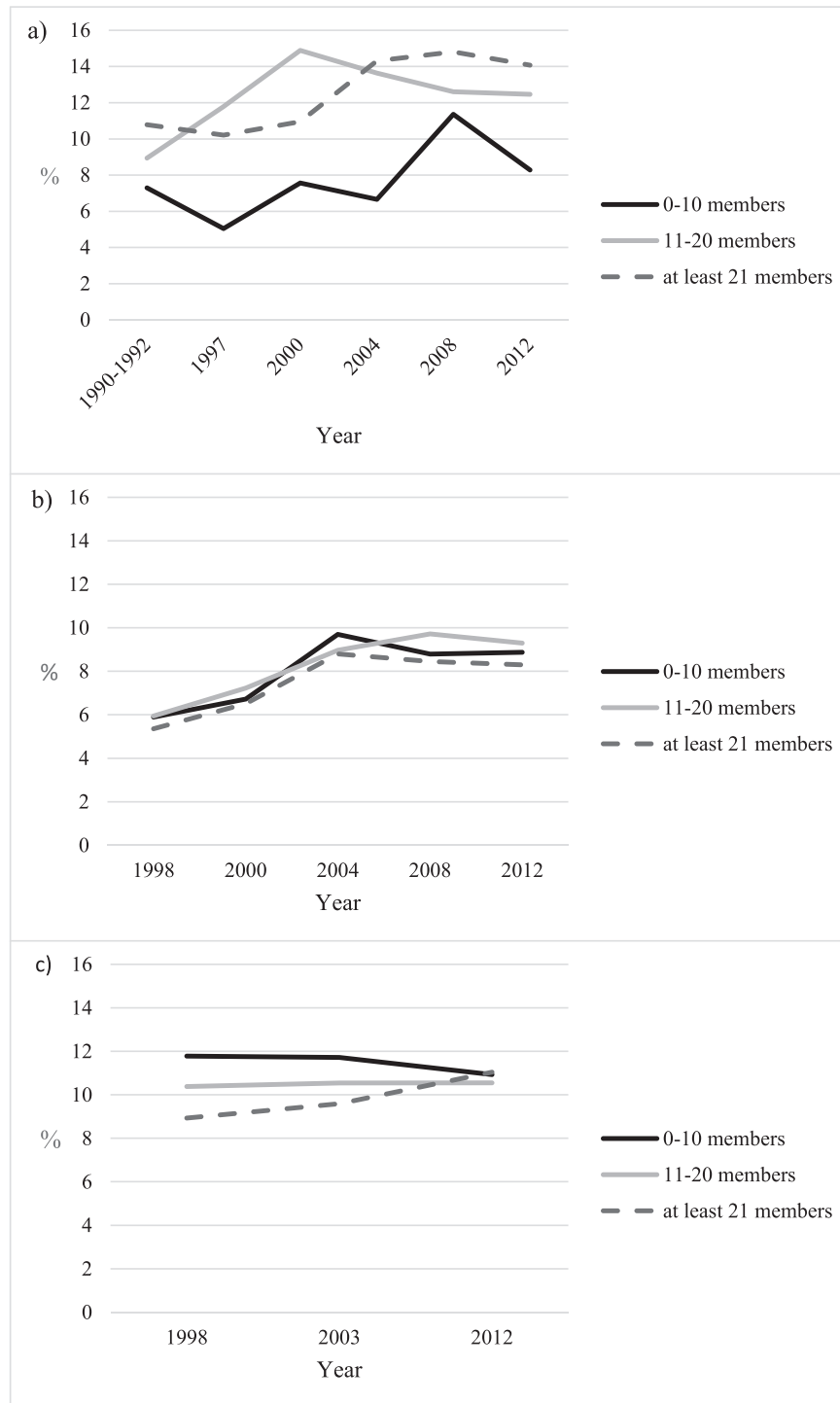
Appendix C

Fig. C.1. Estimated prevalence of heavy alcohol use according to social network size in a) Raisio-Turku cohort (n = 986), b) Hospital cohort (n = 7305), and c) HeSSup cohort (n = 20,113). Heavy alcohol use defined as weekly consumption of absolute ethanol exceeding 192 g among women and 288 g among men.
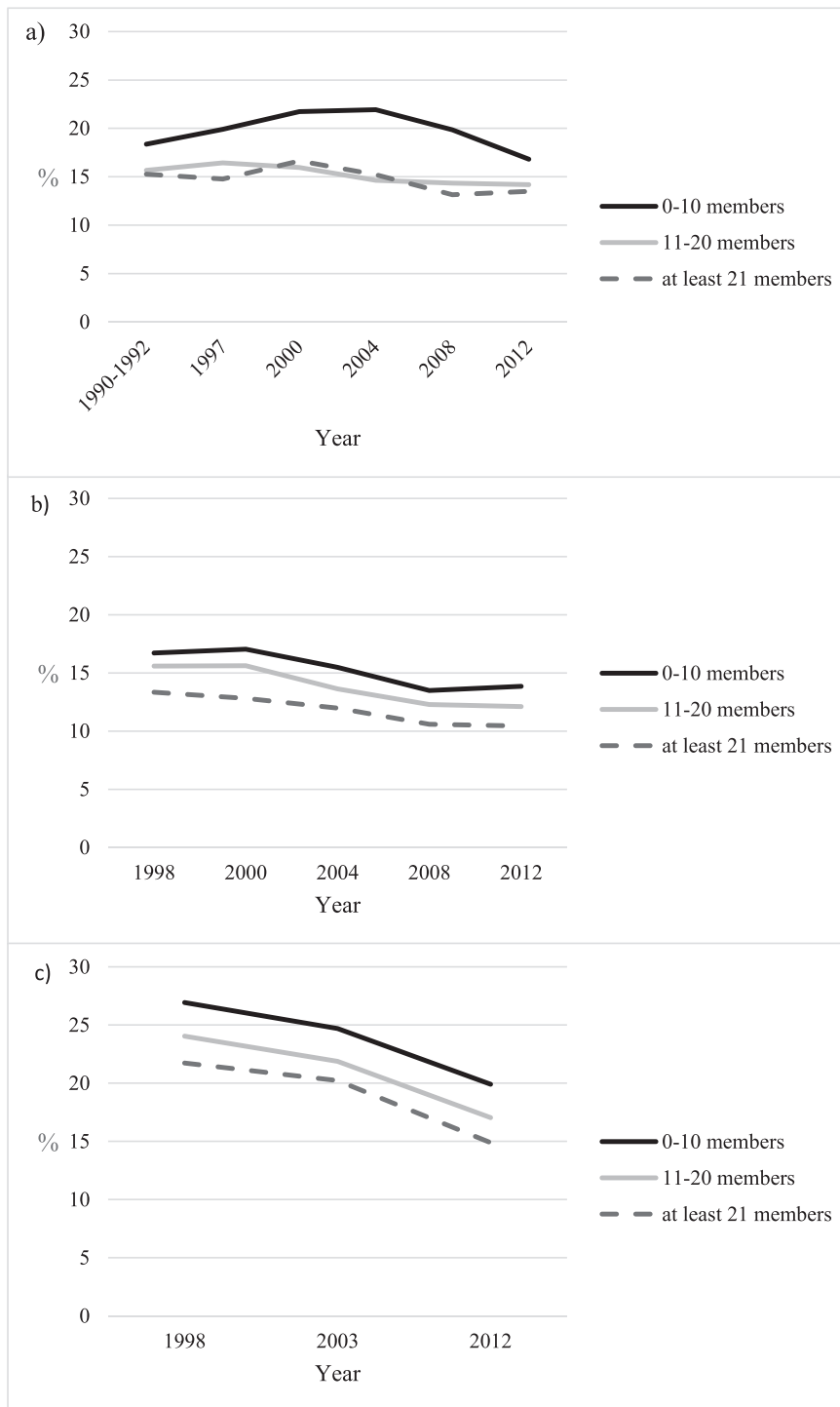
Fig. C.2. Estimated prevalence of smoking according to social network size in a) Raisio-Turku cohort (n = 986), b) Hospital cohort (n = 7303), and c) HeSSup cohort (n = 19,583).
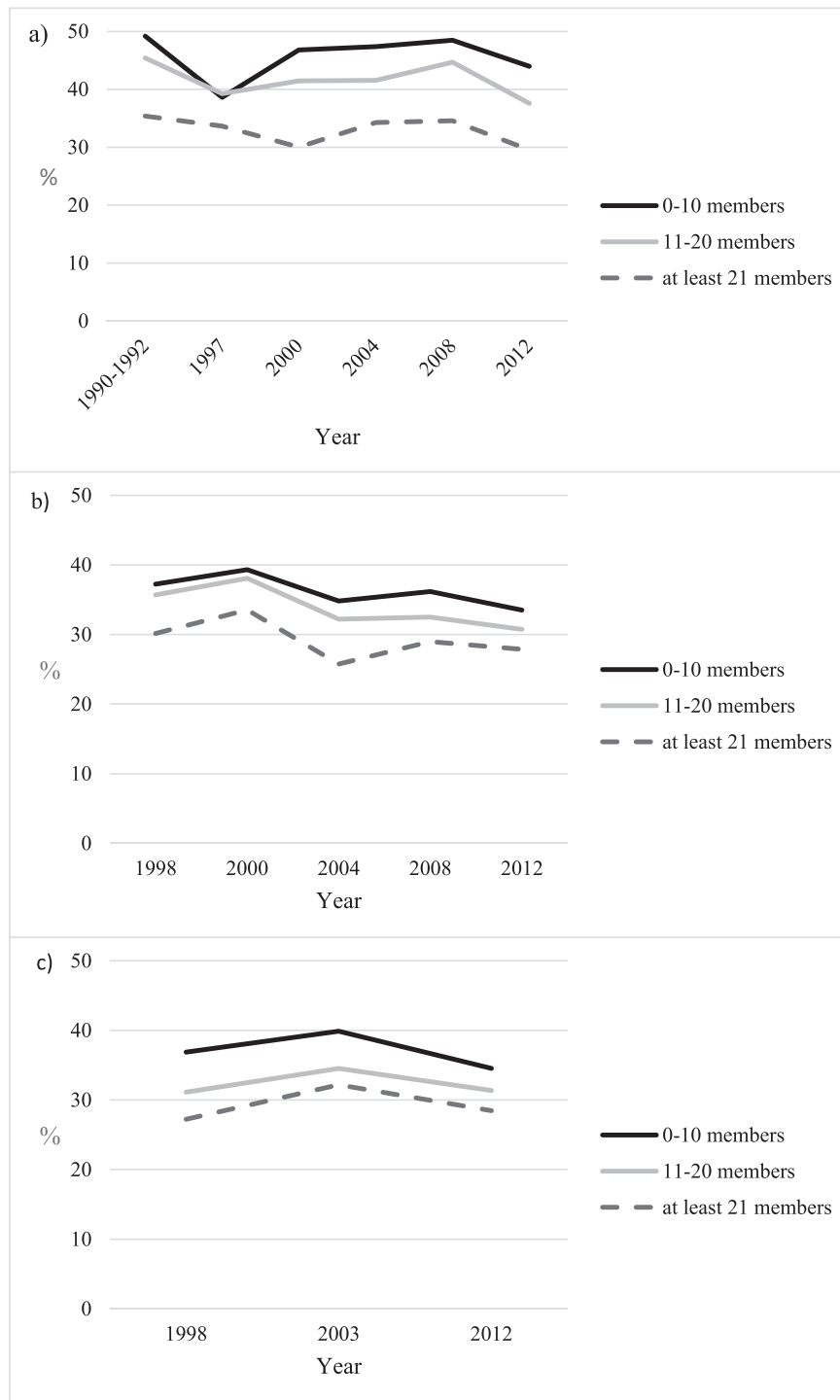
Fig. C.3. Estimated prevalence of low physical activity according to social network size in a) Raisio-Turku cohort (n = 985), b) Hospital cohort (n = 7306), and c) HeSSup cohort (n = 20,113). Low physical activity defined as metabolic equivalent (MET) hours < 14/week.
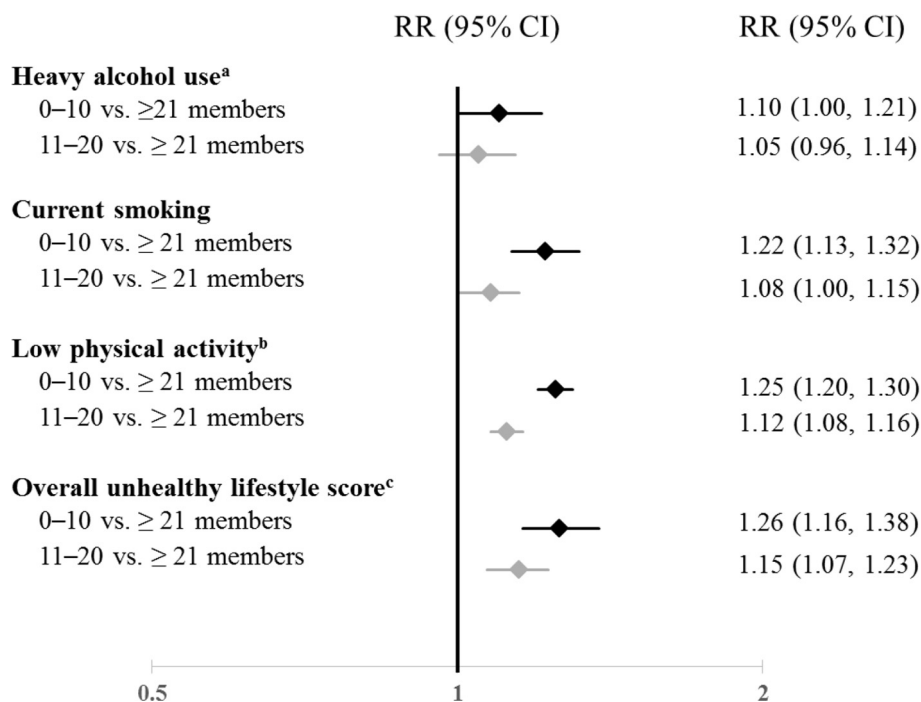
Appendix D

RR (95% CI)   **RR (95% CI)**

Heavy alcohol use[a]
0–10 vs. ≥21 members   1.10 (1.00, 1.21)
11–20 vs. ≥ 21 members   1.05 (0.96, 1.14)

Current smoking
0–10 vs. ≥ 21 members   1.22 (1.13, 1.32)
11–20 vs. ≥ 21 members   1.08 (1.00, 1.15)

Low physical activity[b]
0–10 vs. ≥ 21 members   1.25 (1.20, 1.30)
11–20 vs. ≥ 21 members   1.12 (1.08, 1.16)

Overall unhealthy lifestyle score[c]
0–10 vs. ≥ 21 members   1.26 (1.16, 1.38)
11–20 vs. ≥ 21 members   1.15 (1.07, 1.23)

0.5   1   2

Fig. D.1. Social network size and health risk behaviours among participants with maximal follow-up time (those who had answered to both the first and the last questionnaire). Relative risks (RRs) with 95% confidence intervals (CI) are derived from repeated-measures log-binomial regression analysis using the generalized estimating equations (GEE) method. Summary estimates pooled from cohort-specific (Raisio-Turku, Hospital and HeSSup cohorts) results adjusted for age, gender and survey year. Subjects with 0–10 members and 11–20 members are compared with subjects with at least 21 members in their total social network.
[a]Heavy alcohol use as weekly consumption of absolute ethanol exceeding 192 g among women and 288 g among men.
[b]Low physical activity as metabolic equivalent (MET) hours < 14/week.
[c]Cumulative odds ratio (OR) for overall unhealthy lifestyle (total number of health risk behaviours ranging from 0 to 3).

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