Submitted: 20 November, 2025 Accepted: 12 January, 2026 Published: 30 May, 2026 DOI:10.22514/jomh.2026.040

ORIGINAL RESEARCH

JOMH Journal of Men's Health

The relationship between functional dependency and social isolation among older men: the moderating role of digital competence

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Abstract

Background: Social isolation has become an urgent public health concern in aging societies, yet the unique vulnerabilities of older men remain understudied. This study examined the association between functional dependency, assessed using activities of daily living (ADL) and instrumental activities of daily living (IADL), and social isolation among older men, and whether digital utilization moderates it. **Methods**: This cross-sectional secondary analysis used data from 3779 male participants aged 65 years and older (mean age ± standard deviation (SD), 74.0 ± 6.5 years) from the 2023 National Survey of Older Koreans. Social isolation was defined as nonparticipation in social activities. Functional dependency was assessed through ADL and IADL scales and categorized into four functional subdomains based on the International Classification of Functioning (ICF) framework: mobility, self-care, domestic life, and cognitive-social activities. Binary logistic regression and moderation analyses using the PROCESS macro were performed to identify the main and interaction effects between functional dependency and digital utilization. **Results**: Both ADL dependency (adjusted odds ratio (OR) = 1.86, 95% confidence interval (CI) = 1.40–2.48, $p < 0.001$) and IADL dependency (adjusted OR = 1.37, 95% CI = 1.10–1.69, $p = 0.005$) were significantly associated with social isolation. Among functional subdomains, mobility (adjusted OR = 2.02) and self-care (adjusted OR = 1.71) showed the strongest associations. Digital utilization demonstrated a significant moderating effect on the relationship between ADL dependency and social isolation (B = 0.52, $p = 0.017$), indicating that higher digital competence attenuated the negative impact of functional decline. **Conclusions**: Functional dependency, particularly in mobility and self-care, is a critical determinant of social isolation among older men. Digital utilization serves as a protective resource, buffering the risk of social isolation associated with physical decline. These findings underscore the need for integrated interventions that enhance physical independence and digital engagement.

Keywords

Older men; Social isolation; Activities of daily living (ADL); Instrumental activities of daily living (IADL); Digital utilization; Moderation effect

1. Introduction

The transition into a super-aged society highlights the growing importance of ensuring quality of life and social integration for older adults, making it a critical national challenge [1]. The continuous increase in the older population not only represents demographic change but also poses a qualitative challenge related to changes in the quality of social relationships and social participation in later life, in line with global policy frameworks that emphasize healthy ageing and quality of life [2]. In particular, social isolation among older adults has emerged as a key social risk factor that requires urgent attention in aging societies [3]. In this context, theoretical frameworks that emphasize social participation and integration provide a useful conceptual basis for understanding pathways through which social isolation may be mitigated and quality of life maintained among older adults. According to activity theory, older adults can compensate for lost social roles through active social engagement, thereby maintaining life satisfaction and health [4, 5]. From this perspective, social participation and social integration have been identified as key factors that reduce depression and cognitive decline [6, 7], while improving life satisfaction and subjective health among older adults [8–11]. In contrast, social isolation among older adults goes beyond the mere reduction of social networks and is associated with a wide range of adverse outcomes, including mental

health problems such as depression and cognitive decline [12–14], physical impairment and disability [15, 16], and even increased premature mortality [17–19]. Previous studies have consistently identified several risk factors for social isolation, including advanced age, low income, lower educational attainment, unemployment, and declines in activities of daily living (ADL) and instrumental activities of daily living (IADL) [3, 16, 20, 21].

Among various demographic characteristics, gender differences play a significant role in shaping social isolation. Previous reviews have identified gender, along with marital status, educational attainment, and social support, as factors associated with social isolation and loneliness in later life [22, 23]. Thus, prior research has frequently examined gender differences in social isolation and loneliness in later life, although findings have been mixed and much of the evidence has been generated within gender-comparative designs rather than studies focusing specifically on older men [24]. Regarding loneliness, prior work has discussed potential gender differences, but empirical findings remain inconsistent [25]. Men tend to experience a more abrupt contraction of social networks following retirement, as work-related social ties diminish, which can exacerbate the impact of isolation. In studies conducted among Korean older adults, men showed a sharper decline in social interactions before and after retirement compared to women [26]. Similarly, U.S.-based data have indicated that older men are more vulnerable to both social isolation and severe isolation [3]. Recent research has emphasized the necessity of examining gender-specific differences when analyzing the relationship between social isolation and mortality [19], underscoring the academic importance of focusing specifically on social isolation among older men.

The occurrence and intensification of social isolation cannot be fully explained by the reduction of social networks alone [9, 27]. Social participation in later life is heavily influenced by physical and cognitive functions, particularly the ability to perform daily activities independently [28]. ADL and IADL are widely recognized as essential indicators of autonomy and functional capacity among older adults, and declines in these capacities have been consistently associated with reduced quality of life [29–31]. Earlier studies primarily classified independence and dependence based on total ADL/IADL scores [32, 33], but recent research has highlighted the importance of analyzing these functions across subdomains [34]. The International Classification of Functioning, Disability and Health (ICF) developed by the World Health Organization [35] categorizes daily functioning into mobility, self-care, domestic life, and cognitive and social activities, providing a more refined framework for understanding social participation and quality of life among older adults [36]. In contemporary society, digital literacy and utilization have become critical mediating factors in maintaining and expanding social relationships among older adults [37]. Digital technologies such as smartphones, messaging platforms, and social media transcend physical limitations, extend social connectedness, and complement traditional offline networks, thereby promoting social integration [38]. Furthermore, digital utilization functions as a protective factor by mitigating the social disconnection caused by functional limitations and by facilitating opportunities for social interaction [39].

Therefore, the present study aimed to examine the effects of ADL and IADL dependence on social isolation among older men, to identify risk factors within specific functional subdomains, and to investigate whether digital utilization moderates these relationships. The findings are expected to provide multidimensional intervention strategies and policy implications to alleviate social isolation in aging societies. Based on previous empirical evidence, we hypothesized that higher levels of ADL and IADL dependence would be associated with greater social isolation among older men (Hypothesis 1). We further hypothesized that digital device utilization would moderate the associations between functional dependence and social isolation (Hypothesis 2).

2. Materials and methods

2.1 Study population and data collection

This study conducted a secondary analysis using raw data from the 2023 National Survey of Older Koreans, which was jointly administered by the Ministry of Health and Welfare and the Korea Institute for Health and Social Affairs. The survey, implemented every three years in accordance with Article 5 of the Welfare of the Aged Act, is a nationally approved statistical investigation targeting adults aged 65 years or older residing in general housing across all 17 metropolitan and provincial regions of South Korea. It collected comprehensive information on older adults' sociodemographic characteristics, health status, functional ability (including ADL and IADL), social relationships and participation, digital device utilization, economic conditions, and living arrangements. The sample was designed using a stratified cluster sampling method based on the 2021 Population and Housing Census. Data collection was carried out through face-to-face interviews between September and November 2023. Among the eligible respondents, the analytical sample comprised older adults aged 65 to 98 years, with a mean age of 74.0 $\pm$ 6.5 years. All measures were administered using standardized Korean-language survey instruments employed in the National Survey of Older Koreans, in accordance with official survey guidelines. Cases with missing or inapplicable responses on major variables and potential confounders, including components of social isolation and digital device utilization, were excluded from the analysis. Thus, 3779 participants were included in the final analysis.

2.2 Measures

2.2.1 Social isolation

The social isolation index was derived in line with established population-based research that conceptualizes social isolation as a multidimensional construct reflecting marital status, living arrangements, social contact, and participation in social activities [3, 9, 15, 40]. In this study, lower scores were defined to indicate higher levels of social isolation. A score of 0 was assigned when the participant met any of the following conditions: being unmarried (separated, divorced, widowed, or never married), living alone, having less than contact (face-to-face, telephone, or written/email contact) with each of chil-

dren, other relatives, or friends, and not participating in any social activities during the past month, such as meeting friends, playing games, or attending sports or social clubs, community organizations, or religious activities. The total score ranged from 0 to 4, and participants with scores <2 were classified as socially isolated.

2.2.2 ADL/IADL dependency

In this study, functional independence was assessed using the ADL and IADL scales. The ADL scale consisted of seven items, including dressing, washing the face, and brushing teeth or hair, bathing, or showering, eating prepared meals, getting out of bed, and moving outside the room, using, and cleaning the toilet, and controlling urination and defecation [30]. The IADL scale was measured with ten items covering meal preparation, laundry, money management, shopping, using the telephone, transportation, household chores, personal grooming, taking medication, and short-distance outings [31]. Each item asked, "During the past week, did you need any assistance from another person in performing this activity?", with responses recorded on a three-point scale ("complete independence", "partial assistance", and "full assistance"). Participants who reported "complete independence" on all items were classified as independent in ADL or IADL, whereas those who reported "partial assistance" or "full assistance" on one or more items were classified as dependent in ADL or IADL. In the present study, the ADL and IADL scales demonstrated good internal consistency, with Cronbach's α values of 0.839 and 0.891, respectively.

2.2.3 Subdomains of functional dependency

To examine the characteristics of functional decline in greater detail, the ADL and IADL items were reclassified into four functional subdomains with reference to the conceptual framework of the ICF developed by the World Health Organization [35]: mobility, self-care, domestic life, and cognitive-social activities. In particular, the ICF category of "community, social and civic life" was used as a conceptual reference to organize ADL and IADL items related to cognitive, interpersonal, and social functioning, and this subdomain was operationally labeled as "cognitive-social activities" for the purposes of the present analysis. For each subdomain, participants who reported "complete independence" on all corresponding items were classified as independent, while those who required any level of assistance on one or more items were classified as dependent. The detailed items and classification criteria are presented in **Supplementary Table 1**. The internal consistency of the functional subdomains was acceptable to good, with Cronbach's α values of 0.676 for mobility, 0.841 for self-care, 0.867 for domestic life, and 0.818 for cognitive-social activities.

2.2.4 Digital device utilization level

Digital competence was measured to examine the ability of older adults to operate various electronic devices in daily life. Thirteen binary items were used to assess the use of a mobile phone, computer, smartwatch, and kiosk, as well as functions such as sending or receiving messages, searching for information, taking photos or videos, listening to music, playing games, watching videos, using social networking services (SNS), conducting online shopping or financial transactions, installing applications, and placing orders through a kiosk. Each item was scored as 1 point for a "yes" response and 0 points for a "no" response, and the total score was classified into three levels as low ($\leq$3 points), moderate (4–7 points), and high ($\geq$8 points). The digital competence measure demonstrated good internal consistency in the present data set, with a Cronbach's alpha of 0.882.

2.2.5 Confounding variables

To account for potential confounding effects, the models were adjusted for major covariates and potential confounders that could influence social isolation. Age was categorized into two groups, 65–74 years and 75 years or older, based on the criterion commonly used to distinguish early- and late-stage older adults [41, 42]. Educational level was divided into two categories, middle school or below and high school or above. Residential area was classified as urban or rural. Household income was grouped into three categories representing less than 50% of the median income, 50–99%, and 100% or more of the median income. Employment status was defined based on whether the respondent was currently employed. Health-related covariates included subjective health status (good, fair, or poor) and the number of chronic diseases (0–1 *vs.* $\geq$2). These covariates were selected based on bivariate analyses presented in the manuscript, which showed significant associations between social isolation and most sociodemographic, health-related, and functional characteristics. In addition, residential area (urban *vs.* rural) was included as a covariate based on the literature suggesting that residential context may influence social networks and social isolation among older adults [43, 44].

2.3 Statistical analysis

Descriptive and chi-square (χ^2) analyses were conducted to compare general and functional characteristics according to social isolation status. To examine Hypothesis 1, binary logistic regression analyses were conducted to assess the associations between ADL and IADL dependence and social isolation. Binary logistic regression analyses were conducted to examine the associations of social isolation with functional dependence, including ADL, IADL, and their subdomains (mobility, self-care, domestic life, and cognitive-social activities). Both unadjusted and adjusted models were estimated, without and with the controlling for sociodemographic, health-related, social, and digital variables, respectively. To examine Hypothesis 2, digital device utilization was included in the regression models as a moderating variable in the association between functional dependence and social isolation. To verify whether digital device utilization moderated the pathway in which functional dependence affects social isolation, Model 1 of the SPSS PROCESS macro was employed [45]. This moderation analysis tested the interaction effects between digital utilization and functional dependence, estimating path coefficients to assess conditional relationships. Cases with missing or inapplicable responses on key variables were excluded prior to all analyses. All statistical analyses were performed using IBM SPSS

Statistics version 29.0 (IBM Corp., Armonk, NY, USA).

3. Results

3.1 Sociodemographic, health, and functional characteristics by social isolation status

An overview of the sociodemographic, health, and functional characteristics of the study participants according to social isolation status is presented in Table 1. The proportion of socially isolated individuals was higher among those aged 75 years and older ($p < 0.001$) and among those with an education level of middle school or below ($p < 0.001$) compared to those with a high school education or higher. The proportion of social isolation was also higher among older adults with lower household income ($p < 0.001$) and among those without a job ($p < 0.001$). Participants who reported poor subjective health and those with two or more chronic diseases showed higher levels of social isolation ($p < 0.001$ and $p = 0.005$, respectively). In both ADL ($p < 0.001$) and IADL ($p < 0.001$), dependent older adults showed significantly higher levels of social isolation compared to independent individuals. In their subdomains—mobility ($p < 0.001$), self-care ($p < 0.001$), domestic activities ($p < 0.001$), and cognitive-social activities ($p < 0.001$)—dependent older adults also showed higher proportions of social isolation. Lower levels of digital device utilization ($p < 0.001$) and lower adaptability to the information society ($p < 0.001$) were also associated with a higher prevalence of social isolation. Meanwhile, no significant difference in social isolation was observed between urban and rural residents ($p = 0.785$).

3.2 Associations of functional dependence with social isolation

Functional dependence in ADL and IADL showed significant associations with social isolation in univariate and multivariate logistic regression analyses, as summarized in Table 2. The odds ratio (OR) for ADL dependence was 3.07 (95% CI: 2.38–3.97, $p < 0.001$) in the univariate model and remained significant after adjustment for sociodemographic factors, with an OR of 1.86 (95% CI: 1.40–2.48, $p < 0.001$). The OR for IADL dependence was 2.06 (95% CI: 1.70–2.50, $p < 0.001$) in the univariate model and 1.37 (95% CI: 1.10–1.69, $p = 0.005$) in the multivariate model, both showing statistically significant associations. For age, older adults aged 75 years and above showed a higher risk of social isolation than those aged 65–74 years in the univariate analysis (OR = 1.86, 95% CI: 1.58–2.19, $p < 0.001$), but this association was not statistically significant in the multivariate model ($p > 0.05$). Education level was significantly associated with social isolation in both analyses, indicating that those with a high school education or higher had a lower risk of social isolation (all for $p < 0.001$). In terms of household income, compared to those with less than 50% of the median income, participants with 50–99% and ≥100% of the median income had significantly lower risks of social isolation (both for $p < 0.001$), and these associations remained significant after adjustment (both for $p < 0.01$). For employment status, being unemployed was associated with a higher risk of social isolation compared to being employed in the univariate model (OR = 1.89, 95% CI: 1.60–2.23, $p < 0.001$); however, this relationship weakened and was no longer statistically significant in the multivariate model ($p = 0.072$ or $p = 0.056$). Subjective health status showed a strong association with social isolation. Compared to those who reported being healthy/very healthy, participants who rated their health as neutral had approximately 1.5 times higher odds, and those who reported being unhealthy/very unhealthy had more than 2.3 times higher odds of social isolation (all for $p < 0.001$). In the univariate analysis for the number of chronic diseases, participants with two or more comorbidities had a higher risk of social isolation than those with fewer than two (OR = 1.27, 95% CI: 1.07–1.50, $p < 0.01$). However, in the multivariate model, the opposite pattern was observed, with older adults having fewer than two chronic diseases showing a higher likelihood of social isolation (OR = 0.81, 95% CI: 0.68–0.98, $p = 0.029$).

3.3 Effects of functional subdomain dependence on social isolation

Associations between dependence in specific functional subdomains and social isolation were examined using logistic regression analyses, as summarized in Table 3. The odds ratio (OR) for older adults with mobility dependence compared to those who were independent was 3.34 (95% CI: 2.53–4.40, $p < 0.001$) in the unadjusted model, and the association remained significant after adjustment, with an OR of 2.02 (95% CI: 1.50–2.72, $p < 0.001$). The OR for dependence in self-care function was 2.75 (95% CI: 2.1–3.59, $p < 0.001$) in the unadjusted model and 1.71 (95% CI: 1.28–2.28, $p < 0.001$) in the adjusted model, indicating that impaired self-care ability increased the risk of social isolation. The OR for dependence in domestic activities was 1.99 (95% CI: 1.62–2.46, $p < 0.001$) in the unadjusted model and 1.42 (95% CI: 1.13–1.78, $p = 0.002$) in the adjusted model, showing a consistent and significant association. The OR for dependence in cognitive and social activities was 2.51 (95% CI: 1.85–3.40, $p < 0.001$) in the unadjusted model and 1.48 (95% CI: 1.07–2.04, $p = 0.018$) in the adjusted model. This association also remained statistically significant.

3.4 Moderating effects of digital utilization on the relationship between ADL/IADL dependence and social isolation

Interaction analyses were conducted to assess the moderating effects of digital utilization levels (low, medium, and high) on the association between ADL/IADL dependence and social isolation, as presented in Table 4 and Fig. 1A,B. In the model including ADL dependence, ADL dependence showed a significant positive association with social isolation (B = 0.37, $p = 0.023$), whereas digital utilization demonstrated a significant negative association (B = −0.72, $p < 0.001$). A statistically significant interaction between ADL dependence and digital utilization was also observed (B = 0.52, $p = 0.017$).

TABLE 1. Participant characteristics by social isolation status.

Variable	Categories	No social isolation	Social isolation	*p*-value
Age (yr)				
	65–74	1850 (61.0)	342 (45.7)	<0.001
	≥75	1181 (39.0)	406 (54.3)	
Education				
	≤Middle school	1475 (48.7)	487 (65.1)	<0.001
	≥High school	1556 (51.3)	261 (34.9)	
Residential area				
	Urban	2171 (71.6)	532 (71.1)	0.785
	Rural	860 (28.4)	216 (28.9)	
Household income				
	<50% of middle income	895 (29.5)	353 (47.2)	
	50–99% of middle income	919 (30.3)	193 (25.8)	<0.001
	≥100% of middle income	1217 (40.2)	202 (27.0)	
Employed				
	Yes	1501 (49.5)	256 (34.2)	<0.001
	No	1530 (50.5)	492 (65.8)	
Subjective health status				
	Healthy/very healthy	1568 (52.0)	240 (32.8)	
	Neutral	965 (32.0)	255 (34.8)	<0.001
	Unhealthy/very unhealthy	485 (16.1)	237 (32.4)	
Comorbidity				
	≤1	1256 (41.4)	268 (35.8)	0.005
	≥2	1775 (58.6)	480 (64.2)	
ADL dependency				
	No	2870 (94.7)	638 (85.3)	<0.001
	Yes	161 (5.3)	110 (14.7)	
IADL dependency				
	No	2609 (86.1)	561 (75.0)	<0.001
	Yes	422 (13.9)	187 (25.0)	
Mobility dependency				
	No	2892 (95.4)	640 (85.6)	<0.001
	Yes	139 (4.6)	108 (14.4)	
Self-care dependency				
	No	2864 (94.5)	641 (85.7)	<0.001
	Yes	167 (5.5)	107 (14.3)	
Domestic life dependency				
	No	2666 (88.0)	583 (77.9)	<0.001
	Yes	365 (12.0)	165 (22.1)	
Cognitive-social activity dependency				
	No	2899 (95.6)	664 (88.8)	<0.001
	Yes	132 (4.4)	84 (11.2)	
Digital device utilization level				
	0–3	1055 (34.8)	478 (63.9)	
	4–7	1102 (36.4)	199 (26.6)	<0.001
	≥8	874 (28.8)	71 (9.5)	
Information society adaptation				
	Not difficult at all/not difficult	322 (10.7)	32 (4.4)	
	Moderate	874 (29.0)	140 (19.1)	<0.001
	Difficult/very difficult	1822 (60.4)	560 (76.5)	

ADL: activities of daily living; IADL: instrumental activities of daily living.

TABLE 2. Factors associated with social isolation: univariate and multivariate logistic regression.

Variable	Categories	Univariate			Multivariate (independent: ADL)			Multivariate (independent: IADL)		
		B (SE)	OR (95% CI)	*p*-value	B (SE)	OR (95% CI)	*p*-value	B (SE)	OR (95% CI)	*p*-value
ADL dependency										
	No		1.00 (reference)			1.00 (reference)			–	
	Yes	1.12 (0.13)	3.07 (2.38–3.97)	<0.001	0.62 (0.15)	1.86 (1.40–2.48)	<0.001		–	
IADL dependency										
	No		1.00 (reference)			–			1.00 (reference)	
	Yes	0.72 (0.10)	2.06 (1.70–2.50)	<0.001		–		0.31 (0.11)	1.37 (1.10–1.69)	0.005
Age (yr)										
	65–74		1.00 (reference)			1.00 (reference)			1.00 (reference)	
	≥75	0.62 (0.08)	1.86 (1.58–2.19)	<0.001	0.17 (0.09)	1.18 (0.98–1.42)	0.073	0.18 (0.09)	1.19 (0.99–1.43)	0.059
Education										
	≤Middle school		1.00 (reference)			1.00 (reference)			1.00 (reference)	
	≥High school	−0.68 (0.08)	0.51 (0.43–0.60)	<0.001	−0.42 (0.10)	0.66 (0.55–0.79)	<0.001	−0.42 (0.10)	0.66 (0.55–0.79)	<0.001
Residential area										
	Urban		1.00 (reference)			1.00 (reference)			1.00 (reference)	
	Rural	0.02 (0.09)	1.02 (0.86–1.22)	0.785	−0.12 (0.10)	0.89 (0.73–1.08)	0.237	−0.12 (0.10)	0.89 (0.73–1.08)	0.245
Household income										
	<50%		1.00 (reference)			1.00 (reference)			1.00 (reference)	
(% of median income)										
	50–99%	−0.63 (0.10)	0.53 (0.44–0.65)	<0.001	−0.43 (0.11)	0.65 (0.52–0.80)	<0.001	−0.44 (0.11)	0.65 (0.52–0.80)	<0.001
	≥100%	−0.87 (0.10)	0.42 (0.35–0.51)	<0.001	−0.36 (0.12)	0.7 (0.55–0.88)	0.002	−0.37 (0.12)	0.69 (0.55–0.87)	0.002
Employed										
	Yes		1.00 (reference)			1.00 (reference)			1.00 (reference)	
	No	0.63 (0.09)	1.89 (1.60–2.23)	<0.001	0.18 (0.10)	1.2 (0.98–1.47)	0.072	0.2 (0.10)	1.22 (0.99–1.48)	0.056
Subjective health status										
	Healthy/very healthy		1.00 (reference)			1.00 (reference)			1.00 (reference)	
	Neutral	0.55 (0.10)	1.73 (1.42–2.10)	<0.001	0.39 (0.11)	1.48 (1.21–1.83)	<0.001	0.38 (0.11)	1.47 (1.19–1.81)	<0.001
	Unhealthy/very unhealthy	1.16 (0.11)	3.19 (2.60–3.92)	<0.001	0.85 (0.12)	2.33 (1.84–2.95)	<0.001	0.87 (0.12)	2.38 (1.88–3.02)	<0.001
Comorbidity										
	≤1		1.00 (reference)			1.00 (reference)			1.00 (reference)	
	≥2	0.24 (0.08)	1.27 (1.07–1.50)	<0.005	−0.21 (0.10)	0.81 (0.67–0.98)	0.029	−0.21 (0.09)	0.81 (0.68–0.98)	0.029

ADL: activities of daily living; IADL: instrumental activities of daily living; SE: standard error; B: regression coefficient; OR: odds ratio; CI: confidence interval.

TABLE 3. Functional subdomain dependency and social isolation: univariate and multivariate.

Variable	Category	Unadjusted			Adjusted		
		B (SE)	OR (95% CI)	*p*-value	B (SE)	OR (95% CI)	*p*-value
Mobility dependency							
	No		1.00 (reference)			1.00 (reference)	
	Yes	1.21 (0.14)	3.34 (2.53–4.40)	<0.001	0.7 (0.15)	2.02 (1.50–2.72)	<0.001
Self-care dependency							
	No		1.00 (reference)			1.00 (reference)	
	Yes	1.01 (0.14)	2.75 (2.10–3.59)	<0.001	0.54 (0.15)	1.71 (1.28–2.28)	<0.001
Domestic life dependency							
	No		1.00 (reference)			1.00 (reference)	
	Yes	0.69 (0.11)	1.99 (1.62–2.46)	<0.001	0.35 (0.11)	1.42 (1.13–1.78)	0.002
Cognitive-social dependency							
	No		1.00 (reference)			1.00 (reference)	
	Yes	0.92 (0.15)	2.51 (1.85–3.40)	<0.001	0.39 (0.17)	1.48 (1.07–2.04)	0.018

SE: standard error; B: regression coefficient; OR: odds ratio; CI: confidence interval.

TABLE 4. Moderating effects of digital utilization level on the association between functional dependence and social isolation.

	B (SE)	*z*	*p*-value	LLCI	ULCI
ADL dependency	0.37 (0.16)	2.28	0.023	0.053	0.697
Digital utilization level	−0.72 (0.08)	−9.51	<0.001	−0.871	−0.574
Interaction	0.52 (0.22)	2.38	0.017	0.092	0.952
Model	χ^2 (1, p = 0.022) = 5.27, −2LL = 3389.8, Nagelkerke R^2 = 0.128				
IADL dependency	0.13 (0.13)	1.00	0.318	−0.124	0.383
Digital utilization level	−0.72 (0.08)	−9.16	<0.001	−0.877	−0.568
Interaction	0.25 (0.16)	1.53	0.126	−0.070	0.572
Model	χ^2 (1, p = 0.133) = 2.26, −2LL = 3402.2, Nagelkerke R^2 = 0.123				

ADL: activities of daily living; IADL: instrumental activities of daily living; SE: standard error; B: regression coefficient; LLCI: lower limit of the confidence interval; ULCI: upper limit of the confidence interval; −2LL: −2 log-likelihood.

As shown in Fig. 1A, the influence of digital utilization on social isolation was minimal among older adults with high ADL dependence; however, among those with low ADL dependence, higher digital utilization was associated with a markedly lower risk of social isolation (Fig. 1A). These findings suggest that digital utilization serves as a more influential moderating factor for social isolation among older adults who are independent in ADL. In the model including IADL dependence, only the negative association between digital utilization and social isolation was statistically significant (B = −0.72, $p < 0.001$; Table 4). The effect tended to be more pronounced among older adults with low IADL dependence (Fig. 1B). However, neither the direct association between IADL dependence and social isolation nor the interaction between the two variables reached statistical significance. These results indicate that ADL dependence, rather than IADL, along with digital utilization, is more closely related to social isolation among older adults.

3.5 Moderating effects of digital utilization on functional subdomains and social isolation

The moderating role of digital utilization levels in the association between dependence in functional subdomains and social isolation was further examined through interaction analyses, as presented in Table 5 and Fig. 1C–F. Dependent mobility showed a significant positive association with social isolation (B = 0.40, $p = 0.015$), whereas digital utilization ability demonstrated a significant negative association (B = −0.71, $p < 0.001$). A significant interaction between these two factors was also observed (B = 0.70, $p = 0.008$). In contrast, dependent self-care showed a tendency toward a positive association with social isolation (B = 0.30, $p = 0.067$), while the interaction with digital utilization level was statistically significant (B = 0.49, $p = 0.027$). In the models including domestic and cognitive-social subdomains, only digital utilization ability showed a significant negative association with social isola-

TABLE 5. Moderating effects of digital utilization level on the association between functional subdomain dependence and social isolation.

	B (SE)	*z*	*p*-value	LLCI	ULCI
Mobility dependency	0.40 (0.16)	2.45	0.015	0.079	0.718
Digital utilization level	−0.71 (0.08)	−9.37	<0.001	−0.856	−0.560
Interaction	0.70 (0.26)	2.66	0.008	0.185	1.219
Model	χ^2 (1, p = 0.010) = 6.59, −2LL = 3389.0, Nagelkerke R^2 = 0.128				
Self-care dependency	0.30 (0.16)	1.83	0.067	−0.021	0.623
Digital utilization level	−0.72 (0.08)	−9.49	<0.001	−0.869	−0.571
Interaction	0.49 (0.22)	2.21	0.027	0.055	0.923
Model	χ^2 (1, p = 0.034) = 4.51, −2LL = 3394.7, Nagelkerke R^2 = 0.126				
Domestic life dependency	0.18 (0.14)	1.30	0.194	−0.090	0.443
Digital utilization level	−0.72 (0.08)	−9.20	<0.001	−0.873	−0.566
Interaction	0.24 (0.17)	1.45	0.148	−0.087	0.576
Model	χ^2 (1, p = 0.155) = 2.02, −2LL = 3400.9, Nagelkerke R^2 = 0.123				
Cognitive-social dependency	0.27 (0.18)	1.52	0.127	−0.077	0.614
Digital utilization level	−0.68 (0.07)	−9.14	<0.001	−0.825	−0.533
Interaction	−0.12 (0.39)	−0.30	0.767	−0.891	0.657
Model	χ^2 (1, p = 0.764) = 0.09, −2LL = 3406.2, Nagelkerke R^2 = 0.121				

SE: standard error; B: regression coefficient; LLCI: lower limit of the confidence interval; ULCI: upper limit of the confidence interval; −2LL: −2 log-likelihood.

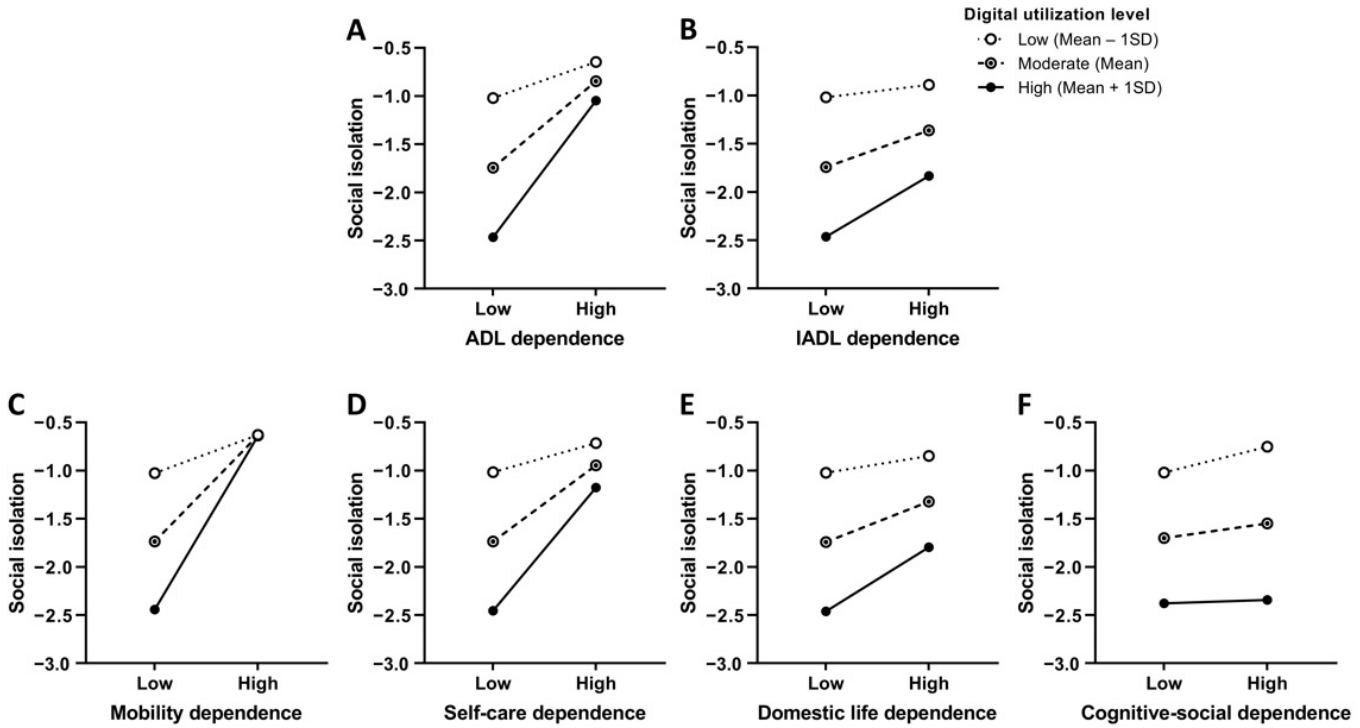

FIGURE 1. Moderating effects of digital utilization level on the relationship between functional dependence and social isolation. Each panel represents the moderating effect of digital utilization on the association between functional dependence and social isolation, assessed separately for ADL (A), IADL (B), mobility (C), self-care (D), domestic life (E), and cognitive–social activities (F). ADL: activities of daily living; IADL: instrumental activities of daily living; SD: standard deviation.

tion, whereas neither the main effects of each subdomain nor their interaction effects with digital utilization were significant. The moderating effects of digital utilization level on the relationship between social isolation and either mobility or self-care dependence were minimal to modest among older adults with higher dependence in each subdomain, but they were more pronounced among those with higher functional independence (Fig. 1C,D). In contrast, similar moderating effects were observed in the domestic and cognitive-social subdomains, but the differences between dependent and independent groups became progressively smaller as the domain shifted from physical to more cognitively and socially complex functions (Fig. 1E,F).

4. Discussion

This study analyzed the effects of ADL and IADL dependence on social isolation among male older adults and examined the moderating role of digital utilization ability. The results revealed that both ADL and IADL dependence significantly increased the risk of social isolation, with particularly pronounced effects in the domains of mobility and self-care. In contrast, digital utilization acted as a protective factor that reduced the likelihood of social isolation, and a clear moderating effect of digital competence was observed in ADL and its subdomains, including mobility and self-care. These results demonstrate that functional independence is a key determinant in maintaining social connectedness among older adults, particularly among men in later life. This finding is consistent with previous studies showing that declines in physical capacity, such as mobility and balance, weaken physical independence, restrict access to social participation, and consequently intensify isolation [9, 28, 34]. In particular, decreases in mobility and self-care ability indicate not only a loss of bodily function but also a structural limitation that constrains opportunities for social engagement among older men.

Digital literacy and utilization were confirmed to function as buffering mediators that maintain and expand social relationships, thereby alleviating social isolation among older men. This finding supports the view that digital technology complements mobility limitations and facilitates new forms of social connectedness [37, 38]. The moderating effect was especially evident among those who were independent in ADL, suggesting that functionally independent older men are more capable of expanding their social networks through online platforms and social media [39]. As a result, digital competence may serve as a new social resource that supplements traditional face-to-face networks and promotes social integration in aging male populations. The moderating effect of digital utilization appeared stronger among individuals with lower levels of functional dependence. In other words, at earlier stages when ADL dependence is minimal and functional independence remains intact, digital proficiency can facilitate social participation and reduce isolation. In contrast, among those with high ADL dependence, the risk of social isolation was already substantial, and the impact of digital utilization was relatively limited. These results indicate that digital technology should be understood not as a universal solution but as a differential social buffer that operates according to the level of functional capacity.

As functional domains become increasingly complex and multidimensional, differences in the risk of social isolation according to digital utilization were also observed among male older adults with higher dependency. This pattern suggests that digital engagement not only compensates for physical limitations but also provides a new resource that mediates cognitive involvement and social interaction. However, these effects were less pronounced in domestic or cognitive-social domains compared with physically based domains such as mobility and self-care. This finding implies that social isolation among men is more strongly influenced by physical function and accessibility than by declines in psychosocial or cognitive activity.

Overall, the findings highlight the need for a dual intervention strategy to alleviate social isolation among older men. The first component involves preventive interventions aimed at slowing or reversing the progression of functional dependence. Community-based physical activity programs and health management services that maintain ADL and IADL performance can help prevent the contraction of social networks. The second component involves strengthening digital literacy at stages when functional independence is preserved. Improving digital proficiency can mitigate social disconnection and encourage social integration through participation in online communities. The combined implementation of physical interventions that maintain function and strategies that enhance digital engagement may therefore reduce social isolation more effectively in male older populations. This study also addresses a research gap by focusing on male older adults and identifying determinants of social isolation specific to this population. Most prior studies on social isolation have centered on women [19], whereas isolation among older men tends to occur more abruptly and have greater psychological consequences [23]. After retirement, men's work-based networks weaken, and their reluctance to seek emotional support increases the risk of social disconnection [26]. By reflecting these gender-specific characteristics, this study provides empirical evidence that can inform gender-tailored intervention strategies for social isolation among older adults. The findings also carry several policy implications. Community-based health programs that support the maintenance and improvement of mobility and self-care abilities may directly reduce social isolation among older men. In addition, education and access initiatives that strengthen digital literacy among older adults can compensate for physical limitations and help sustain social networks. Policies designed to reduce digital inequality in older male populations are likely to serve as essential strategies for promoting social inclusion. Nevertheless, this study has several limitations. Because the analysis was based on cross-sectional data, causal relationships could not be fully established, and qualitative aspects of social isolation, such as loneliness and perceived disconnection, were not assessed. Future studies should employ longitudinal data to explore the dynamic relationship between changes in physical function and social isolation and to investigate the psychosocial mechanisms of digital utilization, including the quality of online interactions and the level of emotional support experienced through digital platforms.

5. Conclusions

Functional dependence was identified as a key determinant of social isolation among male older adults, with basic functional domains such as mobility and self-care exerting the strongest influence. The findings indicate that maintaining physical independence is fundamental to sustaining social participation in later life. Although digital literacy and utilization also served as moderating factors that alleviated social isolation, their effects were most evident among older men who maintained functional independence. This suggests that digital competence functions not as a compensatory mechanism after physical decline but as a preventive resource that promotes early engagement and the expansion of social networks before dependency occurs. Overall, the study emphasizes that reducing social isolation in older men requires an integrated approach that combines the preservation of functional independence with improved digital accessibility.

ABBREVIATIONS

ADL, activities of daily living; IADL, instrumental activities of daily living; ICF, International Classification of Functioning; SD, standard deviation; SE, standard error; B, regression coefficient; OR, odds ratio; CI, confidence interval; SNS, social networking services; LLCI, lower limit of the confidence interval; ULCI, upper limit of the confidence interval; −2LL, −2 log-likelihood.

AVAILABILITY OF DATA AND MATERIALS

The data presented in this study are available publicly online and upon request at: https://mdis.kostat.go.kr.

AUTHOR CONTRIBUTIONS

JL—conceptualization; data curation; interpretation of results; writing-original draft preparation; writing-review and revision. JSC—conceptualization, data analysis, visualization; writing-original draft preparation; writing-review and revision. Both authors contributed to editorial revisions and approved the final manuscript.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

The dataset was provided in a de-identified form through the Ministry of Health and Welfare's data portal (MDIS), and all personally identifiable information had been removed prior to analysis. Every participant gave a written consent prior to their participation in the original survey. All procedures and protocols of this study were approved by the Institutional Review Board of Hannam University (IRB No. 2025-E003) and conducted according to the principles outlined in the Declaration of Helsinki.

ACKNOWLEDGMENT

Not applicable.

FUNDING

This work was supported by 2025 Hannam University Research Fund (no. 2025A048).

CONFLICT OF INTEREST

The authors declare no conflict of interest.

SUPPLEMENTARY MATERIAL

Supplementary material associated with this article can be found, in the online version, at https://oss.jomh.org/files/article/2060284117147107328/attachment/Supplementary%20material.docx.

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How to cite this article: Jiyoon Lee, Jae Seung Chang. The relationship between functional dependency and social isolation among older men: the moderating role of digital competence. Journal of Men's Health. 2026; 22(5): 48-58. doi: 10.22514/jomh.2026.040.