Identifying frail populations for disease risk prediction and intervention planning in the Covid-19 era: a focus on social isolation and psychosocial vulnerability

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ABSTRACT

Background: The early identification of fragile populations in the Covid-19 era would help governments to allocate resources and plan strategies to contain consequences of the pandemic. Beyond frailty, social vulnerability to environmental stressors, such as the social distancing enforced to reduce the SARS-CoV2 contagion, can modify long-term disease risk and induce health status changes in the general population.

Methods: We assessed frailty and social vulnerability indices in 1258 Italian residents during the lockdown phase (March 14-31, 2020) via an on-line survey. We compared indices taking into account age categories (young, middle, older adults and elders) and gender.

Results: While frailty showed a linear increase with age and was greater in females than in males, social vulnerability was higher in young adults and elders compared to middle aged and older adults, and in males than females. Both frailty and social vulnerability contributed in explaining the individual perception of the impact of Covid-19 emergency on health, which was further modulated by proactive attitudes/behaviors and social isolation.

Conclusions: Social isolation and loneliness following the Covid-19 outbreak may exert dramatic psychosocial effects in the general population. The early detection of vulnerable categories, at risk to become ill and develop long-lasting health status changes, would help in the next future to prevent consequences on general well-being by allocating resources to targeted interventions managing psychosocial distress and increasing young adults and elderly resilience towards the post-Covid-19 crisis.

1. INTRODUCTION

Six months after the discovery of the first infected cases in China, the new coronavirus (SARS-CoV-2) is continuing to claim victims all around the world. Beyond the world health emergency, the coronavirus disease 19 (Covid-19) pandemic is bringing down the global economy and threatening the stability of social systems. As the outbreak increased in each country, forced measures of social distancing and isolation were progressively adopted by national governments. In Italy, the abrupt wave of infected cases recorded in Northern regions imposed extreme containment measures and social distancing for three months. All Italian resident inhabitants were bordered within their houses. The massive lockdown disposed by the Italian government (DCPM #iorestocasa – I stay at home – March 9, 2020) forced thus millions of people to change work habits, daily routines, and lifestyles. This large-scale catastrophic event occurring within a very short amount of time hit thousands of singles and families and dramatically decreased the psychosocial well-being of the population.

The rapid diffusion of the SARS-CoV-2 contagion among the population required to reallocate available healthcare resources (e.g., intensive care unit and emergency dedicated personnel) and plan strategies to sustain difficult medical and ethical choices (e.g., guidance for the use of mechanical ventilation, triage systems). In this perspective, the screening of frailty has been suggested as possible key tool to assist clinicians in decision-making (NICE <https://www.nice.org.uk/guidance/ng159/resources/covid19-rapid-guideline-critical-care-in-adults-pdf-66141848681413>, 27 March 2020, date last accessed). People above 65 years of age actually represent the population with higher risk of poor outcomes in case of SARS-CoV-2 contagion (Williamson *et al.*, 2012). They actually account for more than 80% of Covid-19 related deaths ((Bialek *et al.*, 2020), CDC <https://www.cdc.gov/mmwr/volumes/69/wr/mm6912e2.htm>, 26 march 2020, date last

accessed). The characterization of risk profiles and the provision of care in the case of older people cannot be properly based on mono-dimensional criteria (e.g., chronological age) that are poorly informative of the overall health status and needs of the aging individual. In this regard, the adoption of the frailty construct may allow to target choices and interventions to the clinical and biological complexity of the individual, in the premise of a person-centered approach (Hewitt *et al.*, 2020).

Frailty is a condition characterized by reduced homeostatic reserves and increased vulnerability to stressors exposing the individual to negative outcomes (Cesari *et al.*, 2016). It is a widely used clinical measure, both in geriatrics and other medical specialties, resulting from combining different age-related biological determinants leading to decreased functional reserve capacities (Fried *et al.*, 2001). It is growingly recognized as a valid proxy of the individual risk profile towards adverse health outcomes (e.g., disability and/or mortality) (Morley *et al.*, 2013). Recent scientific society guidelines recommend the use of frailty measures to quickly and reliably screen population for clinical vulnerability and to orient the triage procedures (NICE <https://www.nice.org.uk/guidance/ng159/resources/covid19-rapid-guideline-critical-care-in-adults-pdf-66141848681413>). The Clinical Frailty Scale (CFS) has proven to provide more informative data than single measures of cognition, function or comorbidity in assessing medium-term risk of death for Covid-19 infection ((Darvall *et al.*, 2019); NICE <https://www.nice.org.uk/guidance/ng159/resources/covid19-rapid-guideline-critical-care-in-adults-pdf-66141848681413>). Moreover, the use of a Frailty Index at patient hospital admission during the first weeks of Covid-19 pandemic in Italy helped the clinical decision-making process, predicting mortality and ICU admission (Bellelli *et al.*, 2020). However, the individual's risk of negative health-related outcomes is not influenced only by his/her biological asset and complexity. A significant role is also played by diverse social

circumstances and psychological determinants that are not captured by biologically-oriented definitions of frailty (Hubbard *et al.*, 2020).

Frailty and social vulnerability can be both summarized by using a deficit accumulation approach, i.e. arithmetically counting the biological and psychosocial negative attributes presented by the individual. Based on this model, the more deficits an individual has the more he/she will be vulnerable to stressors and at risk for unfavorable outcomes (Mitnitski *et al.*, 2001). Previous studies have shown that the indexes resulting from this approach (i.e., frailty index and social vulnerability index) predict a range of health outcomes (Rockwood *et al.*, 2007; Andrew and Keefe, 2014; Nguyen *et al.*, 2019). A person-centered approach assessing different dimensions that may influence health status – considered as biological, psychological and social well-being – should therefore be promoted in order to assess more thoroughly the risk of short- and long-term adversities and the outcome of pharmacological and non-pharmacological interventions.

In the present study, we evaluated how frailty and social vulnerability, both operationally defined using a cumulative approach, influence the psycho-socio-emotional dimensions and the individual perception of Covid-19 impact on health. Moreover, we assessed the impact of age and sex on these two constructs.

We predicted that, in line with current literature, frailty would increase with age and that females would result more frail than males (Fulop *et al.*, 2010; Gordon *et al.*, 2017; Ahrenfeldt *et al.*, 2019). We expected that, in the light of the social distancing imposed during the lockdown phase, social categories whose significant relationships were held outside the family (e.g., young adults) or away from their living context (e.g., elders) would result more vulnerable compared to people who have active and strong social ties within their home (e.g., middle aged and older adults living with their children). Moreover, we hypothesized

that the frailty and social vulnerability may interact with the psychological and emotional asset of the individual in influencing his/her perception of the pandemic.

PARTICIPANTS AND METHODS

2.1 Participants

Immediately after the lockdown phase disposed by Italian government on March 9, 2020 (DCPM #iorestoacasa – I stay at home), we launched the PsyCOVID study (<https://wprn.org/item/428452>), aiming at evaluating changes in habits, routines and psychosocial dimensions in the Italian population during the social distancing period (see baseline findings at Cerami et al., 2020).

Between Mar 14 and 31, 2020, we conducted an anonymous on-line survey among Italian residents. We used convenience sampling, selecting participants based on their accessibility and proximity to the research group. We created the survey using Google Forms and distributed it through a freely accessible link (<https://forms.gle/5f3yH3aTNJYEuJ7B9>). We distributed the survey link via written invitations through e-mails, WhatsApp and social networks. We then asked initial participants to diffuse the questionnaire through their social networks. Eligibility criteria were age (18 years of age or older) and place of residence (Italy).

Participants provided their consent to the experimental procedure, which was approved by the IUSS-University of Pavia Ethics Committee. After providing informed consent, participants were directed to the survey completion. They did not receive any incentive to take part in the study. The response rate was 98%. We calculated the rate response as the ratio of the number of complete responders to the total number of potential participants who had the chance to access the first page of the study. Non-responders were persons who did not provide their informed consent to participate or who declared an age <18 years old.

A total of 1258 adult Italian residents completed the survey (71.5% females; mean age: 43 ± 13.5 ; age range: 18-81). Table 1 provides details about the socio-demographic characteristics of the sample.

<i>Characteristics</i>	<i>No. (and %) of respondents</i>
Sex	
Male	359 (28.5)
Female	899 (71.5)
Age	
Young adults (18-34 y)	405 (32.2)
Middle adults (35-49 y)	472 (37.5)
Old Adults (50-64 y)	269 (21.4)
Elders (>65 y)	112 (8.9)
Education	
Elementary school (5 y)	2 (0.2)
Secondary school (8 y)	30 (2.4)
High school (13 y)	352 (28.0)
Graduate school (16-18 y)	580 (46.1)
Postgraduate school (>18 y)	293 (23.3)
Occupation	
Student	88 (7.0)
Housewife	33 (2.6)
Unemployed	53 (4.2)
Employee	576 (45.8)
Manager	105 (8.3)
Freelance	230 (18.3)
Professor or Researcher	37 (2.9)
Retired	117 (9.3)
Job field	
Industry	114 (9.1)
Financial and Economy	118 (9.4)
Communication Industry	60 (4.8)
Art and Manufacturing	59 (4.7)
Humanistic	199 (15.8)
Non-profit	99 (7.9)
Construction	25 (2.0)
Trade	65 (5.2)
Healthcare	185 (14.7)
Education and University	61 (4.8)
Public Services	62 (4.9)
Others	205 (16.3)
Geographic Area (place of residence)	
Northern Italy	832 (66.1)
Centre Italy	115 (9.1)
Southern Italy	311 (24.7)

Table 1. Sample description.

The table reports demographic features of the sample (n=1258).

2.2 Measures

2.2.1 Frailty

Frailty was measured by computing a Frailty Index (FI) following a standard procedure (Jones *et al.*, 2004; Searle *et al.*, 2008). A total of 30 variables, representing symptoms, clinical signs, comorbidities, and impaired functions, were considered. For each item, we assigned a score 0 in the absence and 1 in the presence of the deficit. The FI score was then calculated by dividing the sum of the deficits presented by each participant by the total number of variables measured (i.e., 30). The variables incorporated in the FI are listed in Appendix A.

2.2.2 Social vulnerability

Social vulnerability was operationalized analogously to frailty, by calculating a cumulative social vulnerability index (SVI). Thirty self-reported variables pertaining to social and psychological factors were considered. Each item was scored as 0 (absent) or 1 (present). The total number of deficits presented by the subject was then divided by the total number of deficits considered, yielding a continuous SVI score ranging from 0 and 1. The variables incorporated in the SVI are reported in Appendix B.

Of note, the FI and SVI were mutually exclusive, with no deficit overlap between the two instruments.

2.2.3 Psycho-socio-emotional dimensions

In addition to data on socio-demographic characteristics, the questionnaire recorded information about different psycho-socio-emotional dimensions, relevant for emergency settings and post-traumatic situations (i.e., loneliness, empathic skills, coping strategies,

alexithymia) (Bottesi *et al.*, 2015; Khalid *et al.*, 2016; Wang *et al.*, 2018; Edwards, 2019; Passardi *et al.*, 2019). To collect information about these psycho-socio-emotional dimensions we used a battery of validated questionnaires in Italian language. Loneliness was assessed with the Italian Loneliness Scale (ILS) (Zammuner, 2009), including the three sub-scales (General Loneliness, Emotional Loneliness, Social Support). We used the Empathic Concern (EC) and Perspective Taking (PT) sub-scales of the Interpersonal Reactivity Index (IRI) (Davis, 1983) to capture emotional and cognitive facets of empathic abilities, respectively. Coping strategies were investigated with the short version of the Coping Orientation to the Problems Experienced (COPE-NVI-25) scale (Foà *et al.*, 2015), measuring different coping behaviors or styles towards problems and stressful events, reflected in 5 sub-scores (Positive attitude, Problem orientation, Transcendence orientation, Social support, Avoidance strategies). Finally, we recorded information about individuals' ability to identify and describe emotions experienced by one's self or others with the Toronto Alexithymia Scale (TAS-20) (Bressi *et al.*, 1996).

2.2.3 Perceived impact of Covid-19 outbreak on health

We assessed the perceived impact of Covid-19 outbreak on health with a 4-item scale (*average interitem covariance*=0.34; *Cronbach's alpha or α* = 0.74) (see Cerami *et al.*, 2020). This scale required participants to rate the perceived severity of Covid-19 outbreak for health at the local (item 1: city or town), regional (item 2), and global (item 3: national; item 4: international) levels, on a 5-point Likert scale (0=not serious at all; 4=extremely serious). The individual global score results by summing up the item ratings (range 0-16).

2.3 Statistical analysis

We performed statistical analyses using SPSS (<https://www.spss.it/>) and STATA (<https://www.stata.com/>).

Since a small percentage of data were missing in any analysis (<2% of cases), we dropped cases with missing values via list-wise deletion. We set statistical significance at $p < 0.05$ for all statistical tests. We calculated descriptive statistics including frequencies and percentages for categorical variables, and mean and standard deviation for pseudo-continuous variables. We estimated interindividual differences in FI and SVI with a two-way MANOVA, considering sex and age categories (young adults: 18-34 y.o., middle aged adults: 35-49 y.o., old adults: 50-64 y.o., elders: >64 y.o.) as fixed factors.

Then, in order to reduce dataset complexity and optimize interpretability of results, we applied a Principal Component Analysis (PCA) on variables reflecting psycho-socio-emotional dimensions. In particular, after assessing the suitability of the correlation matrix (Keiser-Meyer-Olkin Measure of Sampling Adequacy = 0.702; Bartlett's test of sphericity <0.001), we performed a PCA on the scores of 11 variables, including the three ILS sub-scores, EC and PT sub-scores from the IRI, the five COPE-NVI-25 sub-scores and TAS-20 global score. Both the scree plot and the Kaiser-Guttman criterion (i.e., components with eigenvalue >1) converged in determining the number of components to be retained (= 3). We used an orthogonal rotation (Varimax) to facilitate the interpretation of the resulting components (Abdi and Williams, 2010). Loading factors of the three components obtained were then used in the subsequent correlation and mediation analyses. Correlation analysis (Pearson's r coefficient) was carried out to evaluate the relationship linking FI and SVI with PCA components (C1: *Proactivity*; C2: *Isolation*; C3: *Inactivity*) and the perceived impact of Covid-19 outbreak on health.

Finally, in the light of the correlation results, we assessed two mediation paths. The first (*Social Vulnerability Model*) tested the indirect effect of C1 (*Proactivity*) on the relationship between SVI and perceived impact of Covid-19 outbreak on health. The second mediation path (*Frailty Model*) assessed the indirect effect of C2 (*Isolation*) on the relationship linking FI and perceived impact of Covid-19 outbreak on health.

3. RESULTS

3.1 Sample distribution of FI and SVI

Descriptive statistics are illustrated in Table 2 and Figure 1.

		FI						SVI					
		Males			Females			Males			Females		
		Mean	SD	Range	Mean	SD	Range	Mean	SD	Range	Mean	SD	Range
Age	18-34	0.14	0.07	0.03-0.37	0.16	0.08	0.03-0.43	0.35	0.1	0.10-0.60	0.33	0.1	0.07-0.70
	35-49	0.14	0.07	0.03-0.37	0.16	0.1	0.03-0.83	0.32	0.11	0.03-0.60	0.29	0.1	0.03-0.60
	50-64	0.17	0.09	0.03-0.40	0.18	0.11	0.00-0.63	0.32	0.12	0.03-0.63	0.29	0.11	0.03-0.67
	>65	0.19	0.1	0.03-0.37	0.2	0.11	0.07-0.53	0.36	0.11	0.17-0.57	0.33	0.12	0.13-0.67

Table 2. Descriptive statistics of frailty and social vulnerability indices.

The table reports mean, standard deviation and score range of frailty index and social vulnerability index in the sample (n=1258), grouped by age categories and gender. *Table legend: FI=frailty index; SVI=social vulnerability index; SD=standard deviation.*

3.2 Age and gender effects on FI and SVI

The two-way MANOVA showed a significant multivariate effect of gender ($\Lambda=0.984$ $F_{2,1249}=10.036$, $p<0.001$) and age categories ($\Lambda=0.957$ $F_{6,2498}=9.253$, $p<0.001$) on both FI and SVI. However, the interaction between gender and age categories was not significant

($\Lambda=0.999$; $F_{6, 2498}=0.127$, $p=0.993$). Univariate results confirmed gender and age categories effects on both FI (*sex*: $F_{1,1250}=5.951$, $p=0.015$, with a greater FI in females than males; *age categories*: $F_{3,1250}=9.211$, $p<0.001$), and SVI (*sex*: $F_{1,1250} = 14.040$, $p<0.001$, with a greater SVI in males than females; *age categories*: $F_{3,1250} = 9.309$, $p<0.001$).

Post-hoc analysis (Bonferroni post-hoc test) taking into account between-group differences in age categories showed that while FI was significantly higher in old adults (50-64 y.o.) and elders (>64 y.o.) compared to young (18-34 y.o.) and middle aged adults (35-49 y.o.) (Figure 1), SVI was significantly higher in young adults and elders compared to middle aged and old adults (Figure 1).

3.3 Relationship between FI and SVI, psycho-socio-emotional variables, and perceived impact of Covid-19 on health

The PCA reduced the original 11 psycho-socio-emotional variables into 3 non-collinear components, explaining the 61% of the overall variance (Table S1). Component 1 (C1: *Proactivity*) included variables related to empathy, social support, active and positive coping strategies, denoting an internal locus of control. Component 2 (C2: *Isolation*) included two loneliness variables. Finally, Component 3 (C3: *Inactivity*) encompassed variables related to alexithymia, transcendent or avoidance coping stiles, indicating an external locus of control.

Correlation analyses assessing the relationship between FI, SVI, the three psycho-socio-emotional components (C1, C2, C3) and the perceived impact of Covid-19 on health are reported in Table S2. In particular, we observed that both FI ($p<0.05$) and SVI ($p<0.01$) were significantly correlated with the perceived impact of Covid-19 on health. Based on the correlation patterns emerged, we selected a definite set of variables and tested two mediation paths in one model, with the perceived impact of Covid-19 outbreak on health as dependent variable.

In the *Frailty* path (Figure 2, blue color), we tested the mediation effect of C2 (*Isolation*) – negatively correlated to the dependent variable and positively with the independent variable – on the positive relationship linking FI (independent variable) and the perceived impact of Covid-19 outbreak for health. Results highlighted a significant indirect effect of C2 (Sobel test $p < 0.001$), mediating approximately the 86% of the total effect of FI on perceived impact of Covid-19 outbreak for health. In the *Social Vulnerability* path (Figure 2, green color), we tested the mediation effect of C1 (*Proactivity*) – positively correlated with the dependent variable and negatively correlated with the independent variable – on the negative relationship linking SVI (independent variable) and the perceived impact of Covid-19 outbreak for health. Results highlighted a significant indirect effect of problem-oriented coping (Sobel test $p < 0.001$), mediating approximately the 33% of the total effect of SVI on perceived impact of Covid-19 outbreak for health.

4. DISCUSSION

Social distancing measures and indoor space isolation have been applied as effective actions to contain SARS-CoV-2 contagion. Though differently adopted by governments, these measures entered everyday life for millions of peoples in a few days. Digital solutions to communicate with others and limited physical contacts will characterize our future for a while. It is however not negligible that this may have detrimental effects on the individual psychophysical health status and the well-being of the society. Humans live in a social contextual world and need social interactions to enhance the equilibrium of mind and brain, especially in case of vulnerable individuals.

In line with previous literature, frailty showed a significant increase with age. However, as expected, social vulnerability showed a different pattern. Indeed, younger people and elders

appear the most vulnerable age categories. Women and people between 35 and 64 y.o. represented the less socially vulnerable categories in our sample. This evidence may suggest that the social distancing period during the lockdown phase was critical for those people whose significant relationships are held with contacts outside the family network (e.g., friends, colleagues or mates for young adults, as well as relatives and next of kin for elders living alone). At the same time, individuals less engaged with indoor childcare or caregiving duties (i.e., men) may have suffered the most. This finding diverged from classical studies about social vulnerability (e.g. Andrew *et al.*, 2008), which reported that both frailty and social vulnerability correlate each other and have a linear increase with age, with women showing higher index values than men. However, the extraordinary and unprecedented observation time of this study, together with the fact that we computed FI and SVI on a sample covering all adult ages, and not only elderly, may account for differences with these classical studies.

Both FI and SVI can be considered as predictors of the perceived impact of Covid-19 outbreak on health. However, while FI was directly related to the perceived severity of the Covid-19 impact on health – people having a higher FI perceiving the Covid-19 outbreak as more severe than individuals with lower FI – we observed a negative relationship between SVI and the perceived impact of Covid-19 outbreak for health, indicating that the subjects with higher social vulnerability were perceiving the impact of the Covid-19 outbreak as less severe than people displaying lower SVI. In particular, this latter result is confirming a previous suggestion (Cerami *et al.*, 2020). The lack of social contacts and loneliness made individuals less aware of the impact of the Covid-19 outbreak for health. Conversely, it is straightforward to understand the reason why people with high FI perceived the Covid-19 outbreak impact as more severe. Indeed, a higher degree of comorbidity and somatic symptoms it is likely to enhance the perceived threat and danger for individual psychophysical integrity. Testing two possible indirect effects through which FI and SVI might relate to the perceived impact of the

Covid-19 outbreak for health, we found that both frailty and social vulnerability paths showed significant mediation effects. In line with our previous work (Cerami et al., 2020), the *Frailty* path revealed that the *Isolation* component (C2, including two different loneliness measures) worked as an inconsistent mediator (i.e., suppressor) of the relationship linking FI with the perceived impact of Covid-19 outbreak for health, possibly making those individuals experiencing a greater degree of loneliness less aware of the impact of the Covid-19 outbreak for health. Again, the presence of a larger social network increases the probability to have friends, relatives or colleagues who have been infected and thus to judge the impact of the outbreak as more severe. The *Social Vulnerability* path highlighted the suppression effect of *Proactivity* (C1, including variables related to empathy, social support, active and positive coping strategies) to the negative relationship linking SVI to the perceived seriousness of Covid-19 outbreak impact for health. This might indicate that, in a condition of social vulnerability and lack of connectedness, the presence of empathic skills and proactive coping strategies can reduce the detrimental effect of SVI, increasing people awareness about the health impact of Covid-19.

5. CONCLUSION

Our findings underline the dangers of social isolation in general population, as well as the importance of empathic skills and active coping strategies in promoting the individuals' psychosocial adaptation to a threatening event, like the Covid-19 pandemic. Frailty and social vulnerability, which contributed in explaining the individual perception of the perceived impact of Covid-19 emergency on health, were indeed modulated by proactive attitudes/behaviors and social isolation.

Measure as frailty and social vulnerability indices, coupled with information on personal psychological and emotional attitudes, may thus be helpful to monitor vulnerable populations,

acting early to prevent social distancing from becoming social isolation. Social isolation in students and elderly has been linked to increased risk of mental illness as well as of cognitive decline and immune dysregulation (Cole *et al.*, 2015; Gerst-Emerson and Jayawardhana, 2015; Novotney, 2019; Santini *et al.*, 2020). Moreover, it reduces resilience factors such as self-worth, sense of purpose and feeling valued (Novotney, 2019). These effects may lead to adverse health outcomes and increase susceptibility to infections. Health care systems and society communities must thus consider without further delay the psychosocial burden of social distancing, finding shared support strategies to keep individual engaged and motivated and screening for mental and physical symptoms.

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CONFLICT OF INTEREST

None of the authors have conflicts of interest to declare.

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Appendix A. The 30-item Frailty Index (FI)

1	Hypertension
2	Cardiovascular disorders
3	Chronic obstructive pulmonary disease
4	Gastric diseases
5	Renal failure
6	Cirrhosis
7	Diabetes
8	Thyroid disease
9	Cancer
10	Genitourinary diseases
11	Osteoporosis
12	Peripheral artery disease
13	Neurological diseases
14	Vision or hearing impairments
15	Psychiatric diseases
16	Anxiety
17	Depression
18	Stress
19	Attention deficit
20	Faintness
21	Headache
22	Dizziness
23	Diffuse pain
24	Chest pain
25	Back pain
26	Nausea
27	Soreness
28	Weakness
29	Physical inactivity
30	Mobility disability (inability to walk 400 m)

Appendix B. The 30-Item Social Vulnerability Index (SVI)

<i>Socio-economic status</i>	
1	Education (< 8 years)
2	Working status (unemployed/retired/housewife)
3	No home ownership
4	No Smartphone/iPhone ownership
5	No PC/Tablet ownership
<i>Living situation</i>	
6	Marital status (single/widow/separated)
7	Lives alone
8	Lives with less than two other people
9	Lives in a rural area or a small town
<i>Leisure activities</i>	
10	How often go to clubs, church or community centers (< one a month)
11	How often go to gym or sport clubs (< one a month)
12	How often do charity work (< one a month)
<i>Socially oriented activities of daily living</i>	
13	How often look after kids (< one a month)
14	How often look after grandchildren (< one a month)
15	How often look after parents (< one a month)
16	How often look after grandparents (< one a month)
17	How often look after friends, other people (< one a month)
18	How often take care of pet (< one a month)
19	How often travel (> six months ago)
20	How often have face-to-face contacts with other people (< one a month)
21	How often meet first-degree relatives (< one a month)
22	How often meet second-degree relatives (< one a month)
23	How often meet friends (< one a month)
24	How often talk by phone with first-degree relatives (< one a month)
25	How often talk by phone with second-degree relatives (< one a month)
26	How often talk by phone with friends (< one a month)
27	How often chat with first-degree relatives (< one a month)
28	How often chat with second-degree relatives (< one a month)
29	How often chat with friends (< one a month)
30	No social contacts in the last week

Figures and legends

Figure 1. Distribution of frailty and social vulnerability by age categories and gender. The figure illustrates the mean distribution of the frailty index (on the left) and the social vulnerability index (on the right) grouped by age categories (18-34 y.o.=young adults; 35-49 y.o.=middle adults; 50-64 y.o.=old adults; >65 y.o.=elders). Blue and orange lines indicate distribution patterns of frailty and social vulnerability indices in males and females respectively.

Figure 2. Frailty and Social Vulnerability paths. The figure displays results emerged from the path analysis, including two different paths converging on a common outcome, i.e. the individual perception of the impact of Covid-19 outbreak on health (yellow box). In the Frailty path (blue color) we observed a significant mediation effect of the independent component Isolation (C2) on the relationship between the frailty index (FI) and the perceived impact of Covid-19 outbreak on health. In the Social Vulnerability path we found a significant mediation effect of the independent component Proactivity (C1) on the relationship between the social vulnerability index (SVI) and the perceived impact of Covid-19 outbreak on health.

Supplementary Materials

Identifying frail populations for disease risk prediction and intervention planning in the Covid-19 era: a focus on social isolation and psychosocial vulnerability

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Table S1. Interpretation of principal components

A: Component	B: Variables	C: Functions
#C1: Proactivity	IRI-EC	Emotional Empathy
	IRI-PT	Cognitive Empathy
	ILS-S	Social support
	COPE-NVI-25 PO	Active coping strategies
	COPE-NVI-25 PA	Positive coping strategies
	COPE-NVI-25 SS	Social support coping strategies
#C2: Isolation	ILS-G	Loneliness
	ILS-E	Loneliness
#C3: Inactivity	TAS-20	Alexithymia
	COPE-NVI-25 TO	Transcendent coping style
	COPE-NVI-25 AS	Avoidance coping style

The table illustrates the three principal components – Proactivity, Isolation, Inactivity – obtained as a result of the data reduction procedure performed on psycho-socio-emotional variables, including different facets of loneliness, empathy, coping styles and alexithymia (see main text, paragraph 3.3). In particular, for each principal component (Column A) we listed the variables included (Column B) and the corresponding function (Column C).

Table legend: C1=component 1; C2=component 2; C3=component 3; IRI-EC=Interpersonal Reactivity Index, Empathic concern subscale; IRI-PT= Interpersonal Reactivity Index, Perspective taking subscale; ILS-S=Italian Loneliness Scale, Social support subscale; COPE-NVI-25 OP=Coping Orientation to Problem Experienced-New Italian Version, Problem orientation subscale; COPE-NVI-25 PA=Coping Orientation to Problem Experienced-New Italian Version, Positive attitude subscale; COPE-NVI-25 SS=Coping Orientation to Problem Experienced-New Italian Version, Social Support subscale; ILS-G=Italian Loneliness Scale, General Loneliness subscale; ILS-E=Italian Loneliness Scale, Emotional Loneliness subscale; TAS-20=Toronto Alexithymia Scale; COPE-NVI-25 OP TO=Coping Orientation to Problem Experienced-New Italian Version, Transcendent orientation subscale; COPE-NVI-25 AS=Coping Orientation to Problem Experienced-New Italian Version, Avoidance strategies subscale.

Table S2. Correlation results

	<i>Perceived Covid-19 Impact on Health</i>	<i>FI</i>	<i>SVI</i>	<i>C1</i>	<i>C2</i>	<i>C3</i>
<i>Perceived Covid-19 Impact on Health</i>	-	r=0.062 p=0.028	r=-0.077 p=0.006	r=0.147 p=0.000	r=-0.076 p=0.007	r=0.007 p=0.804
<i>FI</i>		-	r=-0.004 p=0.888	r=-0.003 p=0.918	r=0.424 p=0.000	r=0.182 p=0.000
<i>SVI</i>			-	r=-0.188 p=0.000	r=0.044 p=0.119	r=0.013 p=0.657
<i>C1</i>				-	r=0.000 p=1.000	r=0.000 p=1.000
<i>C2</i>					-	r=0.000 p=1.000
<i>C3</i>						-

The table reports the correlation results taking into account the perceived impact of Covid-19 on health, the frailty (FI) and the social vulnerability (SVI) indices, and the loading factors of the three principal components resulted from the PCA (C1, C2, C3). *Table legend: FI=frailty index; SVI=social vulnerability index; C1=component 1, Proactivity; C2=component 2, Isolation; C3=component 3, Inactivity. Bold values indicate statistical significance at the $p<0.05$ level.*