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Examining the role of structural and functional social network characteristics in the context of

chronic pain: An ego-centered network design

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Abstract

The well-being and functioning of individuals with chronic pain (CP) varies significantly. Social factors, such as social integration, may help explain this differential impact. Specifically, structural (network size, density) as well as functional (perceived social support, conflict) social network characteristics may play a role. However, it is not yet clear whether and how these variables are associated with each other. Objectives were to examine: (1) both social network characteristics in individuals with primary and secondary CP, (2) the association between structural network characteristics and mental distress, and functioning/participation in daily life, and (3) whether the network's functionality mediated the association between structural network characteristics, and mental distress respectively functioning/participation in daily life. Using an online ego-centered social network tool, cross-sectional data were collected from 303 individuals with CP (81.85% women). No significant differences between individuals with fibromyalgia versus secondary CP were found regarding network size and density. In contrast, ANCOVA models showed lower levels of perceived social support and higher levels of conflict in primary (vs. secondary) CP. Structural equation models showed that: (1) larger network size indirectly predicted lower mental distress via lower levels of conflict; (2) higher network density increased mental distress via the increase of conflict levels. Network size or density did not (in)directly predict functioning/participation in daily life. The findings highlight that the role of conflict, in addition to support, should not be underestimated as a mediator for mental well-being. Research on explanatory mechanisms for associations between the network's structure, functionality and well-being is warranted.

Perspective: This paper presents results on associations between structural (network size and density) and functional (social support and conflict) social network characteristics and well-being in the context of chronic pain by making use of an ego-centered network design. Results suggest an indirect association between structural social network characteristics and individuals with CP their mental well-being, but not with physical/social functioning.

Key words: social network, ego-centered, structural and functional network characteristics, mental distress, functioning

Introduction

Chronic pain (CP), defined as persistent or recurrent pain lasting at least three months, is a common and debilitating condition associated with poorer mental, physical, and social well-being [1]. However, the impact of CP varies between individuals, depending – for instance – on factors such as primary versus secondary CP diagnosis playing a role [2]. Individuals with primary CP (such as fibromyalgia), where symptoms cannot be explained by an underlying physiopathology tend to report poorer well-being compared to those with secondary CP, where pain has an identifiable biomedical etiology [3,4].

Research suggests that social factors, particularly social support, may elucidate help explain these variations in well-being [5,6]. On a broader level, social integration plays a crucial role in understanding the impact of pain on well-being [7]. This encompasses the degree to which social networks reflect a satisfactory size (number of people), multiple social roles (e.g., family, friends) and the extent to which individuals with CP and their network members engage in (reciprocal) relationships with others within the network [8–10]. Research has examined engagement in relationships by assessing the network's density (i.e., proportion of interrelationships) and connectivity [11]. Yet, it remains unclear whether individuals with primary CP differ from those with secondary CP in terms of social integration. Furthermore, individuals with primary CP often report higher perceived stigmatization than individuals with secondary CP [3,12], potentially resulting in lower social integration.

Examining structural aspects of personal social networks, such as network size (i.e., number of network members) and density, offers valuable insights into the social integration of individuals with CP. Direct associations between structural aspects of social networks and mortality [13,14] or well-being [15–17] are quite well-established in the general population. For instance, higher density showed an association with lower loneliness [18]. Furthermore, high density often entails rapid information sharing between network members [19], which may benefit the health management.

Possible associations between the network's structure and health highlight the importance of disentangling the mechanisms behind these associations. Berkman and colleagues' [20] conceptual model

of how social networks impact health, emphasizes social support (e.g., instrumental, emotional), a functional network characteristic, as one of the main mediating pathways. Abundant research has demonstrated the positive influence of perceived social support (i.e., perceived availability of support when needed) on pain-related adjustment and well-being among individuals with CP (e.g., [21,22]). Also relationship-specific support may buffer the impact of pain on emotional distress [23]. Conversely, conflicts within the network, arising from increased number of interactions [24–26], may negatively affect well-being. However, the role of conflict in the well-being of individuals with CP is understudied. One study found that conflict with network members was associated with higher sensory (intensity) and affective (unpleasantness) pain [27]. Nevertheless, studies examining the associations between structural network characteristics (i.e., network size and density), the network's functionality (i.e., support and conflict), and well-being outcomes in individuals with CP are scarce.

Using an ego-centered network design, in which individuals with CP report about their personal social network, we descriptively mapped out the network's structure, functionality, and social roles. Subsequently, we hypothesized that levels of structural (network size and density) and functional network characteristics (perceived social support and conflict) differed between individuals with fibromyalgia and secondary CP. Further, we hypothesized that structural network characteristics (greater network size and density) would be related to (lower) mental distress and (higher) functioning/participation in daily life in all individuals with CP. Lastly, we hypothesized that the network's functionality (higher perceived social support and lower conflict) mediated the association between structural network characteristics (greater network size and density), and (lower) mental distress and (higher) functioning/participation in daily life in all individuals with CP.

Methods

Participants

The study was carried out between July 2019 and June 2020. Participants were recruited through the Flemish Pain League (FPL), the League for Rheumatoid Arthritis (LRA), and the Flemish League for Fibromyalgia Patients (FLFP), three patient organizations for people with CP, rheumatoid arthritis,

and fibromyalgia, respectively. All members (N= 1983) of the FPL and the LRA (N= 319) were sent an invitation letter to participate in a study regarding social networks of individuals with CP and the association with patients' well-being. Members of the LRA were also informed via Facebook and via their personal magazine *RAAM*. Members of the FLFP (N= 481) were reached via an announcement on their Facebook page and via their personal magazine *Fibrozine*. Initially, 297 members of the FPL, 91 of the LRA, and 94 of the FLFP agreed to be informed about the study and were contacted by phone by a member of the research team. Further information about the study was provided and the following inclusion criteria were checked: (1) having CP (i.e., persistent or recurrent pain for at least three months), (2) speaking Dutch fluently, and (3) being older than 18 years. An exclusion criterion was having another major health condition, such as cancer. Fifteen people could not be reached. Eventually, 454 members met the inclusion criteria and agreed to participate in the study. Reasons for not agreeing to take part in the study (N= 12) were experiencing a hard time because of personal or family problems, undergoing surgery, not being able to concentrate for half an hour or absence of pain during the last three months. Participants without a computer or with insufficient computer knowledge (N=37) were offered a home visit to fill out the questionnaires. Home visits were scheduled at the end of data collection, but due to the COVID-19 pandemic only eight visits could be carried out. See flow diagram for an overview (Figure 1). Informed consent was applied. The study was approved by the ethical committee of the Faculty of Psychology and Educational Sciences of Ghent University (2018/01/Liesbet Goubert).

Procedure

Upon completion of the phone call, participants received two weblinks via e-mail, one to fill out the social network survey, and another for the sociodemographic and well-being questionnaires. Each participant also received a personal token, which gave access to the survey. The social network survey was administered via an online social network tool, i.e. Graphical Ego-centered Network Survey Interface [28]. The sociodemographic and well-being questionnaires were administered through LimeSurvey, a protected web-based survey tool.

Measurements

Sociodemographic characteristics

Sociodemographic information regarding gender, age, education, and work status was collected at the beginning of the survey using self-report.

Pain characteristics

First the *type of diagnosis* was questioned with an open-ended question. Based upon the IASP classification of chronic pain for ICD-11 [29], we divided the participants in three groups. The primary CP group consisted of participants diagnosed with fibromyalgia (N= 113). As such, we refer to this group as "individuals with fibromyalgia". The secondary CP group consisted of participants with rheumatoid arthritis, arthrosis, Ehlers Danlos syndrome, failed back injury, and other conditions with clear pathophysiology (N= 130). The third group consisted of people for whom it was unclear whether it was primary or secondary CP (N= 60). Because we do not know what kind of conditions the latter group entails, we opted to not use this group in the analyses regarding the comparison of network characteristics.

The Dutch *Graded Chronic Pain Scale* (GCPS) [30] was included to assess pain intensity and disability. Three items of the GCPS assess current, worst, and average experienced pain intensity during the past six months, and were rated on an 11-point scale from 0 (= "No pain") to 10 (= "Worst imaginable pain"). Pain disability was assessed by four items of the GCPS, i.e., the reported days in which the person was prevented from carrying out his/her usual activities (work, school, or household duties) during the past six months and three items measuring whether the participant was prevented from carrying out daily activities, recreational/social/familial activities, and work during the past six months. These items were answered on an 11-point scale from 0 (= "No difficulties at all") to 10 (= "Impossible to execute activities"). Mean pain intensity was calculated by averaging the items measuring worst and average pain experienced during the past 6 months. The disability score was a combined score related to the number of disability days (<7 d=0 points, ≥7 and <15=1 point, ≥15 and <31=2 points, ≥31=3 points) and points related to 3 items that measure pain interference (score <30=0 points, score ≥30 and <50=1 point, score ≥50 and <70=2 points, score >70=3 points). In the current study, Cronbach's alpha

was .82 for mean pain intensity and .90 for the disability score. In line with Von Korff and colleagues (1992), participants were classified into 5 grades based on the scores for mean pain intensity and disability: grade 0 'no pain', grade 1 'low intensity and low disability' (disability points <3 and pain intensity <50), grade 2 'high intensity and low disability' (disability points <3 and pain intensity ≥50) and, grade 3 'moderate disability, regardless of pain intensity' (disability points = 3 or 4), grade 4 'high disability, regardless of pain intensity' (disability points = 4 or 5).

Social network

Structure of the network. In the current study, we focused on ego-centered social networks, which means that individuals with CP (i.e., egos) report on their network members (i.e., alters). First, participants were asked to name all the important adults (i.e., alters) in their life. They could name up to 80 people (i.e., network size with a maximum of 80 alters). In social network research this is referred to as a name generator [31]. Further, participants were asked to indicate to which social role the alters belong (i.e., partner, parent, children, family-in-law, friends, colleagues, healthcare professionals, people from organizations e.g., sport club, acquaintance, other). Subsequently, participants were asked to identify the 10 most important alters, about whom they answered multiple questions (i.e., name interpreter questions) [31]. The list was reduced to 10 alters (i.e., *network size* with a maximum of 10 alters) to reduce respondent burden, guaranteeing better quality of the data [32]. The subsequent part of the social network questionnaire only referred to these 10 (or less) important alters. Participants specified the gender and education level of each named alter. Participants also registered whether the alters have direct contact with each other (i.e., name interrelator question), which enables us to calculate the network's density, i.e., the interconnectivity between the alters. *Network density* was calculated by dividing the actual number of connections in the network by the number of possible connections. Afterwards, we normalized this score resulting in a number between 0 and 1. Higher scores represented denser networks.

Functionality of the network. A selection of questions from the Quality of Relationships Inventory [33] (QRI) was included in the social network survey in order to assess the network's functionality. The QRI assesses relation-specific self-reports of perceived social support, conflict, and

depth of relationships. For the current study, we only used the perceived social support and conflict items. These items were chosen based on their factor loadings on the three constructs [34] and meaningfulness for our target group. Perceived social support was assessed via the following four items: "To what extent can you count on this person for help with a problem?", "To what extent can you count on this person to listen to you when you are very angry at someone else?", "To what extent can you really count on this person to distract you from your worries when you feel under stress?", "To what extent can you turn to this person for advice about problems?". These items were answered on a scale ranging from 1 (= "Not at all") to 5 (= "A lot"). A total support score for each alter was calculated by summing the scores on these items; the score ranged from 1 to 20 and higher scores reflected higher perceived social support. Conflict was measured via three items: "How often do you have to work hard to avoid conflict with this person?", "How much does this person make you feel guilty?", "How often does this person make you feel angry?". Conflict items were rated on a scale from 1 (= "Never") to 5 (= "Always"). A total conflict score for each alter was calculated by summing the scores on these items; the score ranged from 1 to 15 and higher scores reflected higher conflict. Perceived social support from the self-registered network was calculated by summing the alters' scores on the support items and dividing this by the number of alters. The same procedure was applied for conflict.

Mental distress and functioning/participation in daily life

The 8-item short-forms of the *Patient-Reported Outcomes Information System* [35] (PROMIS®) were used to assess depression, anxiety, anger, ability to participate in social roles and activities, physical functioning and pain interference: PROMIS item bank v1.0 Emotional Distress-Depression – Short Form 8a (e.g., "I felt worthless"); PROMIS item bank v1.0 Emotional Distress-Anxiety – Short Form 8a (e.g., "It is very hard for me to focus on anything other than my anxiety"); PROMIS item bank v1.1 Anger – Short Form 5a (e.g., "I felt angry"); PROMIS item bank v2.0 Ability to Participate in Social Roles and Activities – Short Form 8a (e.g., "I have a hard time doing all my regular leisure activities with others."); PROMIS item bank v1.1 Pain Interference – Short Form 8a (e.g., "To what extent did the pain interfere with your daily activities?"): PROMIS v1.2 item bank Physical functioning – Short Form 8b (e.g., "Are you able to run errands and shop?")

All PROMIS items were answered about the past 7 days on a 5-point scale from 0 (= "Never") to 4 (= "Always"). In the current study, Cronbach's alpha was .95 for depression, .95 for anxiety, .91 for anger, .95 for ability to participate in social roles and activities, .94 for pain interference, .92 for physical functioning.

Analytic strategy

Analyses were conducted in R version 4.1.3. Significance levels were set at .05. First, Pearson correlations and Spearman's rho were used to explore the associations between the sociodemographic characteristics (i.e., gender, age, and education) and all other variables. AN(C)OVA models and one t-test were used to compare social network characteristics between individuals with primary and secondary CP. The type of diagnosis included two groups: fibromyalgia and secondary CP. We will control for sociodemographic characteristics significantly related to the outcome variables (in a second step). Next, Structural Equation Models (SEM) were used to test the mediation model utilizing the Lavaan package by means of maximum likelihood. These SEM models were estimated in the total sample. We controlled for sociodemographic variables significantly correlating with outcome variables. Bootstrapping was applied with 1000 repetitions. The following fit indices were used in line with recommendations of Kline [36] and Hooper et al. [37]: χ^2-square (χ^2, p-value > .05), Root Mean Square Error of Approximation (RMSEA, <.08), Comparative Fit Index (CFI, >= .90), and Standardized Root-Mean-square Residuals (SRMR, <.08). As sample size increases X^2 tests are often significant (N>200), indicating a misfit of the model. Subsequently, χ^2 tests will be reported, but interpreted with caution. Standardized estimates are reported. Bootstrapping was applied with 1000 repetitions. In these analyses, the indirect effect (ab) is considered significant if the bootstrap confidence interval does not include zero. Overall, mediation is assumed if 1) the total effect is significant and 2) the indirect effect a*b is also significant. However, if the a*b effect is significant, but the total effect is not, it is assumed as an indirect effect.

Results

Descriptive results

In the end, 335 participants completed the survey. One hundred and thirteen people who received the weblink did not or only partially completed the survey. For some of them, completing the survey was too exhausting, but most did not reply to the reminder e-mails. Further, data from three participants were excluded because they had a diagnosis of cancer. Data of 29 participants were incomplete or inconsistent and therefore not included in the analyses. The final sample for the current study consisted of 303 individuals with CP. Table 1 shows the sociodemographic and pain characteristics of the sample. No missing values were present in the participants' responses as the software made them complete all questions. Most of the sample were Belgian women (81.85%), aged between 21 and 81. About two thirds were married or cohabiting (67.66%) and approximately 26% were single. Almost half of the sample had a partial or full allowance (47.19%), which is a monthly payment by the health insurance or government. Most participants followed higher vocational education or had a bachelor's degree (67.33%). About 60% were classified in pain grade IV, 22% in grade III, 11% in grade II, 6% in grade I and none in grade 0. This means that the majority was highly disabled due to the pain.

Results of the bidirectional correlations between sociodemographic characteristics, mediation variables, and outcome variables are shown in Table 2. As gender was related to network size, we will control for gender in the model for research question 1 with network size as dependent variable (in a second step). As gender and age were related to conflict, we controlled for gender and age in the model for research question 1 with conflict as dependent variable (in a second step). Further, we controlled for age and education in the analyses regarding the mediation model as age was significantly related to almost all outcome variables and education to half of them.

Perceived social isolation (PROMIS®) was not correlated ($r= -.05$, $p= .409$) with network size with a maximum of 80 alters, but was significantly correlated with network size with a maximum of 10 alters ($r= .23$, $p< .01$). Perceived social isolation was not significantly correlated to network density ($r= -.11$, $p= .061$). Additionally, questions about support and conflict were only answered for the 10 most important alters. Therefore, we used network size with a maximum of 10 alters in the subsequent analyses.

Most of the participants named between 0 and 20 important people. In the supplementary files, figure 1 shows the histogram regarding the important alters with a maximum of 80 people. Most participants (72.6%) had a partner. Parents were not often named (227 out of 606 possible parents), but this could be related to the age of the participants. Noteworthy, 533 healthcare providers were mentioned to be part of individuals with CP's networks in total. These results can be found in the supplementary files, including a table showing the distribution of the social roles with the important alters (with a maximum of 80 people). One-hundred and fifteen participants (38%) named less than 10 important persons, see figure 2 in the supplementary files which shows the histogram regarding the important alters with a maximum of 10 people.

Table 3 (presenting the means, standard deviations, and Pearson intercorrelations for each of the continuous variables) shows that network size with a maximum of 80 alters was not correlated with density, perceived social support, conflict, or with well-being/functioning outcome variables. Network size with a maximum of 10 alters was correlated negatively with network density, conflict, depressive symptoms, and anger. Network density was related to support and conflict. Perceived social support was related to conflict, depressive symptoms, anxiety, pain interference, ability to participate in social roles and activities. Conflict was related to depressive symptoms, anxiety, and anger.

(1) Do structural (network size, density) and functional (perceived support, conflict) network characteristics differ between individuals with fibromyalgia versus secondary CP?

Table 4 shows the results of the AN(C)OVAs and t-test with CP diagnosis as a between-subjects factor (i.e., primary vs. secondary CP) and the structural or functional network characteristic as outcome variables. Results showed no significant differences between the two groups regarding *network size* ($F_{(1, 240)} = 0.210$, p= .647) and *density* ($F_{(1, 240)} = 0.972$, p= .325). In contrast, significant differences could be observed in the functional network characteristics. The group with secondary CP reported

higher levels of perceived *social support* ($F_{(1, 240)}$= 6.106 p= .014) and lower levels of *conflict* ($F_{(1, 240)}$= 6.070; p= .014) in their network than the group with fibromyalgia, though effect sizes were small.

After including gender and age as control variables, the difference for perceived social support remained significant ($F_{(1, 238)}$= 8.140, p= .005, ηp^2 =0.033), but not for conflict ($F_{(1, 238)}$= 2.613, p=.107, ηp^2 =0.011).

(2) Are structural network characteristics (network size and density) related to mental distress and functioning/participation in daily life?

Two SEM models were estimated, one with network size as predictor and one with density as predictor. Two latent variables were included as outcome variables in both models. The latent variable "mental distress" was defined by the sum scores of the PROMIS subscales depressive symptoms, anxiety, and anger. Higher scores represent more distress. The latent variable "functioning/participation in daily life" was defined by the PROMIS subscales pain interference, ability to participate in social roles and activities, and physical functioning. Higher scores represent better functioning. Total scores on perceived support and conflict were included as mediators. Age and education were included as control variables. The measurement model (i.e., associations between latent variables and indicators) was tested using confirmatory factor analysis (CFA). CFA showed that the measurement model had a good fit , $\chi2_{(8)}$= 41.826 (p< .001), RSMEA= 0.118 (90% CI= 0.084 - 0.155), CFI= 0.970, SRMR= 0.068. Only the RMSEA was a bit too high, but this could be related to the low number of indicators [38]. Standardized factor loadings on the latent variable mental distress were .892 for depressive symptoms, .861 for anxiety, and .792 for anger. Factor loadings on the latent variable functioning/participation in daily life were .658 for physical functioning, .852 for ability to participate in social roles and activities, and -.969 for pain interference.

Regarding **network size**, results revealed that the hypothesized structural model (i.e., associations between predictor, control and outcome variables) had an excellent fit, $\chi2_{(48)}$= 99.880 (p< .001), RSMEA= 0.060 (90% CI= 0.043 - 0.076), CFI= 0.959, SRMR= 0.038 (see Figure 2). More

specifically, network size was neither directly related to mental distress, nor to functioning/participation in daily life. The total effect of network size on mental distress was significant (B= -0.435, p= .019), but the total effect on functioning/participation in daily life was not significant (B= 0.082, p= .483).

Regarding **network density**, the hypothesized structural model had an excellent fit, $\chi 2$ (48)= 96.804 (p< .001), RSMEA= 0.058 (90% CI= 0.041 - 0.077), CFI= 0.961, SRMR= 0.037 (see Figure 3). Density was neither directly related to mental distress, nor to functioning/participation in daily life (c'= 2.466, p= .461). The total effects of network density on mental distress (B= 6.029, p= .175) and on functioning/participation in daily life (B= 3.086, p= .304) were not significant.

(3) Does perceived social support or conflict mediate the association between structural network characteristics (network size and density) and mental distress and functioning/participation in daily life?

Network size as predictor. Results of the SEM model with network size as predictor are shown in Figure 2. Perceived social support did not mediate the association between network size and, respectively, mental distress ($a1_m * b1_m = 0.013$, p= .665), and functioning/participation in daily life ($a1_{funct/part} * b1_{funct/part} = -0.009$, p= .682). Higher levels of perceived support were related to lower levels of mental distress and higher levels of functioning/participation in daily life.

The indirect effect of network size and conflict on mental distress was significant ($a2_m * b2_m = -0.164$, p= .035). The confidence interval for the bootstrapped indirect effect was [-0.344 ; -0.036]. As the direct effect is not significant, there is only an association between density and mental distress via conflict. Larger networks were associated with lower levels of conflict. Lower levels of conflict were related to lower levels of mental distress.

Conflict did not mediate the association between network size and functioning/participation in daily life ($a2_{funct/part} * b2_{funct/part} = 0.012$, p= .774), nor did it predict functioning/participation in daily life.

Network density as predictor. Results of the SEM model with network density as predictor are shown in Figure 3. Perceived social support did not mediate the association between network density and mental distress ($a1_m*b1_m$ = -1.499, p= .162). Individuals with CP with denser networks reported higher levels of perceived social support, but perceived social support was not related to mental distress. Social support did also not mediate the association between network density and functioning/participation in daily life ($a1_{funct/part}*b1_{funct/part}$ = 1.175, p= .156) and was also not significantly related to functioning/participation in daily life.

The indirect effect of network density and conflict on mental distress was significant ($a1_{funct/part}*b1_{funct/part}$= 3.666, p= .018). The confidence interval for the bootstrapped indirect effect was [1.156; 7.070]. As the direct effect was not significant, there was only an association between density and mental distress via conflict. Denser networks were associated with higher levels of conflict, which in turn were related to higher levels of mental distress.

Conflict did not mediate the association between density and functioning/participation in daily life ($a2_{funct/part}*b2_{funct/part}$ = -0.555, p= .434) and conflict was not related to functioning/participation in daily life.

Discussion

This study explored the social networks of individuals with CP, consisting of self-nominated important people and the association with CP outcomes. Findings indicate that individuals with fibromyalgia and secondary CP describe similar network structures in terms of density and size. However, results showed significantly lower levels of perceived social support in fibromyalgia (vs. secondary) CP, when controlling for age. Differences in perceived conflict did not remain significant after controlling for gender and age. Second, structural network characteristics were neither directly related to mental distress, nor to functioning/participation in daily life. However, and finally, we found evidence for the indirect effects of structural network characteristics upon mental distress (but not functioning/participation) through perceived conflict.

The structure and functionality of personal social networks may differ between patients with fibromyalgia versus secondary CP (e.g. [5,6]). Our findings partially supported this. Although we did not find differences in network structure between the two groups, individuals with primary CP did report less perceived availability of support and more conflict (parameters for network functionality) with network members as compared to individuals with secondary CP. This difference in network functionality is consistent with a previous study by Faucett [39], yet other research did not find a difference in perceived support between individuals with primary and secondary CP [40]. In our study, the difference in perceived support remained significant after considering individuals with CP their gender and age, unlike conflict. Overall, networks of individuals with fibromyalgia are less facilitating for the well-being as they are at a higher risk for lower levels of perceived social support. The size and density of networks did not differ between fibromyalgia and secondary CP, suggesting that these simple structural social network characteristics do not play a significant role in differential well-being and functioning.

In this study, network size indirectly influenced mental distress through perceived conflict, which is consistent with prior research on individuals with acquired brain injury, where no direct association between network size and mental health was observed [41]. The current findings did not show that network size was (indirectly) related to functioning/participation in daily life, contrasting a study observing that network size predicted physical and cognitive health over time in the general population [42]. Further, network density was not directly related to mental distress, nor to functioning/participation in daily life. However, it was indirectly related to mental distress via perceived conflict. This finding contradicts a study in the general population in which was found that network density was directly related to life satisfaction and happiness [43]. It is widely acknowledged that social integration is favorable for individual's well-being. Structural sociological theories state that social integration is characterized by higher network density [44], but findings in this regard turned out to be inconsistent. For instance, one study in a convenience sample found that the association between network density and well-being depends on self-affirming (self-verification) social environments [45]. However, caution is needed when comparing results between the general population and individuals with CP, particularly regarding social networks.

No indirect effects via perceived social support were found as well as no mediating effects regarding functioning/participation in daily life as an outcome. The latter indicates that the structure and functionality of social networks in individuals with CP may be more important in explaining mental well-being rather than physical/social well-being. The lack of indirect effect through perceived social support contrasts a previous study that found that social engagement (i.e., time spent in social activities) and emotional support mediated the relationship between network structure (i.e., network size and frequency of contact) and affect in elderly [46]. However, this could be related to the latter study measuring received social support while the current study measured perceived availability of support. Perceived support is related to individual characteristics, such as attachment style [47], and may be less influenced by the network's structure. Specifically, perceived social support was related to mental distress in the model with network size as predictor, but not in the one with density as a predictor. This is probably related to the fact that conflict is explaining a much greater variance in mental distress in the model with density as predictor. Denser networks with more interactions between people have the opportunity to be associated with higher levels of conflict. Negative social interactions usually have a stronger influence on mental well-being than positive ones. This is in line with previous studies on interconnectivity between perceived social support and conflict. For instance, two studies - one on prenatal depression [48] and another on female service members [49] - indicated that social support and conflict were associated with depressive symptoms and mental distress, respectively. However, conflict emerged as the strongest predictor in both studies.

The current study's mediation models enable us to focus specifically on associations between structural and functional network characteristics. Denser networks were related to higher levels of perceived social support. Another study in individuals with CP also found that higher density was related to higher reported quality of social support [50]. In the current study, network size was not related to perceived social support. This finding is in line with a study in participants with acquired brain injury and healthy controls [41]. It seems that it is not the quantity of relationships that matters for perceived availability of support in individuals with CP, but the number of interrelationships between the network

members (cfr. density). Other pain research indicated that the amount of time spent with family, and the quality of family relationships, may be critical [51]. This supports the idea that sharing information between people surrounding individuals with CP, is important for the well-being of individuals with CP. However, in the current study larger networks were associated with lower levels of conflict, whereas denser networks were linked to higher levels of conflict. Achieving a balance in interconnectedness is crucial to mitigate the adverse impact of conflict. Having enough network members allows for meaningful interactions and support, but an excessive number of interactions is associated with higher conflict levels. Heider's balance theory [52] describes that low-density networks may be related to higher support, while high-density networks could be related to higher conflict and distress. The latter part corresponds with the current study's findings. However, Stokes [53] observed that the advantage of low-density networks may be limited to particular populations, namely people who are in the midst of a transition (for instance recently divorced). This could explain why this study in a CP population found the opposite, which is that denser networks were related to higher perceived support. Nevertheless, Hirsh found that in college students denser networks were related to higher support, but perceived satisfaction with support was lower than in low-dense networks [54]. Further investigation into these dynamics is warranted.

In line with previous research [55], it was found that higher levels of perceived social support were related to lower levels of mental distress and higher levels of functioning/participation in daily life in the model with network size as predictor. This was not the case in the model with network density as predictor. Also the lack of indirect effect through social support contrasts with a previous study that found that social engagement (i.e., time spent in social activities) and emotional support mediated the relationship between network structure (i.e., network size and frequency of contact) and affect in elderly. The role of conflict has not been studied thoroughly before. Interestingly, it was observed that conflict was positively related to mental distress in both models. A previous study examining the general population's personal social networks found that relationships with both support and conflict are associated with intermediate stress levels [56]. These results emphasize the need to focus on support as well as conflict when aiming to elucidate the functions of individuals with CP their social networks.

The current study has some limitations. First, the study did not capture negative connections or network members that individuals with CP chose not to connect with, which could provide crucial information regarding support, conflict, and well-being [20]. Second, the name generator (i.e., "Name important people in your life") used in this study may have introduced bias in the nominated network members [57]. We argue that the variable with a maximum of 80 alters was less valid than the one with maximum 10 because participants were naming as many people as possible in the first question. The variable with a maximum of 10 alters is probably related to really important people in their life. Future studies could consider using alternative name generators, such as "Name people whom you feel closest too", which is also an affective and thus more subjective generator, or "Name people whom you see at least monthly", which is a more objective generator [57]. Third, the survey design might have influenced the results by participants nominating many people due to social desirability, potentially confounding network size and density levels. Fourth, the data are cross-sectional, so the direction of the studied associations cannot be disentangled. It is also possible that people with lower levels of well-being and functioning also report lower perceived support and conflict (maybe due to confirmation bias), which may in turn be related to alteration in the social network's structure. Fifth, a possible selection bias due to the recruitment method should also be considered. Members of patient organizations may have more elaborate and denser social networks than other individuals with CP. Additionally, people who responded to invitation letters may differ in terms of social integration from people who did not respond, so this may also contribute to a possible bias. Sixth, as it was difficult to predict effect sizes a priori, we did not perform a sample size calculation before the start of the study. We relied on a convenience sample that resulted in an appropriate sample size considering other studies in the field (e.g. [58,59]). Seventh, no data was collected on race or ethnicity. Lastly, the primary CP group only consists of people with fibromyalgia and/or chronic fatigue syndrome, so we should be cautious about generalization to other primary CP conditions.

The current study holds clinical implications, underscoring the significance of the commitment of the personal social network so that patients have sufficient network members to interact with. This is related to the perception of available support and conflict, which may, in turn, be related to individuals

with CP their well-being. This may be of particular importance for people having fibromyalgia. Isolated individuals with CP might have greater difficulty accessing healthcare services, again leading to poorer well-being [60]. Increased awareness for isolated individuals with CP is necessary as they may need an extra hand to manage their pain and well-being. Support groups and self-help organizations have been identified as playing a vital role [61], but further examination is needed to determine their implementation in clinical settings [62]. Lastly, in this study, individuals with CP nominated many healthcare providers. Direct communication between providers and other network members may be a crucial feature of stable and favorable networks.

Future studies should also examine the larger macro-social context in which networks of individuals with CP form, sustain, and develop [20]. A multi-informant perspective (i.e., different members of the same network responding about the relationships with each other) on individuals with CP their networks would be highly informative because in this way reciprocity, i.e., balance between giving and receiving in relationships, can be examined which is important for beneficial social integration. [8,9,63]. Finally, studies focusing on connections between informal (e.g., partner, family, friends) and formal (e.g., healthcare professionals) network members may be crucial to understand CP management. For instance, examining whether well-connected networks including connections between informal and formal members are associated with higher levels of well-being/functioning.

In conclusion, our results suggest an indirect association between structural (network size and density) social network characteristics and individuals with CP their mental well-being, but not with physical/social functioning. The findings highlight that the role of conflict, besides support, cannot be underestimated as a mediator for mental well-being.

Figure legends

Figure 1. Flow diagram of recruitment and participation in the study.

Figure 2. Results of structural equation model related to mediation model with network size as predictor, perceived support and conflict as mediators and mental distress and functioning/participation in daily life as outcome latent variables. Estimates and p-value are reported.

Figure 3. Results of structural equation model related to mediation model with network density as predictor, perceived support and conflict as mediators and mental distress and functioning/participation in daily life as outcome latent variables. Estimates and p-value are reported.

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Table 1. *Sociodemographic and pain characteristics*

	Fibromyalgia (N=137)	Secondary CP (N=130)	Unclear diagnosis (N=60)
	M (SD) or N(%)	M (SD) or N(%)	M (SD) or N(%)
Gender			
Women	123 (89.8)	108 (83.1)	35 (58.3)
Men	14 (10.2)	22 (6.9)	25 (41.7)
Other gender identities	0	0	0
Age (years)	50 (12)	56 (12)	56 (11)
Nationality			
Belgium	131 (95.6)	123 (94.6)	59 (98.3)
Other	6 (4.4)	7 (5.4)	1 (1.7)
Marital status			
Married or cohabiting	95 (69.3)	95 (73.1)	36 (60)
In a relationship	10 (7.3)	3 (2.3)	6 (10)
Single	32 (23.4)	32 (24.6)	18 (30)
Work status			
Student	0	1 (0.8)	0
Working	23 (16.8)	33 (25.4)	8 (13.3)
Housewife/-man	4 (2.9)	4 (3.1)	0
Unemployed	6 (4.4)	2 (1.5)	3 (5.0)
Full or partial allowance	71 (51.8)	50 (38.5)	33 (55)
Retired	33 (24.1)	40 (30.8)	16 (26.7)
Education			
Primary school	1 (0.7)	0	1 (1.7)
Lower secondary 1st grade	11 (8.0)	8 (6.2)	7 (11.7)
Higher secondary 2nd and 3rd grade	51 (37.2)	10 (7.7)	19 (31.7)
Higher education – short cycle	25 (18.3)	48 (36.9)	9 (15)
Higher education – (professional) bachelor	43 (31.4)	46 (35.4)	19 (31.7)
Higher education - master	6 (4.4)	18 (13.9)	5 (8.3)
Pain duration (years)	18.5 (11.6)	17.5 (11.1)	18.4 (11.9)
Pain grades			
Pain grade I	3 (2.2)	17 (13.1)	3 (5.0)
Pain grade II	12 (8.8)	20 (15.4)	7 (11.7)
Pain grade III	27 (19.7)	35 (26.9)	11 (18.3)
Pain grade IV	95 (69.3)	58 (44.6)	39 (65.0)

N = number, M = mean, SD = Standard deviation. Grade 0 = no pain, Grade I = low intensity and low disability, Grade II = high intensity and low disability, Grade III = moderate disability, regardless of pain intensity, Grade IV = high disability, regardless of pain intensity.

Table 2. *Bidirectional correlations between sociodemographic characteristics, mediation variables, and outcome variables in the entire sample.*

	Network size	Density	Social support	Conflict	Depressive symptoms	Anxiety	Anger	Pain interference	Social roles and activities	Physical functioning
Age	.016	-.061	-.101	-.26**	-.17**	-.17**	-.30**	-.13*	.12*	-.027
Gender	-.12*	.062	-.014	-.14*	.001	-.065	-.024	-.066	.087	.050
Education	.100	-.054	.056	.027	-.12*	-.093	-.064	-.16**	.12*	.19*

* p< .05; ** p< .01

Table 3. *Means, standard deviations, and Pearson correlation matrix in the entire sample.*

	M (SD)	Range	2	3	4	5	6	7	8	9	10	11
1 Network size max 80	15.64 (13.48)	2-80	.234**	-.038	.019	-.069	-.017	-.050	-.049	.015	.022	-.111
2 Network size max 10 (= NS)	8.37 (2.44)	2-10	-	-.429**	-.031	-.303**	-.186**	-.108	-.135*	-.055	.074	.008
3 Density	.26 (.09)	2/NS-1		-	.176**	.178**	-.071	-.050	-.057	-.027	.049	.051
4 Perceived support	9.50 (2.67)	Σ support alters/number of alters			-	-.269**	-.165**	-.146*	-.107	-.148*	.147*	.069
5 Conflict	2.64 (1.50)	Σ conflict alters/number of alters				-	.239**	.239**	.327**	.113	-.104	.042
6 Depressive symptoms	19.60 (7.90)	8-40					-	.768**	.695**	.479**	-.363**	-.173**
7 Anxiety	21.67 (7.15)	8-40						-	.696**	.377**	-.284**	-.079
8 Anger	13.98 (4.25)	5-25							-	.406**	-.297**	-.085
9 Pain interference	29.77 (7.07)	8-40								-	-.823**	-.633**
10 Social roles and activities	17.52 (6.80)	8-40									-	.615**
11 Physical functioning	19.61 (6.91)	8-40										-

M= mean, SD = standard deviation

Table 4. *Results of AN(C)OVA models and t-test with type of chronic pain as predictor and structural and functional social network characteristics as outcome variables.*

	Secondary CP (N= 113) M (SD)	Fibromyalgia (N= 129) M (SD)	F(df) or T-test	P-value	(Partial) Eta-squared or Cohen's d
Network size	8.35 (2.44)	8.49 (2.41)	0.082 (1,239)	.775	<.001
Density (t-test)	0.27 (0.10)	0.25 (0.09)	0.986 (1,110)	.325	.09 (Cohen's d)
Social support	9.98 (2.28)	9.19 (2.70)	6.106 (1,240)	.014	.025
Conflict	2.44 (1.45)	2.90 (1.45)	6.070 (1,240)	.014*	.025

* Did not remain significant after controlling for age, gender.
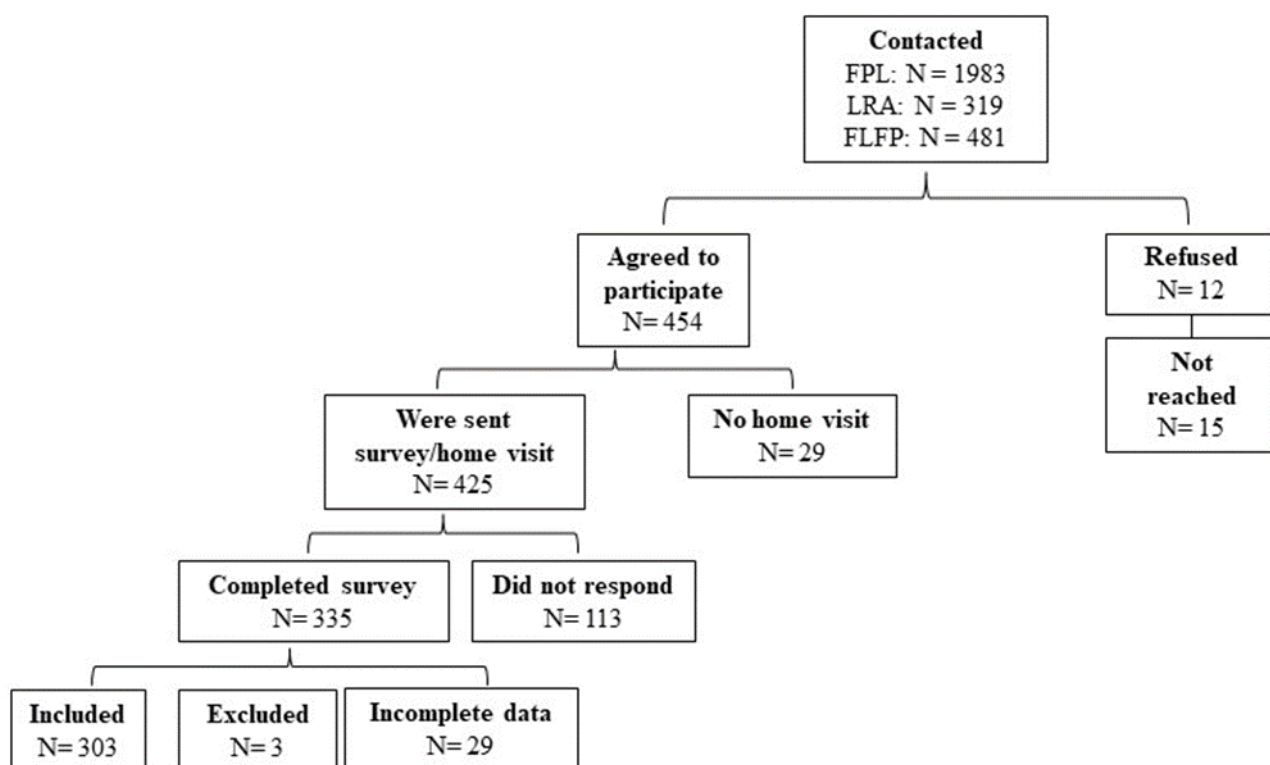
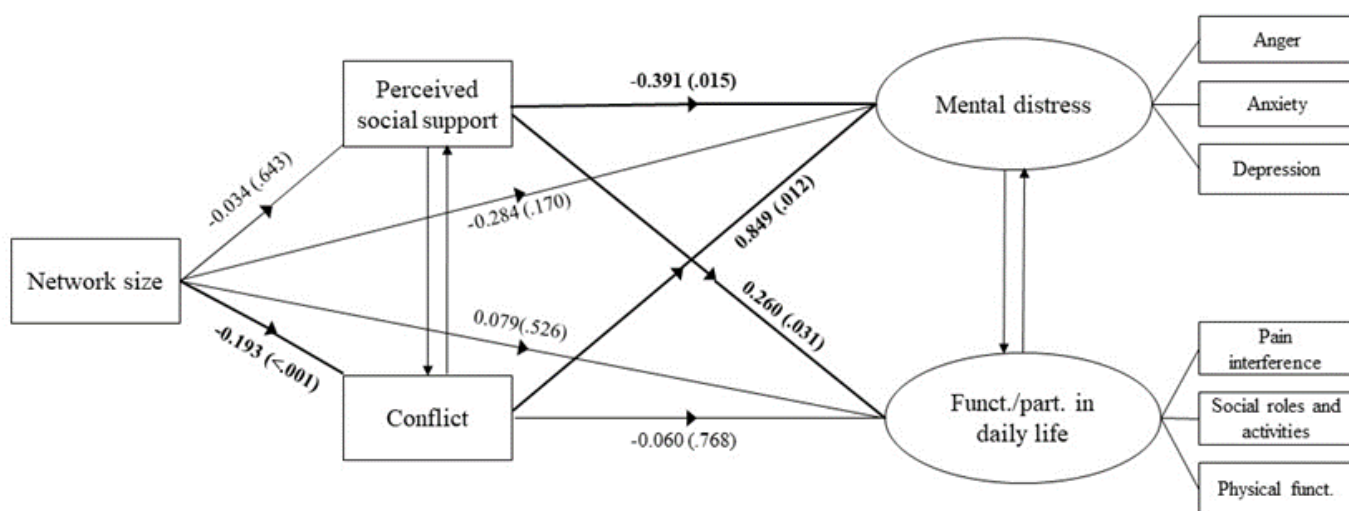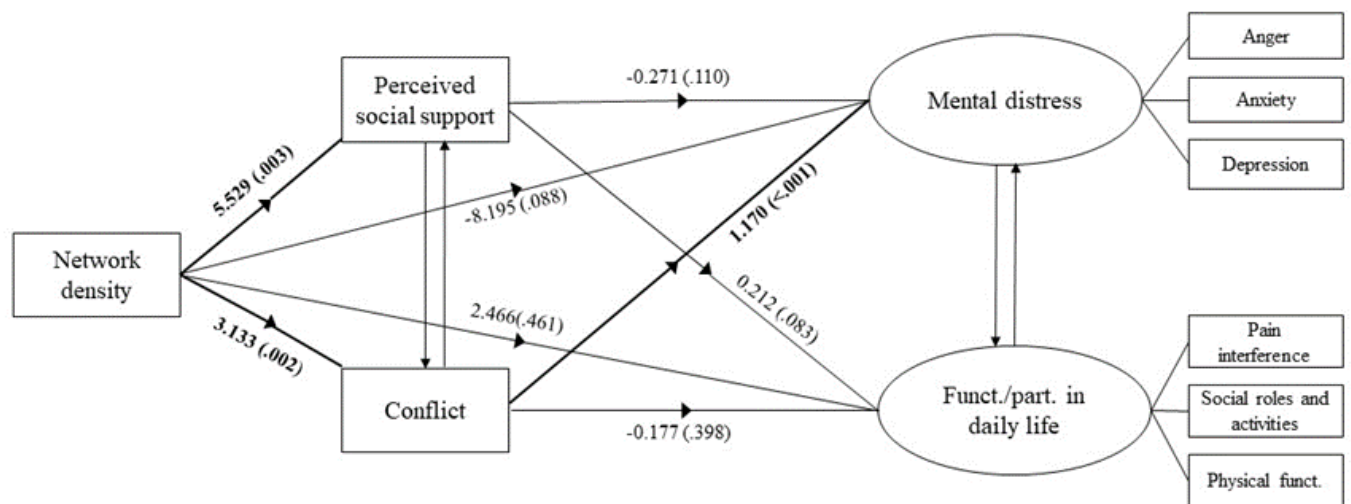N= number, M= mean, SD= standard deviation
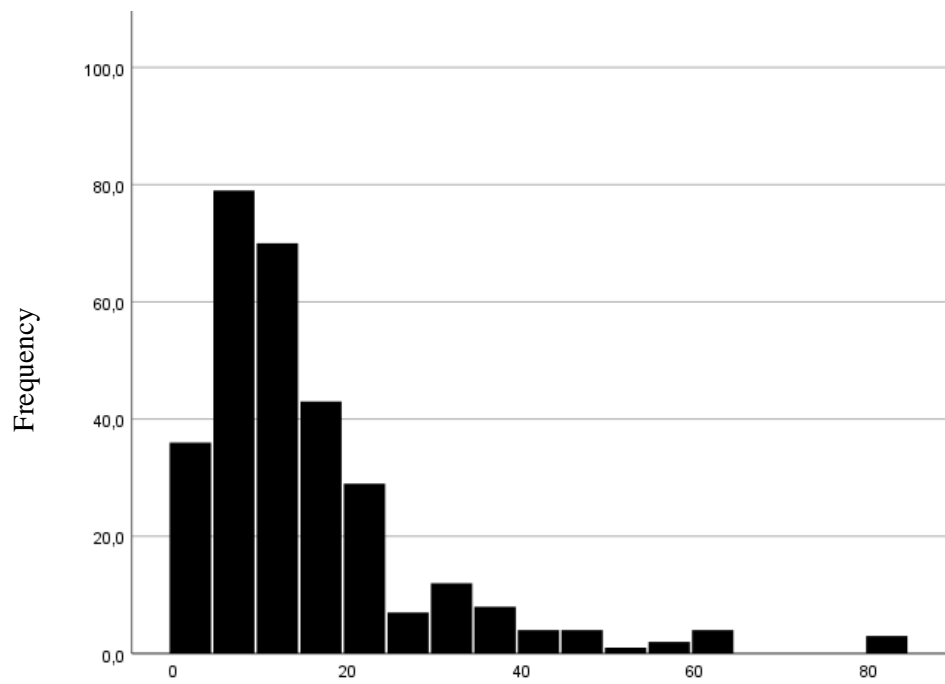
Figure 1

Figure 2

Figure 3

Figure 1. Distribution of the number of nominated network members
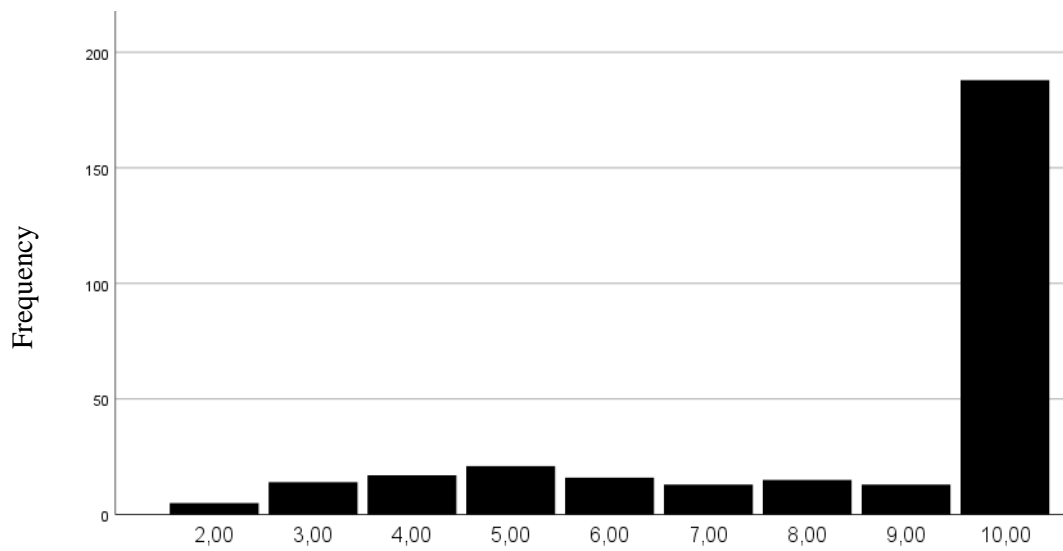(= alters) with a maximum of 80 alters.

Figure 2. Distribution of the number of nominated network members (= alters) with a maximum of 10 alters.

Table 1. *Number of times that a social role was mentioned in the network with a maximum of 80 people.*

Social category	N
Friends	974
Healthcare providers	533
Children/grandchildren	525
Other family	418
Family-in-law	400
Brother/sister	345
Members of organizations	260
Colleagues	229
Father/mother	227
Partner	220
Neighbors	201
Acquaintance	101
Other	51

N= number