Ageing International
https://doi.org/10.1007/s12126-024-09567-8

Multi-Dimensional Healthy Aging Interventions: Evidence from an Age-Friendly Community Program in Italy

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Accepted: 29 May 2024

Abstract

In this paper, we evaluate a pre-pandemic multi-dimensional healthy aging program promoted by an Italian private Foundation to provide new insights on interventions that address both health and social needs within an age-friendly community framework. Using propensity score matching and linear regression models, with specific controls for individuals' self-selection into the program, we compare lifestyles, physical health, mental conditions, and healthy life expectancy of subjects enrolled into the program with those of similar, but non-enrolled, subjects. Our main finding is that, to be more effective, healthy aging interventions should target the key dimensions of aging - physical, mental, and social - in a holistic approach. Indeed, we show that the multi-dimensionality of the healthy aging intervention under study - the contemporaneous target of older adults' physical, mental, and social health - is crucial in improving both quantity and quality of life.

Keywords Healthy Aging · Social Engagement · Physical, Social, and Mental Health

Introduction

The global population is experiencing an unprecedented increase in longevity, with projections indicating that, by 2050, the number of individuals aged 60 years or older will double, reaching 2.1 billion, while the population aged 80 years or above will triple, reaching 426 million (UN, 2023). Despite the significant rise in life expectancy, efforts to extend the duration of a healthy, inclusive, and fulfilling life have faced challenges. Age-related conditions now contribute to nearly 25% of the global burden of disease and continue to escalate (Domaszewska et al., 2022).

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Published online: 24 June 2024

The physical and cognitive changes associated with aging may result in limitations to mobility, emotional distress, and social exclusion. To address these challenges, the World Health Organization has launched a global movement advocating for the promotion of age-friendly communities. In this context, communities are defined as groups of individuals sharing distinctive characteristics tied to a common geography, identity, purpose, or interest. These communities are envisioned as capable of providing services that promote health and address critical social issues related to aging, such as isolation.

The aim of this work is to evaluate a pre-pandemic multi-dimensional healthy aging intervention developed at the community level in Italy. The setting under study is a Foundation, created and financed by a large company,[1] which offers age-friendly activities to the population of the company's older employees and retirees. This firm holds a significant presence in the local socio-economic environment. It employs more than 4,000 employees in a rural area, and is actively involved in the development of local social plans. "The company should allocate both human and financial resources to express gratitude to its senior employees and retirees. This involves establishing a robust and enduring facility that serves as a vital hub of activity, fostering a supportive community to promote successful aging" declared the company's founder when inaugurating the Foundation in 1983. All firm's employees with at least twenty-five years of tenure are eligible to participate to the Foundation's activities. Enrollment to the Foundation's program entails a customized health plan, organized by the Foundation's medical professionals, to uphold and enhance participants' health conditions based on their individual needs. Additionally, the Foundation provides a portfolio of activities categorized into three health domains: physical (exercise), mental (creative courses, such as theatre acting), and social (volunteer opportunities).

The multi-dimensionality of the intervention is a key, and rare, feature of the program. Indeed, aging is a complex and multifaceted process that encompasses physical, mental, and social changes (Kirkwood, 2008). Biologically, the molecular and cellular damages associated with aging gradually lead to the development of chronic-degenerative conditions and general decline in the functional capacity of the individual (Steves et al., 2012; Vasto et al., 2010). These physical changes are highly heterogeneous among the older population, and only poorly correlated with age in years. In this sense, individuals' life habits and social interactions play a fundamental role in defining an optimal aging trajectory (Riva et al., 2014). A sedentary lifestyle, malnutrition, tobacco smoking, and alcohol consumption are all avoidable risk factors that negatively affect health and precipitate death (Chapman, 2008; McPhee et al., 2016). It has been shown that improvements in each factor towards healthier life habits have positive impacts on older people's health and survival

[1] To support and integrate public-health interventions, private firms and organizations are increasingly undertaking initiatives to help promoting healthy aging through the mobilization of non-public resources. Many companies in Europe are now focusing more and more on their employees' quality of life and well-being, proposing a wide range of welfare services. Resources spent in corporate welfare for older workers and retirees have more than doubled in less than ten years (Eurofound, 2006). Most corporate programs aim at promoting healthy lifestyles: interventions against smoking, drinking and other addictions, obesity and sedentary life, personalized diet plans that often require the advice of doctors and experts.

(Fusco & Pani, 2013; Landi et al., 2014), but their combination has even stronger effects (Haveman-Nies et al., 2002; Knoops et al., 2004). A similar positive effect has been reported for social and productive activities (Glass et al., 1999). Social disengagement and loneliness have been suggested as possible risk factors for cognitive decline in older adults (Fratiglioni et al., 2000) and, in general, for depression and lower quality of life (Hussenoeder et al., 2020). Participating in social, productive, and recreational activities is also associated with lower risk of dementia among the older adults (Wang et al., 2002). Healthy habits and good social interactions positively influence mental wellness (Seah et al., 2019).

The requirements and methodological considerations for the development of healthy aging interventions should reflect the complexity of the aging process and address physical, mental, and social health by integrating person-focused with environment-focused contents (WHO, 2015). Components and dimensions of healthy aging programs vary broadly and differently influence the quality of life, health behaviors, and health-related outcomes of older adults. While there is a long tradition of studies evaluating programs promoting each dimension (King et al., 1998; Zhou et al., 2018), evidence on the effectiveness of their combination on health and well-being is still scarce. Through the evaluation of an intervention that combines multiple health domains, our work contributes to the existing, but still limited, evidence that addresses both health and social outcomes in the development of age-friendly programs at the community level (see Hong et al., 2023 for a review). We study a unique program, which develops a holistic framework that combines both person-and environment-based approaches to healthy aging.

To perform our analysis, we rely on a representative sample of 356 retirees eligible to participate into the program. We then categorize them according to their participation status, defining two groups: participants *vs* non-participants. To examine the effects of the program on participants' life habits, health, well-being, and life expectancy, we use both linear regression models, with specific controls for individuals' self-selection into the program, and propensity score matching techniques. Four are the main outcomes under analysis: i) the probability of adopting healthy habits; ii) the probability of being socially engaged; iii) physical and mental health status; iv) disability-free life expectancy. We find that subjects participating into the program have a larger probability of following a healthier lifestyle, in particular of exercising, have a wider social network, enjoy better health conditions, and live a larger proportion of their remaining life in absence of chronic conditions.

The structure of the paper is as follows. "The Program" section describes the program. The "Methods" section presents the methodologies used to perform the analysis, while the "Results" section presents the main findings. The "Discussion" section discusses the results, while the "Conclusions" section concludes.

The Program

Upon reaching 25 years of tenure within the company, employees become eligible for participation in the program, with the potential of ongoing involvement throughout their lifespan. The 356 subjects under study consists of retirees with

an average company service of 35 years, ranging from a minimum of 25 years to a maximum of 40 years. At enrollment into the program, the medical staff of the Foundation interviews each participant on healthy habits (smoking, drinking, nutrition), presence or familiarities with chronic conditions, and presence of invalidities and/or allergies. They also perform some health checks, such as BMI calculation and basic blood tests. Once acquired a complete picture of participants' health status, the Doctor of the Foundation defines a personalized health plan that varies according to participants' health characteristics and can change in case of a sudden health shock, e.g., a stoke. The health plan involves regularly scheduled visits by the Foundation's Doctor, occurring at least bimonthly. These consultations encompass discussions on treatments, prescriptions, and lifestyle adjustments to support and enhance each participant's health conditions. The Foundation also serves as intermediary in facilitating participants' access to renowned hospitals and health centers in Italy, particularly for the treatment of age-related medical conditions, such as maculopathy. Additionally, the Foundation organizes events where health professionals deliver presentations on lifestyle choices and disease preventions and management. Furthermore, participants have the option to request basic health services, such as blood pressure measurements, performed by the two nurses enrolled in the Foundation.

In addition to these health screens, participants are offered a portfolio of extra activities organized and managed by the Foundation. These activities can be classified under three health domains: i) the "physical" domain, which includes three main physical activity courses, namely *Nordic Walking*, that participants could perform in groups in the paths around the Foundation with the support of a fitness trainer, *Thai Chi* classes, and postural gymnastics to prevent frailty with specialized instructors; ii) the "mental well-being" domain, which includes activities aimed at boosting creativity and memory, e.g., theatre acting or photography courses; iii) the "social" domain, which includes activities aimed at improving participants' social engagement, e.g., volunteering in the Foundation, local schools, or nursing homes. All visits and courses are free of charge.

Table 1 shows that, on average, participants have been enrolled in the program for 15 years. 91% of participants declare to visit the Doctor of the Foundation according to their health plan since enrollment. Almost 68% of participants

Table 1 Description of participants' involvement in the different activities offered by the Foundation

Average years of enrollment into the program	14.9
% of participants visited according to their health plan	91.4
% of participants who exercise in physical activity courses	67.7
% of participants who attend creativity courses	37.5
% of participants involved in social activities	58.0
Average weekly hours of exercising	3.5
Average weekly hours of creativity courses	4.2
Average weekly hours of social activities	4.0
Observations	269

The Table describes participants' involvement in the program and the different types of activity offered by the Foundation

declare to exercise in a training course offered by the Foundation. 58% of participants are involved in a volunteering activity under the social domain, while 38% in a creativity course under the mental well-being domain. Participants who are enrolled in a physical activity course spend, on average, 3.5 hours per week in such activity. One hour more, on average, is spent each week by participants who attend a creativity course or are involved in a social activity within the community.

Methods

Sample and Data Sources

A sample of 356 subjects aged between 65 and 100 was drawn from the population register of the firm's retirees eligible for participating in the Foundation's program.[2] The sample was stratified by gender, age, and former occupational category. To ensure its representativeness, we additionally used the distance in Km between the Foundation and the residence of each subject and calculated individual weights as the inverse of the predicted probability of inclusion in the sample. A large amount of information on participation into the program, socio-demographic characteristics, lifestyle, social engagement, health conditions, mental well-being, was collected through a survey, administered by medical staff employed in the Foundation between February 2018 and August 2019 via computer-assisted, face-to-face interviews. The different data sources have been matched to the individual records via an anonymous personal identification number. Out of the 356 subjects, 269 were actively participating in the healthy aging program during the survey administration period. We define this group as the "participants". 87 subjects did not participate in any activity. We define this group as the "non-participants". To better understand the reasons for non-participating, in Table 6 in the Appendix we explore whether burdens in family care responsibilities can account for non-participation. Approximately 72% of participants and 68% of non-participants are married. Although information regarding the health status of spouses is unavailable, a substantially majority of subjects, more than 80% in both groups, report having family members capable of aiding and supporting when needed. 86% of participants and 80% of non-participants have children, while 65% of participants and 59% of non-participants have grandchildren. The average number of children in both groups is 1.7. Participants' children, on average, are approximately 44 years old, while non-participants' children are slightly older, averaging around 46 years old. The age of grandchildren is similar for both groups, averaging around 11 years old. By performing, for each observed characteristic, a t-test for difference in mean, we do not detect significant differences among the two groups. This exercise, although descriptive, reassure us in claiming that we do not detect significant differences in the profiles and main attributes of participants and non-participants' families.

[2] We remind that eligibility in the program requires at least 25 years of tenure within the company.

The purpose of the study is to compare lifestyles, health outcomes, and healthy life expectancy between the two groups and describe the association between participation into the multi-dimensional program and health and social outcomes. Since the allocation of subjects among the group of participants and non-participants is clearly non-random, in the empirical exercise we explicitly model individuals' self-selection into participation, controlling for observable characteristics as well as the distribution of unobservable traits correlated with the decision of taking part into the program.

Variables

Healthy lifestyle was assessed based on self-reports on nutrition, exercise, smoking and alcohol consumption. Four healthy lifestyle indicators have been constructed: i) Active, which indicates whether the individual is regularly active - walking, cycling; ii) Physical exercise, which indicates whether the individual regularly exercises; iii) Healthy nutrition, which identifies adherence to the Mediterranean diet - daily consumption of fruit and vegetables, weekly consumption of fish and dried fruit, limited consumption of sugars; iv) Smoking and drinking. Following the literature on the relationship between lifestyles and health conditions (Haveman-Nies et al., 2002) these four indicators have been combined to define a synthetic indicator of healthy lifestyle. This indicator takes value 1 if the subject regularly performs some movement or physical exercise, follows a healthy diet, does not smoke, and does not habitually consume alcohol.

Social engagement was assessed based on self-reports on social relationships. The outcomes of interest are the quantity of social interactions - the size of the social network - and the intensity of these interactions. To measure the size of the social network, subjects were asked *"Do you have one or more people you can count on?"*. 90% of the interviewees answered positively. Subsequently, the subjects were asked to name, in order of relevance, the first four people with whom they usually interact. The indicator on quantity of social interactions takes value 1 if the individual nominated at least three persons. To measure the frequency of interactions, subjects were asked, for each person indicated, *"How often do you see him/her?"*. Possible answers were *"Every day"*, *"More than once a week"*, *"Once a week"*, *"A few times a month"*, *"A few times a year"*. The frequency indicator assumes value 1 if the individual declares to interact with each member of the social network at least once per week. The social engagement indicator takes value 1 if both the quantity and frequency indicators are equal to 1.

Health status was assessed based on self-related health. Self-related health is generally considered a good summary of the overall health of an individual, although it may suffer from substantial reporting heterogeneity, resulting from differences in health perception. Subjects were asked to rate their overall health on a five-point scale: very good, good, fair, bad, and very bad. Using the answers to this question we built an indicator of self-assessed health, *SAH*, equal to 1 if the subject perceives his/her health condition *"Bad"* or *"Very bad"*. In addition, the survey includes several other self-reported objective health measures (e.g., suffering from chronic diseases and disabilities). To summarize this large amount of health information we

followed Bound et al. (1999) and Mazzonna and Peracchi (2017) and built a single health index by estimating the following model:

$$SAH_i = \pi' H_i + \varepsilon_i$$

where SAH_i is the dichotomous variable on self-assessed health equal to 1 if the individual i assess his/her health condition as *"Bad"* or *"Very bad"*. H_i is a vector of objective measures of health status (chronic diseases, obesity, diabetes, dyslipidaemias, hypertension, diseases of the respiratory system, disability), while ε_i is the erratic component of the equation relating to unobservable factors that can influence health conditions (the hypothesis is that the error terms are independent and identically distributed, *IID*). Our summary health status variable is conditioned on objective health conditions and computed as the predicted probability of suffering from bad health.

Mental well-being was assessed based on self-related psychological well-being. Subjects were asked *"During the past four weeks, how many times did you feel sad, discouraged?"*. Possible answers were *"Often"*, *"Sometimes"*, *"Rarely"*, or *"Never"*. We built an indicator of mental distress equal to 1 if the subject reported to feel sad and discouraged "*Often*" or "*Sometimes*".

Empirical Analysis

Effects of the Program on Lifestyles and Social Engagement

In a first step of the analysis, we assessed how participating into the healthy aging program directly affects the probability of following a healthy lifestyle and being socially engaged. The relationship between the status of participant versus non-participant and the indicators of healthy lifestyle and social engagement was estimated with ordinary least squares (OLS), controlling for a series of observable - age and gender - and unobservable confounding factors. The distribution of unobservable confounding factors is retrieved from the latent decision to participate or not in the Foundation's activities. Using a propensity score methodology, we calculated the conditional probability of attending the program on the basis of a vector of individual characteristics - age and gender - and an exclusion restriction - distance in Km between the place of residence and the Foundation. Notice that, since the location of the Foundation is different from the main factory where the workers were employed before retirement, we regard the distribution of the distance from the Foundation as good as random.[3] From the estimated propensity scores, we computed deciles of the latent propensity to participate in the Foundation's activities. Following a control function approach, the vector of these deciles was then included in the equations of interest (Lunt, 2014). As discussed above, this method allows to assimilate the distribution of the subjects to treatment-control as if it were in the presence of a (quasi) random allocation.

[3] This would be invalidated only if individuals would change address upon retirement to be closer to the Foundation for health reasons. Upon inspection of the changes of addresses of the respondents in the administrative records of the Foundation this is not the case.

In practice, we estimated the following equation:

$$Y_i(HL_i, S_i) = \alpha_0 + \alpha_1 P_i + \alpha_2 g_i + \delta_c + D'_i\varphi + \varepsilon_i \quad (1)$$

where Y_i represents, for each individual i, the indicator of healthy lifestyle (HL_i), or social engagement (S_i). P_i is an indicator equal to 1 if the subject participates in the Foundation's program, 0 otherwise. g_i is an indicator for being female. δ_c controls for age cohorts. D_i is the vector of deciles of propensity scores that controls for the decision to participate into the program. ε_i is the error term.

Mediation Analysis: Direct and Indirect Effects of the Program on Health Status

In a second step, we assessed the effects of the program on participants' health conditions and mental well-being through a mediation analysis. Rather than looking only at the direct effects of attending the Foundation's activities on psycho-physical health, we propose a mediation model in which we assume that participating in the program induces relevant indirect changes in behaviours - such as healthier lifestyles and higher social engagements - and these, in turn, influence health outcomes and mental well-being. To verify this assumption, we estimate the following equation:

$$Y_i(\widehat{SAH}_i, M_i) = \gamma_0 + \gamma_1 P_i + \gamma_2 HL_i + \gamma_3 S_i + \gamma_4 g_i + \delta_c + D'_i\varphi + \varepsilon_i \quad (2)$$

where $\widehat{SAH}_i$ is the predicted probability of suffering from bad health, a number ranging from 0 (good health) to 1 (bad health). M_i is the indicator for mental distress. The other variables are defined as in Eq. (1). In practice, we are assuming that P_i affects $\widehat{SAH}_i$ and M_i both directly and indirectly by affecting HL_i and S_i. We thus want to capture the size and significance of these effects by estimating the impact of the program on the outcomes under analysis, conditional on lifestyle and social engagement.

As a robustness check, we replicated the two analyses with propensity score matching. This approach - widely used in observational studies to try to reduce the bias due to the selection of individuals into treatment - allows to evaluate the effects of a given intervention controlling for the confounding factors that predict participation in the intervention itself. The estimated effect is the *average treatment effect on the treated (ATT)*, i.e., exactly the parameter of interest: the effect of the participation in the program on the outcomes of interest.

Disability-free Life Expectancy

We calculated the disability free life expectancy by Sullivan's method. Health expectancy calculated by Sullivan's method is the number of remaining years, at a given age, which an individual can expect to live in a healthy state. We define healthy state as the absence of chronic conditions. The mortality (survival) rate of participants and non-participants was built based on the number of deaths recorded in the two groups, information contained in the population register of the company's employees eligible to participate in the program. The morbidity rate was constructed from

Table 2 Descriptive statistics of variables used in the empirical analysis

	Non-Participants $n=87$ Mean (SD)	Participants $n=269$ Mean (SD)	p
Female	0.53 (0.06)	0.47 (0.03)	0.382
Age	76.8 (0.78)	75.4 (0.35)	0.090
Healthy lifestyle	0.18 (0.05)	0.42 (0.03)	0.000
Social engagement	0.26 (0.05)	0.52 (0.03)	0.000
Has chronic diseases	0.43 (0.06)	0.41 (0.03)	0.709
Predicted prob. Of bad health	0.07 (0.01)	0.04 (0.00)	0.002
Mental distress	0.23 (0.05)	0.12 (0.02)	0.008

Subjects divided by participation status in the Foundation's program. Healthy lifestyle: being active or regularly exercising, following a healthy diet, not smoking and not regularly consuming alcohol. Social engagement: having intense social interactions with at least three people. Has chronic diseases: suffering from at least one chronic condition. Predicted prob. of bad health: predicted probability of suffering from bad health conditions. Mental distress: indicator for bad mental well-being

SD standard deviation, *p* p-values from adjusted Wald test

the information on chronic diseases collected in the survey. Healthy life expectancy was separately calculated for participants and non-participants in the following way:

$$DFLE_n = \frac{1}{l_n}\sum(1 - \pi_n)L_n \tag{3}$$

where $DFLE_n$ is the disability-free life expectancy, the life expectancy in absence of chronic conditions for the age cohort n (65–69, 70–74, 75–79, 80–84, 85+). l_n is the number of surviving in cohort n; π_n is the proportion of subjects in cohort n suffering from a chronic condition; L_n is the person-years lived in cohort n.[4]. The index is calculated as a standard indicator of life expectancy for each age cohort, with the only difference that the cumulative number of years lived is multiplied by the proportion of subjects who do suffer from chronic conditions.

Results

Table 2 shows descriptive statistics of the variables used in the empirical analysis. The overall percentage of gender and age distribution among participants and non-participants is proportionally acceptable. On average, participants follow a healthier lifestyle, have a wider social network and, in general, are less likely to suffer from bad physical and mental health.

Table 3 reports results of Eq. (1), which estimates the association between participating to the Foundation's healthy aging program and the probability of following a healthy lifestyle and be socially engaged. This association is positive, statistically

[4] A detailed description on the indicators used to build the *DFLE Index* is in the Appendix.

Table 3 Effect of the program on the probability of following healthy lifestyle and social engagement

	Healthy lifestyle		Social engagement	
	(1) OLS	(2) ATT	(3) OLS	(4) ATT
Participant $n=356$	0.23*** (0.13, 0.33)	0.25*** (0.14, 0.36)	0.19** (0.08, 0.31)	0.18* (0.04, 0.32)
Participant over 75 $n=219$	0.27*** (0.16, 0.39)	0.31*** (0.21, 0.42)	0.16* (0.02, 0.31)	0.17* (0.01, 0.34)

Covariates in columns (1) and (3) include age cohorts, gender, and deciles of propensity score to control for observable and unobservable confounding factors that affect the decision of participating in the program. ATT: average treatment effect on the treated estimated through propensity score matching. *Outcomes:* i) Healthy lifestyle: being active or regularly exercising, following a healthy diet, not smoking and not regularly consuming alcohol; ii) Social engagement: having intense social interactions with at least three people. *Variable of interest*: Participant, indicator for attending the Foundation's program. 95% confidence intervals in parenthesis

significant, and robust to both the OLS - Columns (1) and (3) - and propensity score matching specifications - Columns (2) and (4). Participating in the program increases the probability of following a healthy lifestyle by 23 percentage points. In Fig. 2 in the Appendix we additionally report findings on the four single lifestyle indicators: being active, exercising, following a healthy diet, not smoking and not regularly consuming alcohol. The larger results are on physical exercise, smoking and drinking. The program also increases the probability of having a good and satisfying social network by 19 percentage points. When stratifying the analysis by age group, we find, for both outcomes, a stronger association for older participants, those aged more than 75.

In the Appendix Table 7, we present evidence suggesting that adhering to a healthy lifestyle and engaging in social activities is positively and significantly related to subjects' health conditions and mental well-being.[5] Reading these findings together with those presented in Table 2, we can assume that the observed positive impact of the program on participant's health and well-being may be attributed to the program's efficacy in encouraging individuals to embrace healthier behaviours and cultivate social relationships. In Table 4 we evaluate how relevant is the contribution of these mediating effects on both health status and mental well-being. We start by showing that, without conditioning for the mediating factors, participating in the program has a positive effect on health status, reducing the probability of suffering from bad health by 4% (Column (1)). This result is robust to estimation through propensity score matching, shown in Column (2). To perform the mediation analysis, we include in our estimated model, on top of the indicator for participating into the program, the indicators for healthy lifestyle and social engagement. If the

[5] In this analysis, we do not distinguish between participants and non-participants, but use the whole sample to estimate the impact of lifestyle and social engagement on the probability of suffering from bad health conditions and mental distress by estimating the following equation: $Y_i(\widehat{SAH_i}, M_i)=\beta_0+\beta_1 X_i\ (HL_i, S_i)+\beta_2 g_i+\delta_c+u_i$.

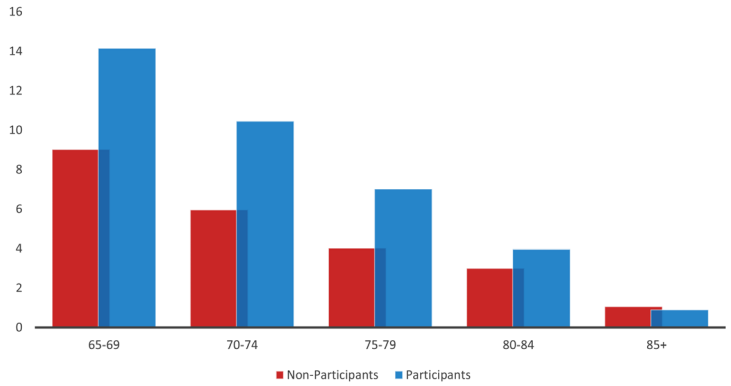
Table 4 Mediation analysis: direct and indirect effects of the program on health status and mental well-being

	Bad physical health			Bad mental well-being		
	(1) OLS	(2) ATT	(3) OLS	(4) OLS	(5) ATT	(6) OLS
Participant *n = 356*	-0.04** (-0.06,-0.01)	-0.03** (-0.05,-0.01)	-0.03** (-0.05,-0.01)	-0.09 (-0.19,0.10)	-0.07 (-0.17,0.02)	-0.06 (-0.16,0.04)
Participant over 75 *n = 219*	-0.05** (-0.08,-0.02)	-0.05** (-0.08,-0.02)	-0.04** (-0.07,-0.01)	-0.16* (-0.29,-0.02)	-0.17** (-0.30,-0.05)	-0.13 (-0.26,0.01)
Healthy lifestyle n = 356			-0.01* (-0.03,-0.00)			-0.06 (-0.04, 0.01)
Healthy lifestyle if participant is over 75 *n = 219*			-0.04 (-0.04,0.00)			-0.05 (-0.16,0.05)
Social engagement *n = 356*			-0.01 (-0.02,0.01)			-0.08* (-0.15,-0.01)
Social engagement if participant is over 75 *n = 219*			-0.01 (-0.02,0.02)			-0.11* (-0.21,-0.02)

Covariates in columns (1), (3), (4) and (6) include age cohorts, gender, and deciles of propensity score to control for observable and unobservable confounding factors that affect the decision of participating in the program. ATT: average treatment effect on the treated estimated through propensity score matching. *Outcomes*: probability of suffering from bad health in Columns (1), (2), and (3). Probability of suffering from bad mental well-being in Columns (4), (5), and (6). *Variables of interest*: i) Participant: indicator for attending the Foundation's program; ii) Healthy lifestyle: being active or regularly exercising, following a healthy diet, not smoking and not regularly consuming alcohol; iii) Social engagement: having intense social interactions with at least three people. 95% confidence intervals in parenthesis

impact of these mediating factor on health status and mental well-being prevails, we should expect their coefficients to be large and highly significant, and, at the same time, we should observe a decrease in the magnitude and significance of the coefficient on participation. On the other hand, if the impact of the mediating factors is limited, we should not detect significant changes in the coefficient on participation. Findings on the mediation analysis are reported in Column (3). We can state that the inclusion of the indicator for healthy lifestyle only slightly affects the coefficient on participation, while the inclusion of the indicator for social engagement has no significant effect. This means that, although participating in the program strongly affects these indicators, which, in turn, are strong predictors of health, the direct effect of the program on health status prevails. In practice, the combination of adherence to the health plan and the participation to the portfolio of physical, mental and social activities accounts for the large majority of the positive association between program's participation and health status, around three-quarter, while only one-quarter is mediated by changes induced in lifestyles. The results on mental well-being are different. We find that the program improves the mental wellness of older participants - it reduces the probability of feeling sad and discouraged by 16 percentage points among subjects aged more than 75, Column (4) - but this result is entirely explained by the indirect positive effect that the program has on social engagement, Column (6).

It was shown that active participation in the Foundation's healthy aging program improves lifestyles, and, more generally, health status and mental well-being. We now want to quantify how much this effect translates into a healthier and longer-lasting aging trajectory. Exploiting information on deaths reported in the population register of the firm's retirees, we calculated, separately for participants and non-participants, the mortality rate and survival curve. Findings are reported in Table 8 and Fig. 3 in the Appendix. For each age cohort, the mortality rate is higher among non-participants, reaching 40% among those aged more than 85, *versus* 17% among participants. The proportion of survivors among participants is higher than that of non-participants. The gap between the two groups increases considerably with age, reaching a difference of about 30 percentage points between those aged more than 85. Therefore, those attending the Foundation's healthy aging program tend to live longer. But does this increase in the "quantity of life" also translate into an increase in its "quality"? To answer this question, we calculated the 'Disability Free Life Expectancy Index' (DFLEI). Results are shown in Fig. 1. A participant aged between 65 and 69 can expect to live additional 14 years - 68% of his/her remaining life - in the absence of chronicity. A non-participant in the same age cohort, instead, can expect to live only additional 9 years - 44% of his/her remaining life - in good health. As Fig. 1 shows, the DFLEI gap between participants and non-participants persists until the age cohort 75–79. After age 80, this gap decreases to finally disappear after age 85. The lack of significant differences for older cohorts confirms the Italian trend characterized by a large onset of chronicity after 80 years of age. Despite being one of the oldest countries in the world, Italy performs very poorly when considering quality of life of its older population. 60% of Italian aged more than 80 suffer from at least one serious chronic disease, about 50% from physical limitations (Istat, 2017).



Notes: The Figure depicts the disability-free life expectancy, in years, for non-participants and participants.

Fig. 1 Participation in the program and disability-free life expectancy (in years)

Discussion

In the current study, we examined the effectiveness of a multi-dimensional aging program developed at the community level to promote both healthy aging and social participation. The community under study is that of former employees of a large company that holds a significant presence in the local socio-economic environment. The company strongly recognizes that former employees are vital assets for the local system. This recognition involves empowering them to be involved in activities aligned with their health status, motivations, and aspirations, which is a key component of successful active aging programs (Lucantoni et al., 2022). The program has unique features since, on top of a personalized health plan, it offers a portfolio of activities aimed to sustain physical, mental, and social health.

Our first result is that participants to the intervention under study, when compared to substantially identical non-participants, tend to follow a healthier lifestyle, and be more socially engaged. This finding suggests that participating into the program effectively contributes to increase participants' awareness on the importance of leading an adequate lifestyle for healthy aging. In particular, they are significantly more likely to be physically active, and this result is relevant since regular physical activity supports healthy aging including brain and physiological health and prevents aging-related disorders, such as Alzheimer Disease (Gronek & Tang, 2023). Group-based activities, as the *Nordic Walking* groups organized by the Foundation, have been proved to be effective in creating a fertile environment for older adults to act and engage in health-promoting behaviours: they learn from peers, benefit from role models and through the sharing of problems and doubts (Behm et al., 2013). Such interventions contribute to increase physical exercise, improve nutrition - increasing the consumption of vegetables and fibre and decreasing fat and alcohol intake - take-up vaccinations and health screening (Anspaugh et al., 2000; Dapp et al., 2011; Harari et al., 2008; Stuck

et al., 2015). We additionally show that the association between participation and positive health and social outcomes is larger for older participants. This is another interesting result, given the large literature showing that changing behavioural factors in the direction of a healthier lifestyle pattern contributes to postpone the age of onset of chronic diseases and disabilities and has a major effect on quality of life and mortality (Haveman-Nies et al., 2002). Randomized controlled studies have shown that it is never too late to reap the positive benefits of controlling the deleterious effects of bad life habits (Estruch et al., 2013; Hamer et al., 2014; Ohara et al., 2015). Moreover, since loneliness tend to be common among the very old (Dykstra, 2009), our findings suggest that the program effectively helps improving the quantity and quality of social life of older participants.

Our second, and most novel, finding is that adopting a holistic approach that targets all dimensions of health - physical, mental, and social – is the key feature that makes this intervention successful. Indeed, the main novelty of our study stands in the disentanglement of the direct and indirect effects that the multi-dimensional intervention explicates on participants' health and well-being. We were thus able to assess how much of the total impact of the program is due to the multi-dimensionality of the intervention. Focusing on physical health, we showed that most of the positive impact of the program in reducing the probability of suffering from chronic conditions and disabilities, around three-quarter, is directly due to the multi-dimensionality of the intervention: the combination of adherence to the health plan and participating to the different activities organized by the Foundation. Only one-quarter of the total effect is due to the indirect positive changes in life habits induced by the program itself, i.e., its ability to contrast sedentary lifestyles, malnutrition, tobacco smoking and alcohol consumption. The positive impact on mental wellness, instead, is entirely explained by the indirect effect that the program has on improving the size and quality of social relationships. In this sense, we confirm that encouraging social engagement improves older adults' mental well-being (Gonzales et al., 2015). Particularly, the personal benefits of volunteering for the older population have been shown to be substantial and include positive psychosocial outcomes - reduced depressive symptoms - improved quality of life, social supports and networks, physical and mental health - functional independence, fewer doctor-diagnosed conditions, lower mortality, mental status, memory, and executive functions (Anderson et al., 2014). Our results are in line with a large evidence suggesting that volunteering and group-based activities create a supportive environment for older adults, helping them to improve their self-esteem, mood and ability to cope with negative life events, depression and anxiety (Escolar Chua & De Guzman, 2014).

We additionally showed that the positive effects of the intervention translate into a healthier and longer-lasting aging trajectory. At 65, participants can expect to live additional 14 years in good health conditions, around 68% of the remaining life expectancy and 5 years longer than non-participants. Longevity is the prototypical indicator for successful aging and evidence that programs promoting healthy aging

have significant effects on survival is well-established (Haveman-Nies et al., 2002). However, lifespan, per se, does not offer information about the quality of aging. For example, in a study of 602 Italian centenarians, only 6% could conduct all activities of daily living (Motta et al., 2005).

Strengths and Limitations

Our study acknowledges significant limitations, particularly in addressing the non-random selection of participants into the program. To tackle this challenge, our design explicitly models individuals' self-selection into participation, controlling for both observable characteristics and the distribution of unobservable traits correlated with the decision to participate. Despite these efforts, we exercise caution in interpreting our results, treating them as associations rather than causal impacts.

A noteworthy strength of our research stands in the comprehensive dataset built to perform the evaluation of a unique healthy aging program. We collected information on subjects' demographic and socio-economic characteristics, detailed life habits, chronic conditions, and quantity and quality of social connections through in-person meetings with medical professionals. The richness of the information at our disposal allowed us to build a reliable and comprehensive and objective measure of health status. Leveraging this valuable information, we were able to disentangle the direct and indirect effects of the multi-dimensional intervention on participants' health and well-being. These findings are particularly interesting, considering the limited evidence of interventions addressing both health and social needs in an age-friendly community framework, as highlighted by (Hong et al., 2023).

Conclusions

In this study, we assess the impact of a holistic community healthy aging intervention designed to enhance the physical, mental, and social well-being of retirees from a large company in Italy. Our analysis is based on a representative sample of 356 eligible retirees, with 269 actively participating and 87 not involved in the program.

Utilizing both linear regression models and propensity score matching, we explore the associations between program participation and health and social outcomes. Our findings suggest that participants are more likely to adopt a healthier lifestyle, in particular to exercise more, and engage more actively in social interactions. Moreover, they experience improved health conditions and enjoy a larger proportion of their remaining life free from chronic conditions.

The central takeaway from our work is that interventions that integrate person-focused elements, such as personalized health plans, with environment-focused components, like social integration, are effective in enhancing both the quantity and quality of life for individuals in a community setting.

Appendix

Appendix A: Methods

Propensity Scores and Balancing Checks

The propensity score is the conditional probability of assignment to a particular treatment given a vector of observed covariates. Rosenbaum and Rubin (1983) showed that subjects with the same propensity score have, on average, the same potential outcomes. In this sense, comparing participants and non-participants with the same propensity score provides an unbiased estimate of the effect of participating in the Foundation's multi-dimensional healthy aging program on participants' life habits, health outcomes and disability-free life expectancy.

The conditional probability of participating in the program has been estimated through the following logistic regression:

$$Pr(P_i = 1) = a + \gamma_1 x_{1i} + \gamma_2 x_{2i} + \gamma_3 x_{3i} + \varepsilon_i \quad (4)$$

where x_1, x_2 and x_3 are three demographic variables: gender (female = 1), age (in years) and distance in Km from the place of residence and the Foundation.

All the subjects participating in the study were divided into different "strata" on the basis of their propensity score. Specifically, they were divided into deciles of propensity scores and indicator variables for each decile were then included in the main equation of interest.

It is useful to verify that the variables used for their calculation are balanced between participants and non-participants. Table 5 reports the results of this balancing check. For each group, the average values of the three variables used in Equation 4 and their standardized difference are presented. The exercise is repeated after the stratification. As shown, no significant differences were found.

Table 5 Balancing checks

	Mean Participants n = 256	*Mean Non-participants n = 87*	*Standardized difference*
Before stratification			
Age	76.65	78.99	-0.352
Female	0.48	0.52	-0.083
Av. distance	6.11	6.93	-0.061
After stratification			
Age	76.75	76.75	0
Female	0.48	0.50	-0.05
Av. distance	6.11	5.93	0.013

Age is measured in years, Female is an indicator equal to 1 if the subject is a woman, av. Distance is the average distance in Km between each subject residence and the Foundation

Indicators Used to Calculate the Disability-Free Life Expectancy

Mortality rate in cohort *n:*

$$m_n = D_n/P_n$$

where:

- D_n: number of deaths in cohort n;
- P_n: number of subjects in cohort n.

Numbers surviving to cohort *n:*

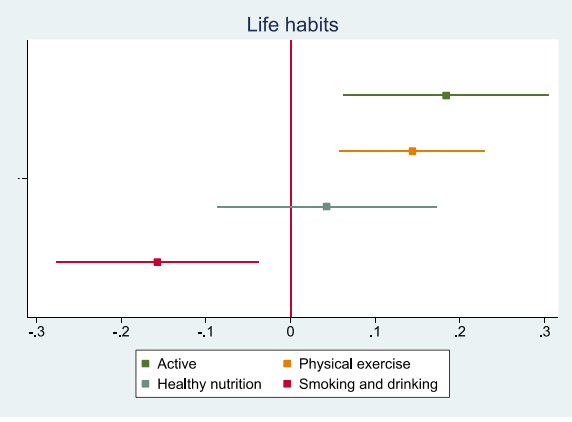
$$l_{n+1} = l_n * (l - q_n)$$

where: $q_n = \frac{n*m_n}{1 + n*0{,}5*m_n}$

Person years lived in cohort *n:*

$$L_n = n^*0{,}5^*l_{n+1} + n^*0{,}5^*l_n$$

Appendix B: Additional Results



Notes: Active: indicates whether the individual is regularly active -- walking, cycling; *Physical exercise* indicates whether the individual regularly exercises; *Healthy nutrition* identifies adherence to the Mediterranean diet -- daily consumption of fruit and vegetables, weekly consumption of fish and dried fruit, limited consumption of sugars; *Smoking and drinking* indicates whether the individual is a smoker and regularly consumes alcohol.

Fig. 2 Effects of participating in the program on each life habit indicator

Table 6 Family characteristics of the subjects under study

	Non-Participants $n=87$ Mean (SD)	Participants $n=269$ Mean (SD)	p
Married	0.71 (0.35)	0.67 (0.47)	0.379
Widow	0.21 (0.41)	0.23 (0.43)	0.565
Family support	0.85 (0.36)	0.81 (0.39)	0.434
Children	0.80 (0.40)	0.86 (0.35)	0.192
Number of children	1.70 (0.69)	1.73 (0.76)	0.761
Grandchildren	0.59 (0.49)	0.65 (0.48)	0.309
Number of grandchildren	2.75 (1.40)	2.45 (1.52)	0.278
Age youngest grandchild	11.55 (7.91)	11.29 (8.31)	0.765

This Table shows descriptive statistics of family characteristics of non-participants (Column1) and participants (Column 2) into the program

p p-value from t-test for difference in means

Table 7 Effects of healthy lifestyles and social engagement on health status and mental well-being

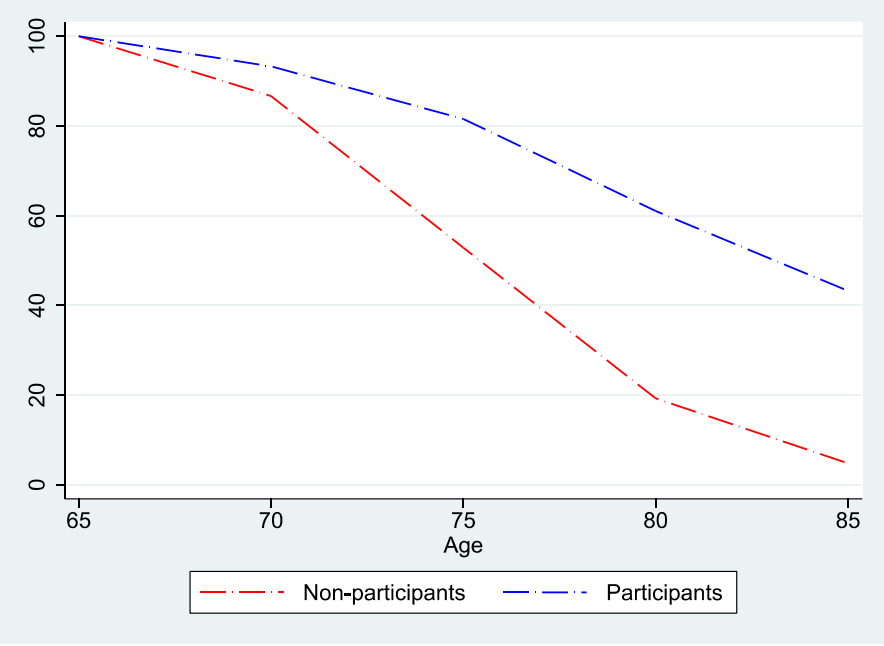
	Bad physical health			Bad mental well-being		
	(1)	(2)	(3) >75	(4)	(5)	(6) >75
Healthy lifestyle	-0.02** (-0.03, -0.01)		-0.03** (-0.05, -0.01)	-0.09** (-0.16, -0.02)		-0.12* (-0.21, -0.03)
Social engagement		-0.01* (-0.03, -0.00)	-0.01 (-0.03, 0.01)		-0.10** (-0.17, -0.03)	-0.15** (-0.24, -0.06)
Observations	356	356	219	356	356	219

Covariates in columns (1), (3), (4) and (6) include age cohorts, gender, and deciles of propensity score to control for observable and unobservable confounding factors that affect the decision of participating in the program. *Outcomes*: probability of suffering from bad health in Columns (1), (2), and (3). Probability of suffering from bad mental well-being in Columns (4), (5), and (6). Columns (3) and (6) report findings on the subsample of individuals aged 75 or more. *Variables of interest*: Healthy lifestyle: being active or regularly exercising, following a healthy diet, not smoking and not regularly consuming alcohol; iii) Social engagement: having intense social interactions with at least three people. 95% confidence intervals in parenthesis

Table 8 Mortality rate by age cohort

	P_n	D_n	m_n
Non-participants			
65–69	210	6	0,03
70–74	196	19	0,10
75–79	177	33	0,19
80–84	199	48	0,24
85+	187	75	0,40
Participants			
65–69	144	2	0,01
70–74	149	4	0,03
75–79	139	8	0,06
80–84	177	8	0,07
85+	88	15	0,17

P_n number of subjects in cohort n, D_n number of deaths in cohort n, m_n mortality rate in cohort n



Notes: The Figure depicts the proportion of surviving individuals by age cohort.

Fig. 3 % of surviving by participation status and age cohort

Acknowledgements We are deeply thankful to Dr. Ettore Bologna, Laura Rolfo, and Fabio Timelli for their precious support and assistance. We benefited from discussions with Carmen Aina, Fabrizio Faggiano, Laura Fratiglioni, Alex Murdock, Carmela Rinaldi, Roger Spear, as well as seminar participants at ISIRC 2021 Conference, 2020 Aging Project Seminar Series, and 2019 International Conference on Healthy Aging. We also thank two anonymous referees for their insightful comments and suggestions.

Funding Open access funding provided by Università Cattolica del Sacro Cuore within the CRUI-CARE Agreement. Financial assistance for the administration of the survey was given by the Fondazione Piera, Pietro e Giovanni Ferrero Onlus (Alba, Cuneo, Italy). Claudio Lucifora acknowledges co-funding from Next Generation EU, in the context of the National Recovery and Resilience Plan, Investment PE8 – Project Age-It "Aging Well in an Ageing Society". This resource is co-financed by the next generation EU [DM 1557 11.10.2022]. The views and opinions expressed are only those of the authors and do not necessarily reflect those of the European Union or the European Commission. Neither the European Union nor the European Commission can be held responsible for that. The funding source did not have any role in study design; collection, analysis, and interpretation of data; in the writing of the report; and in the decision to submit the article for publication.

Code Availability The codes are available upon request.

Availability of Data This research uses confidential data.

Declarations

Conflict of Interest The authors declare that they have no competing interests.

Informed Consent Informed consent was obtained from all individual participants included in the study. The purpose of the research was explained to the participants, who then signed a consent form indicating their willingness to participate.

Ethical Treatment of Experimental Subject (Animal and Human) The study was conducted in accordance with the ethical standards approved by ASL CN2. The confidentiality and anonymity of the participants were ensured throughout the research process. No experimental treatment was conducted in this study.

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