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Multidimensional frailty as a predictor of older adults' internet use: moving beyond the use/non-use dichotomy

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Abstract

Aim: Moving beyond the traditional use/non-use dichotomy, this study examines how variations in older adults' internet use relate to their multidimensional frailty status.

Methods: Data were drawn from the Belgian Ageing Studies (BAS), a large-scale cross-sectional survey conducted in Flanders (Belgium) and included 2,312 individuals aged 60 and older. Internet use was categorized into non-users, basic users, selective users and allround users. Multidimensional frailty was assessed using the Comprehensive Frailty Assessment Instrument (CFAI), covering physical, psychological, social and environmental domains. Multinomial logistic regression and Chi-squared automatic interaction detection (CHAID) were conducted.

Results: Regression analysis revealed that older adults with mild or high levels of physical frailty, as well as those with high levels of environmental frailty, were more likely to not use the internet. Furthermore, individuals with high physical frailty and high social frailty were more likely to be basic internet users. Social frailty was also linked to allround internet use, with those in the mild and high frailty categories being less likely to be allround users. However, CHAID analysis highlighted that sociodemographic factors—particularly low education and advanced age—are more strongly associated with low internet usage than frailty itself.

Conclusions: Multidimensional frailty is associated with internet use, with mild and high frailty groups being less internet savvy.

Keywords

Internet use, multidimensional frailty, older adults

Introduction

Over the past decades, world's population has been aging rapidly, and this trend is expected to continue for several decades [1, 2]. According to Eurostat [3], 29.5 percent of the European population will be at least 65 years old by 2050, compared to 21.2 percent in 2022. To address the challenges of a rapidly aging population and to reduce the high costs of institutionalization, governments motivate older people to age in place and remain living in their own homes and environments for as long as possible [4]. In this context, institutionalization in residential aged care facilities typically occurs during the later stages of life [5]. However, ageing in place is not only a key policy objective, but also the preference of older people themselves [6]. Most older individuals feel emotionally attached to their home or neighborhood because the environment enables a sense of connection to memories and allows them to maintain links to existing social networks and retain full independence, control and privacy [7–10]. This can explain why the vast majority of older adults prefer to age in place [6, 11].

However, ageing in place can become notably challenging due to various factors such as poor social networks, little support from family and friends and restricted access to healthcare facilities and essential services [12]. Consequently, there is a growing interest in internet technologies that have the potential to foster independent living and empower older adults to reside safely, securely and for longer periods in their own homes [13–15]. Furthermore, internet applications can play a crucial role in alleviating isolation among older individuals by enhancing their connections with the outside world [16, 17]. The array of e-technologies supporting older people as they age in place is diverse, including, for instance, telecommunication systems, social and assistive robots, emergency help systems, smart home technologies, eHealth programs and sensor-based networks for activity, health or home monitoring [17–20]. However, to benefit from such technologies, older adults must use the internet [13]. Nonetheless, it is widely acknowledged that not all older adults have access to and make use of the internet [13, 21, 22]. To understand which subgroups of older individuals use the internet, several scholars have extensively examined associations between sociodemographic characteristics and internet (non-)use among older adults, e.g., [22–29]. Research indicates strong associations between internet use and older adults' age and socioeconomic status, with the oldest old and those with limited educational backgrounds and lower income being less likely to use the internet [22, 30, 31].

While associations between older adults' sociodemographic characteristics and internet use have been well-documented, little is known about the relationship between frailty and internet use in older people [17, 32]. Studies focusing on internet use among frail older adults have primarily examined the effectiveness of particular internet-based interventions that aim, for instance, to detect or prevent frailty, e.g., [33, 34], improve the overall health or frailty status of older people, e.g., [35, 36] or assist family caregivers in caring for frail older people, e.g., [36]. While many researchers in the field of frailty and internet use focus on evaluating online-interventions, there is limited research examining the extent to which frail older people use the internet. For instance, Díaz-Ramos and Avelar-González et al. [37] aimed to determine the prevalence of frailty and its association with internet and mobile phone use, revealing that frailty was independently associated with the non-use of mobile phones and social networks, as well as e-mail. Similarly, Keränen and Kangas et al. [38] demonstrated that frail older adults were less likely to use the internet and mobile information and communication technologies. However, in both studies, frailty has been considered as a unidimensional concept, focusing exclusively on its physical aspects.

Instead of solely focusing on the physical component of frailty, several scholars in the field of frailty have already proposed considering frailty as a multidimensional concept arising from complex interactions between biological, psychological and social aspects [39–41]. Furthermore, as older adults can become frail due to poor-quality housing and deprived living environments, some scholars suggest considering frailty as

a combination of physical, physiological, social and environmental indicators [42–44]. Therefore, in previous research, we explored the relationship between multidimensional frailty—consisting of physical, psychological, social and environmental domains—and internet (non-)use among older adults [23]. The findings indicated that the physical domain is most strongly associated with internet (non-)use, with individuals scoring high on physical frailty being up to 8.0% more likely to be internet non-users compared to those who are not physically frail. However, the binary approach, exclusively comparing internet users and non-users, has faced criticism for its oversimplification, as it fails to recognize the diversity of internet use [45, 46]. In light of this, many scholars suggest moving away from the binary categorization of use/non-use and instead focusing on the continuum in between, recognizing the diversity in older adults' internet use [31, 46, 47]. Indeed, internet usage varies widely among individuals, ranging from highly skilled and experienced users engaging in diverse internet activities to those with limited opportunities to become internet savvy and reap the benefits of online engagement [45, 46]. Consequently, increasing numbers of scholars concentrate on the diversity in internet usage among older adults, e.g., [31, 48–50]. However, to the best of our knowledge, no previous studies have explored the connection between multidimensional frailty and variations in internet use among older adults. Hence, using a categorization into non-, basic-, selective-, and allround internet use among older adults and using representative data collected between 2016 and 2021 from people aged 60 and older in Belgium (n = 2,312), the objective of this study is to examine the association between multidimensional frailty and internet use.

Materials and methods

Data collection and participants

The data for this study span the years 2016 to 2021 and originate from the Belgian Ageing Studies (BAS). BAS is a largescale cross-sectional survey study conducted in Flanders (the Dutch-speaking part of Belgium). Since 2004, data for the BAS have been collected using a standardized self-administered questionnaire that examines various aspects concerning the quality of life and living conditions of individuals aged 60 and older residing in their own homes (older individuals living in residential care facilities are not part of the study). In each municipality, a sample of individuals aged 60 and above is randomly chosen from municipal registers, with stratification based on age and gender. Age classification follows WHO guidelines, segmenting participants into three subgroups: 60–69 years, 70–79 years and 80 years or older [51]. This sampling procedure ensures alignment with the underlying population, with particular attention to adequately representing the 80+ age group, a demographic often overlooked in previous studies on internet use (e.g., Eurostat applies a threshold at the age of 75 when reporting internet usage statistics).

Since 2004, data collection has been based on the principles of peer research. Thereby, older people are involved as voluntary partners in the data collection process. After training, the volunteers visit older persons who are assigned to them, invite the respondents to participate in the research project and hand over the questionnaire. Although the questionnaire was designed to be self-administered, volunteers are allowed to clarify questions or provide help, if requested. Participants were informed about the voluntary, anonymous and confidential nature of the study and their right to decline participation or answer any questions. In cases of refusal or inability to participate, replacement addresses within the same age and gender strata were provided. The study protocol was approved by the ethical committee of the Vrije Universiteit Brussel (B.U.N. 143201111521).

Internet use

The original BAS-questionnaire, established in 2004, initially covered four internet activities: searching information, email correspondence, communication with (grand)children and interaction with e-government services. By 2010, the questionnaire was expanded to include three additional variables, encompassing internet usage for social media, telecommunications, and online shopping. Furthermore, in 2016, two supplementary items were incorporated into the questionnaire, one regarding internet usage for banking purposes and the other for administration-related purposes. All internet activities were evaluated

using a binary scale, where 0 indicated non-use and 1 indicated usage. In a previous study, we used the 2016–2021 data precisely because this wave provided the most comprehensive measurement of internet behaviors. Based on these data, we developed and validated the previously mentioned internet typology (using both Two-step Cluster Analysis and Latent Class Analysis), which categorizes older adults as non-users, basic users, selective users and allrounders [52]. The first group comprises older adults who abstain from internet usage, whereas basic users primarily employ the internet for traditional purposes such as information search and email correspondence. Positioned between basic users and allrounders, selective users predominantly employ the internet for tasks like information search, email communication, online banking, and interaction with (grand)children. Allrouders engage in almost all of the examined internet activities, including information search, email communication, online banking, interaction with (grand)children, accessing e-government services, social media engagement, administrative tasks, online shopping, and telecommunication. More information on the internet typology can be found in Table S1. In the present study, we build on that typology and use the same dataset to analyze the association between internet use profiles and frailty.

Frailty

The Comprehensive Frailty Assessment Instrument (CFAI) was utilized to assess multidimensional frailty. The CFAI is a self-administered instrument consisting of 23 items measuring four domains of frailty. The physical domain of frailty evaluates the degree to which respondents are hindered by their health status in performing physical activities (e.g., walking up a hill or stairs). The psychological domain assesses mood disorders (e.g., losing self-confidence) and emotional loneliness (e.g., experiencing a general sense of emptiness). Similarly, social frailty includes two components: social loneliness (e.g., having enough people feeling close to) and social support, assessing the persons respondents could rely on for help if necessary. Finally, the environmental domain evaluates respondents' actual housing and environmental conditions. A full description of the CFAI can be found in De Witte and Gobbens et al. [42].

Scores for each of the four frailty domains ranged from 0 to 25, with higher scores indicating higher frailty [43]. The total frailty score was obtained by summing the four frailty domain scores, resulting in a score ranging from 0 to 100. The higher the score, the frailer the respondent. Based on the authors' instructions, frailty scores (0–25) were classified into three classes (no-low frail, mild frail and high frail) [53]. The CFAI was previously validated using a second-order confirmatory factor analysis and was cross-validated against the Tilburg Frailty Indicator [42, 43].

Sociodemographic variables

Age, educational level, net monthly household income, gender and living together with a partner were included as covariates. Age was assessed as a continuous variable and, consistent with the stratified sampling approach, was recategorized into three categories: 60–69 years old, 70–79 years old and 80 years and older. Educational attainment was divided into four categories: no degree or primary education, lower secondary, higher secondary and higher education. Net monthly household income was segmented into three groups: < €1,500, €1,500–1,999 and ≥ €2,000. Gender was assessed as a binary variable (0 = men, 1 = women). Lastly, cohabitation status was evaluated as a dichotomous variable (0 = no partner, 1 = living with a partner).

Data analysis

First, we applied listwise deletion, resulting in a final sample of 2,312 respondents with complete data on all variables included in the analyses. Second, descriptive statistics were used to examine respondents' characteristics (presented in Table 1) and frailty status (presented in Table 2). Third, Chi-square analyses (presented in Table 3) and multinomial logistic regression analyses (presented in Table 4) were performed to assess associations between multidimensional frailty and the typology of non-, basic-, selective- and allround-use. Multinomial logistic regression, which simultaneously considers two or more independent variables, is an extension of bivariate regression used to predict the value of a dichotomous dependent variable [54]. If the dependent variable has more than two categories, multinomial logistic regression

analysis is used [55]. Compared to multivariate logistic regression analysis, multinomial logistic regression does not make any assumptions for the independent variables [56]. The reference category plays the same role in multinomial logistic regression as in the dummy-coding of a logistic regression analysis. It is arbitrary to decide which category is designated as the reference category [57]. Changing the reference category does not change the model structure, but it does change the values and interpretation of the parameter estimates in the model [58]. In this study, 'selective internet use' was selected as the reference group since it contained the largest number of individuals, meaning that Table 4 presents the probabilities of being a non-, basic- or allround-user rather than a selective user. The validity of the model was measured through McFadden's pseudo R^2. Gender, age, education, income and living together with a partner were included as control variables.

Additionally, we investigated how frailty and sociodemographic variables interact and how they collectively influence variations in internet use. A conventional statistical method for exploring such interactions involves incorporating interaction terms into regression analyses [59]. However, including an excessive number of interaction terms in a regression model is impractical as it increases the number of coefficients to be estimated and significantly reduces the statistical power to generate reliable results [60]. Therefore, Berger and Berger [61] suggest to apply a data mining approach which allows to automatically discover interrelationships and meaningful patterns in data. In this study, we employed the data mining technique Chi-squared automatic interaction detection (CHAID) to investigate the interactions between frailty and sociodemographic variables and examine how these factors collectively influence internet use among older adults. The CHAID method is a classification tree technique in which the most impactful explanatory variable of the outcome variable segregates the entire sample into two or more distinct subgroups. Subsequently, these subgroups are further partitioned by the subsequent most influential predictor, with this process repeating iteratively until no further meaningful associations between independent variables and the target variable are identified [62, 63]. The results of this analysis are presented in an upside-down tree structure (illustrated in Figures 1 and 2) to visualize the interrelationship among the explanatory variables [63]. All statistical analyses were performed using SPSS 29.0 (IBM, SPSS, Armonk, NY: IBM Corp). The threshold for statistical significance was set at $p \leq 0.05$.

Results

Respondents' characteristics

Table 1 presents descriptive statistics for the sample. Of the respondents, 50.7% were women. In terms of age distribution, 48.6% were between 60 and 69 years old, 31.4% were aged 70–79 and 20.0% were 80 years or older. Regarding educational background, 16.5% had no degree or only primary education, whereas 28.9% had attained higher education. A net monthly household income of €2,000 or more was reported by 52.1% of the respondents. Furthermore, 73.6% were in a cohabiting relationship. Regarding internet use, 74.3% of the respondents were categorized as internet users, which included basic users (19.0%), selective users (34.8%) and allrounders (20.5%).

Regarding frailty scores, 18.1% of the respondents scored high on total frailty. When examining the frailty subdomains, 11.1% scored high on physical frailty. Similarly, for environmental frailty, 12.9% were rated as highly frail. In terms of psychological frailty, 8.0% of the respondents were classified as highly frail. Finally, 20.9% scored high on social frailty. All frailty prevalence rates can be found in Table 2.

Associations between multidimensional frailty and internet use

We performed Chi-square tests to explore associations between frailty scores and the typology of non-, basic-, selective- and allround-use of the internet. Results are reported in Table 3.

For all frailty domains, as well as total frailty, the percentage of non-users was consistently higher in the high frailty groups compared to the mild and low frailty groups. Similarly, the high and mild frail groups had higher proportions of basic users than those in the low frailty groups. In contrast, the high frailty groups had lower proportions of selective users and allrounders than those in the mild or low frailty groups.

Table 1. Respondents' sociodemographic characteristics and their internet use (*n* = 2,312)

Characteristics	*n*	%
Gender		
Men	1,139	49.3
Women	1,173	50.7
Age (year)		
60–69	1,123	48.6
70–79	727	31.4
80+	462	20.0
Educational level		
No degree or primary	381	16.5
Lower secondary	650	28.1
Higher secondary	613	26.5
Higher education (university college/university)	668	28.9
Net monthly household income		
< €1,500	635	27.5
€1,500–1,999	473	20.5
≥ €2,000	1,204	52.1
Living together with a partner		
Yes	1,702	73.6
No	610	26.4
Internet use between 2016 and 2021		
Non-user	594	25.7
Basic user	440	19.0
Selective user	805	34.8
Allrounder	473	20.5

Table 2. Respondents' frailty status (*n* = 2,312)

Frailty status	*n*	%
Physical frailty		
No-low	1,641	71.0
Mild	415	17.9
High	256	11.1
Psychological frailty		
No-low	1,545	66.8
Mild	582	25.2
High	185	8.0
Social frailty		
No-low	572	24.7
Mild	1,257	54.4
High	483	20.9
Environmental frailty		
No-low	1,324	57.3
Mild	690	29.8
High	298	12.9
Total frailty		
No-low	1,071	46.3
Mild	823	35.6
High	418	18.1

Table 3. Associations between older adults' frailty status and the typology of non-, basic-, selective- and allround-use of the internet (*n* = 2,312)

Frailty status	Non-user		Basic user		Selective user		Allrounder	
	n	%	*n*	%	*n*	%	*n*	%
Physical frailty								
No-low	301	18.3	300	18.3	638	38.9	402	24.5
Mild	163	39.3	89	21.4	118	28.4	45	10.8
High	130	50.8	51	19.9	49	19.1	26	10.2
χ^2 (*p*-value)	204.715 ($p < 0.001$)							
Psychological frailty								
No-low	338	21.9	291	18.8	576	37.3	340	22.0
Mild	171	29.4	116	19.9	185	31.8	110	18.9
High	85	45.9	33	17.8	44	23.8	23	12.4
χ^2 (*p*-value)	60.815 ($p < 0.001$)							
Social frailty								
No-low	131	22.9	87	15.2	200	35.0	154	26.9
Mild	298	23.7	236	18.8	465	37.0	258	20.5
High	165	34.2	117	24.2	140	29.0	61	12.6
χ^2 (*p*-value)	61.009 ($p < 0.001$)							
Environmental frailty								
No-low	309	23.3	243	18.4	488	36.9	284	21.5
Mild	173	25.1	141	20.4	232	33.6	144	20.9
High	112	37.6	56	18.8	85	28.5	45	15.1
χ^2 (*p*-value)	30.535 ($p < 0.001$)							
Total frailty								
No-low	160	14.9	182	17.0	436	40.7	293	27.4
Mild	235	28.6	170	20.7	275	33.4	143	17.4
High	199	47.6	88	21.1	94	22.5	37	8.9
χ^2 (*p*-value)	219.0 ($p < 0.001$)							

We further investigated the relationship between the four frailty domains and internet use, using multinomial logistic regression analysis controlling for sociodemographic characteristics. The results can be found in Table 4. Regression analysis showed that respondents scoring mild on physical frailty were more likely to be internet non-users (OR = 1.665) and those scoring high on the physical frailty domain were more likely to be internet non-users and basic users (respectively OR = 2.195 and OR = 1.553). Similarly, high social frailty was associated with higher odds of being a basic user (OR = 1.811) and lower probabilities of allround internet use (OR = 0.590). Those scoring mild on social frailty were also less likely to be allround internet users (OR = 0.727). Finally, high environmental frailty was associated with higher odds of non-use (OR = 1.554).

Regarding the sociodemographic factors, men were less likely to be non-users and basic users (respectively OR = 0.675 and OR = 0.758) and more likely to be allround users (OR = 1.563). Concerning respondents' age, those aged 70–79 and 80 years or older were more likely to be non-users (respectively OR = 2.525 and OR = 9.768) and basic users (respectively OR = 1.411 and OR = 3.011), with those aged 80+ less likely to be allround users as well (OR = 0.293). Having a higher education diploma was linked to lower odds of non-use (OR = 0.217) and basic use (OR = 0.538) and greater likelihood of allround use (OR = 1.621). In contrast, lower education levels (no diploma or only primary education) were associated with higher odds of non-use and basic use (respectively OR = 3.599 and OR = 2.277). Lastly, lower monthly household income (< €1,500 or €1,500–1,999) was associated with lower odds of allround use (respectively OR = 0.554 and OR = 0.555), and income below €1,500 increased the odds of non-use (OR = 2.032).

Table 4. Associations between older adults' frailty status and the typology of non-, basic-, selective- and allround-use of the internet (*n* = 2,312)

Characteristics	Non-user versus selective user					Basic user versus selective user					Allrounder versus selective user				
	B	OR	Sig.	Lower	Upper	B	OR	Sig.	Lower	Upper	B	OR	Sig.	Lower	Upper
Intercept	–1.552		***			–1.008		***			–0.457		*		
Gender (ref.: female)															
Male	–0.392	0.675	**	0.520	0.878	–0.277	0.758	*	0.592	0.970	0.447	1.563	***	1.227	1.990
Age (years, ref.: 60–69)															
70–79	0.926	2.525	***	1.879	3.392	0.344	1.411	*	1.076	1.851	–0.248	0.780	0.063	0.600	1.013
80+	2.279	9.768	***	6.814	14.004	1.102	3.011	***	2.107	4.304	–1.226	0.293	***	0.170	0.506
Educational attainment (ref.: lower secondary)															
No degree or primary	1.281	3.599	***	2.453	5.279	0.823	2.277	***	1.513	3.427	–0.311	0.733	0.291	0.412	1.305
Higher secondary	–0.571	0.565	***	0.409	0.781	–0.114	0.892	0.471	0.655	1.216	0.144	1.155	0.388	0.833	1.603
Higher education	–1.530	0.217	***	0.147	0.320	–0.620	0.538	***	0.386	0.749	0.483	1.621	**	1.193	2.204
Income (ref.: ≥ €2,000)															
< €1,500	0.709	2.032	***	1.451	2.847	0.069	1.071	0.689	0.765	1.498	–0.591	0.554	**	0.381	0.806
€1,500–1,999	0.158	1.171	0.361	0.835	1.644	–0.049	0.952	0.761	0.695	1.305	–0.590	0.555	***	0.397	0.775
Partner (ref.: yes)															
No partner	0.283	1.326	0.083	0.964	1.825	–0.006	0.994	0.969	0.719	1.373	0.186	1.204	0.284	0.857	1.692
Physical frailty (ref.: no-low)															
Mild	0.510	1.665	**	1.207	2.298	0.247	1.280	0.135	0.926	1.769	–0.334	0.716	0.085	0.490	1.048
High	0.786	2.195	***	1.442	3.340	0.440	1.553	*	1.011	2.415	0.088	1.092	0.737	0.653	1.827
Psychological frailty (ref.: no-low)															
Mild	0.059	1.060	0.706	0.782	1.438	0.008	1.008	0.958	0.753	1.349	0.183	1.201	0.216	0.898	1.606
High	0.174	1.191	0.486	0.729	1.945	–0.170	0.844	0.526	0.499	1.427	0.291	1.338	0.317	0.757	2.365
Social frailty (ref.: no-low)															
Mild	–0.056	0.945	0.733	0.685	1.304	0.136	1.145	0.387	0.842	1.558	–0.319	0.727	*	0.555	0.952
High	0.390	1.477	0.052	0.996	2.190	0.594	1.811	**	1.240	2.644	–0.527	0.590	**	0.399	0.874
Environmental frailty (ref.: no-low)															
Mild	0.194	1.214	0.197	0.904	1.630	0.217	1.242	0.120	0.945	1.632	0.000	1.000	0.998	0.766	1.305
High	0.441	1.554	*	1.065	2.268	0.139	1.150	0.484	0.778	1.699	0.035	1.035	0.868	0.688	1.558
McFadden R^2	0.165														

B = unstandardized regression coefficient, CI = confidence interval, OR = odds ratio, Sig. = significance. Levels of significance: *** $p \leq 0.001$, ** $p \leq 0.01$, * $p \leq 0.05$

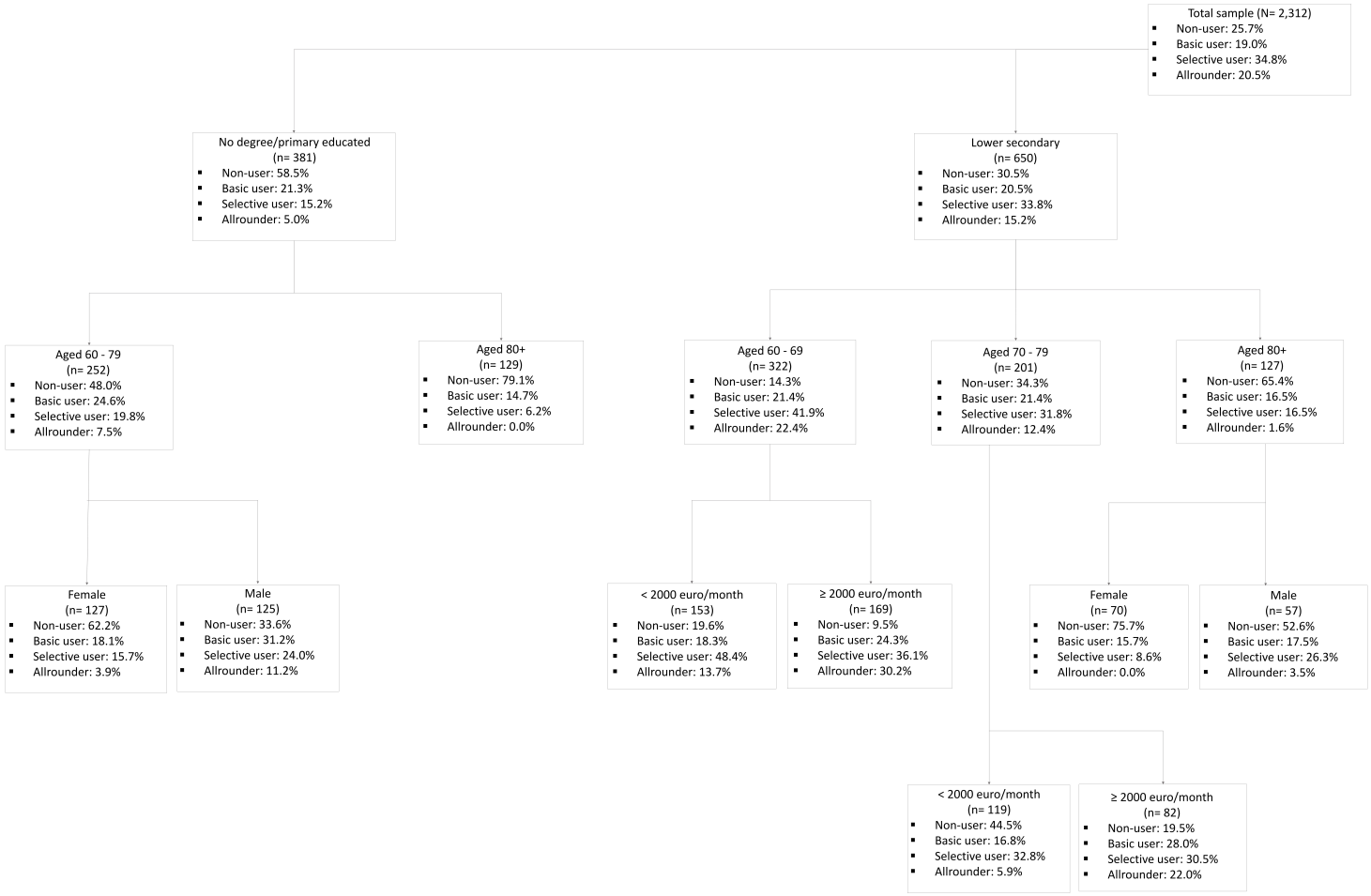

Figure 1. CHAID classification tree (left part of the CHAID tree structure) showing associations between internet use and frailty and sociodemographic characteristics (all splits are significant at $p \leq 0.001$)

Furthermore, CHAID analysis was applied to investigate the relationship between frailty and sociodemographic characteristics and to understand their joint associations with internet use. As depicted in the decision tree diagrams (see Figures 1 and 2), education was positioned in the initial layer, emerging as the principal determinant of internet use. Age emerged as the second most crucial variable, shaping the splits in the subsequent layer of the decision tree. Furthermore, income and gender were sociodemographic predictors in the third layer of the decision tree and, in doing so, were less strongly associated with internet use than education and age.

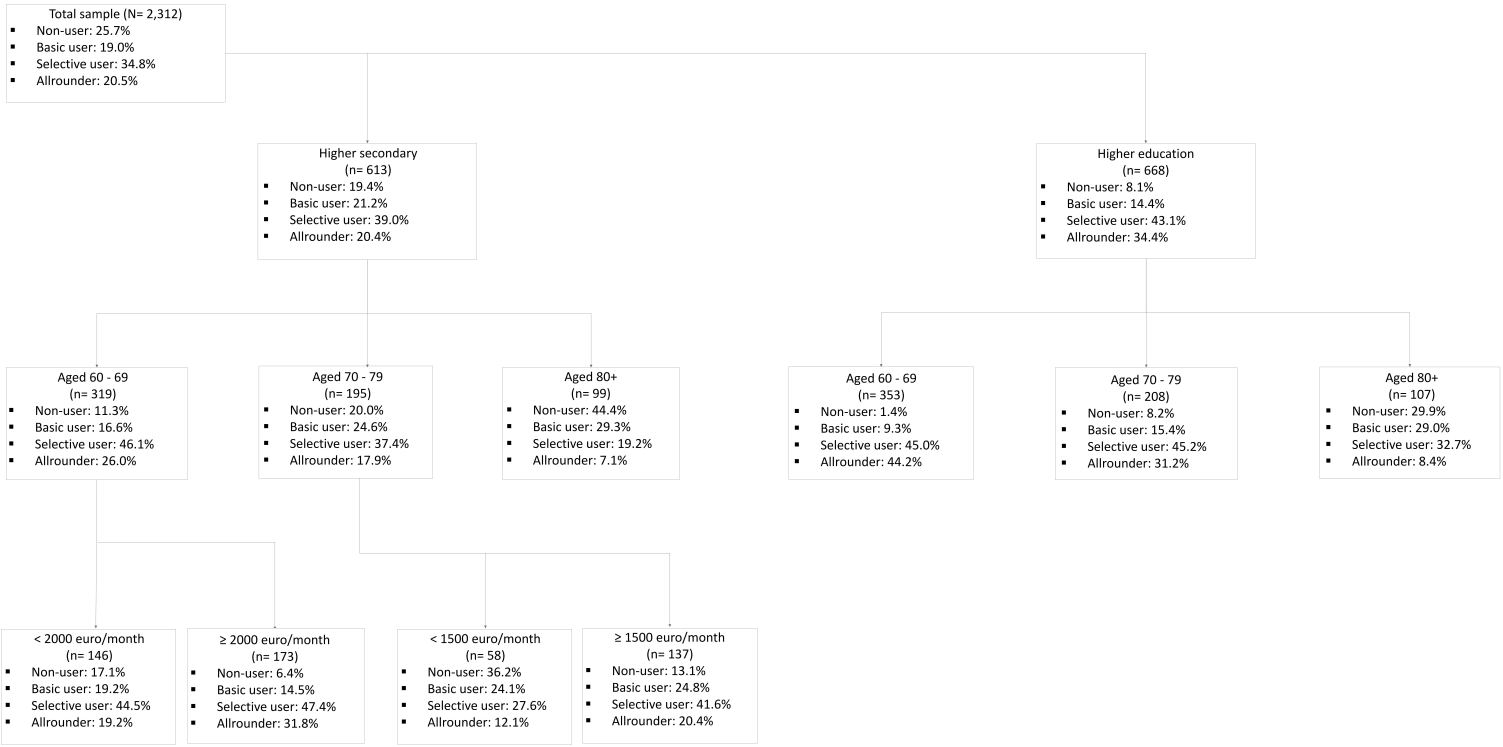

Figure 2. CHAID classification tree (right part of the CHAID tree structure) showing associations between internet use and frailty and sociodemographic characteristics (all splits are significant at $p \leq 0.001$)

With regard to frailty, the physical, psychological, social and environmental domains did not appear in the CHAID classification tree and, thus, are less strongly associated with the typology of internet use.

Discussion

Nowadays, the internet is an integral part of everyday life and supports older individuals in successfully ageing in place [13–15]. In the context of frailty among older adults, it offers opportunities to implement online frailty detection applications and frailty training packages, thereby helping to maintain their health [64–66]. However, the extent to which frail older adults engage in internet use remains unclear. Therefore, this study utilized data from the BAS, which included 2,312 individuals aged 60 and older, and performed multinomial logistic regression analysis and CHAID analysis to investigate how frailty relates to a typology of non-, basic-, selective- and allround internet users [52]. Regression analysis revealed that older individuals scoring mild or high on physical frailty, as well as those scoring high on environmental frailty, were more inclined to be internet non-users. Similarly, scoring high on physical frailty, but also scoring high on social frailty,

was associated with higher probabilities of being a basic user. Social frailty also correlated with allround internet use, with the mild and high frailty groups being less likely to fall into this category.

The finding that physical frailty correlates with internet non-use and basic use aligns with previous research emphasizing that physical changes, such as declining fine motor skills, deteriorating eyesight or hearing impairment, can pose significant challenges to effectively engage with internet technologies [67–70]. Therefore, this result serves as a call for technology developers and interface designers to prioritize the creation of internet technologies tailored to the needs of aging populations to maximize internet usage equity. It becomes paramount to actively involve older adults in the development of internet technologies that are user-friendly, accommodate physical limitations and improve accessibility and ease of use to harness the benefits they offer. Indeed, as emphasized by Wilson-Menzfeld and Brittain [71], internet technologies must be accessible and usable to ensure they can be utilized by as many people as possible. This becomes especially critical as society increasingly integrates technologically, with many institutions such as shops, banks and public authorities transitioning from onsite to online services [72, 73].

The result indicating that environmental frailty was associated with higher probabilities of being an internet non-user is consistent with Dequanter and Gorus et al. [74] who revealed a negative correlation between environmental frailty and internet use. The authors note that environmental frailty, encompassing aspects of poor-quality housing and deprived living environments, is interrelated with socioeconomic status. This may (partially) explain the link between the environmental frailty domain and internet non-use. However, our study demonstrated that, even after adjusting for sociodemographic factors such as income level, the association between environmental frailty and internet non-use persists.

Similarly, the relationship between social frailty and high probabilities of basic internet use, as well as low probabilities of being an allround internet user, remained significant after controlling for sociodemographic variables. Given that the social frailty domain encompasses social loneliness—indicating a lack of adequate broad social networks—and social support networks, individuals scoring high on social frailty may lack the social connections and relatives necessary to support them in internet use. Indeed, Geerts and Schirmer et al. [75], who examined how to support older adults with their internet technology use, found that family and other social ties serve as primary sources of motivation and reasons for the adoption of (internet) technologies. They argue that older adults may find motivation to embrace technology when encouraged and supported by their informal network, and they may be further inspired to adopt these technologies when their network actively utilizes them, providing them with the opportunity to discover potential benefits. In this context, a lack of support can adversely affect digital engagement. This aligns with the finding that socially frail older individuals are less likely to be allround internet users and more inclined to remain at the level of basic internet use. Moreover, social networks may also encourage older individuals to stay up to date and try new internet activities or services [75], which, once again, can explain the association between high social frailty and low probabilities of allround internet use.

Although regression analysis revealed associations between the physical, social and environmental frailty domains and internet use, with the mild and high frailty groups being less internet savvy, our results should not be interpreted as evidence that frail older adults are incapable of learning new skills and using internet technologies. Bivariate analysis indicated that 26.3% of individuals scoring mild or high on total frailty managed to become allround internet users. Moreover, CHAID analysis demonstrated that frailty factors are not the primary determinants of internet use, as sociodemographic variables are more strongly associated with the internet use typology. Specifically, educational level and age emerged as the strongest and second-strongest factors, respectively, in determining whether someone is a non-, basic-, selective- or allround-user. In this regard, our results align with previous research indicating that diversity in internet use among older adults can be attributed to personal factors (e.g., age) and positional inequalities (e.g., education or employment). Indeed, these factors are linked to the unequal distribution of social and material resources, including internet access, resulting in disparities in internet skills and usage [76].

The finding of associations between sociodemographic and internet use inequalities underscores the need for policies that address barriers preventing individuals from becoming allround internet users. This

includes strategies enabling those with low income levels to afford internet infrastructure, as well as internet training programs designed to meet the needs of older individuals with limited educational backgrounds.

Limitations

This study has some limitations that need to be acknowledged. First, its cross-sectional design limits the ability to draw causal conclusions and prevents us from identifying changes in internet use and its association with frailty over time. Therefore, future research should adopt a longitudinal design to investigate how this relationship evolves, considering that today's and future generations of older adults may differ significantly in digital experience from previous cohorts.

Second, this study relied on self-reported data. However, the questionnaire includes validated instruments, such as the CFAI, that are specifically designed for self-assessment and have demonstrated reliability in previous research.

Third, as internet usage is progressively transitioning to mobile technology, future research should also focus on these emerging media. Mobile devices may present usability advantages or pose different accessibility challenges compared to traditional desktops. Therefore, it should be investigated how frailty relates specifically to the use of smartphones, tablets and other mobile devices, and how mobile technologies may support or hinder internet use in this population. More broadly, future studies should incorporate the technological context by examining how evolving digital infrastructure and interface innovations shape the relationship between frailty and internet use.

Fourth, some associations yielded confidence intervals that bordered on statistical significance. These findings may indicate underlying trends that warrant further investigation. Therefore, we recommend replication in future studies to determine whether these associations hold in different samples and settings. Furthermore, such replication studies should also examine how internet use profiles have evolved—particularly in the post-COVID context—and how these profiles relate to older adults' frailty status.

Conclusion

This study demonstrates that physical, social and environmental frailty are associated with lower levels of internet use among older adults, with frail individuals more likely to be non-users or basic users and less likely to be allround users. However, sociodemographic factors, particularly education and age, emerged as stronger predictors of internet use profiles. These findings highlight the importance of not only designing age- and frailty-friendly digital technologies but also addressing broader social inequalities that hinder digital inclusion.

Abbreviations

BAS: Belgian Ageing Studies

CFAI: Comprehensive Frailty Assessment Instrument

CHAID: Chi-squared automatic interaction detection

Supplementary materials

The supplementary table for this article is available at: https://www.explorationpub.com/uploads/Article/file/101159_sup_1.pdf.

Declarations

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Author contributions

JC: Conceptualization, Methodology, Formal analysis, Writing—original draft. PtB: Conceptualization, Formal analysis, Writing—review & editing. MNA: Writing—review & editing. NDW: Conceptualization, Data curation, Investigation, Methodology, Supervision, Writing—review & editing. All authors read and approved the submitted version.

Conflicts of interest

The authors declare that they have no conflicts of interest.

Ethical approval

This study was approved by the ethical committee of the Vrije Universiteit Brussel (B.U.N. 143201111521).

Consent to participate

Informed consent to participate in the study was obtained from all participants.

Consent to publication

Not applicable.

Availability of data and materials

The data analyzed in this study was obtained from the Belgian Ageing Studies (BAS). The dataset is not publicly available because access is restricted to protect the integrity of the research and comply with BAS's data governance policies. For further discussion regarding this study, please contact the corresponding author.

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