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Internet use patterns and their relationship with frailty in older Japanese adults

Yaya Li[1*], Kayo Godai[1], Michiko Kido[1], Susumu Komori[2], Ryoichi Shima[3], Kei Kamide[1] and Mai Kabayama[1*]

Abstract

Background Internet use is increasing among older adults worldwide, raising interest in its potential empowering effects on healthy aging. However, the relationship between internet use and frailty among older adults remains underexplored.

Methods We conducted a postal survey between February and March 2021 in Osaka, Japan. The survey included 1,288 respondents aged ≥ 65 years, yielding a response rate of 71.6%. Internet use patterns were divided based on the frequencies of 8 internet use activities using a k-means cluster analysis. Frailty was assessed using the Japanese Kihon Checklist with a cut-off score of ≥ 8 defining a frail status. Covariates included age, sex, living alone, economic status, work, multimorbidity, smoking, and physical activity. We employed logistic regression models to investigate the associations. Stratified analyses were also conducted by sex and age (65–74 years, ≥ 75 years).

Results After excluding individuals with incomplete data on internet use or long-term care users or living a nursing home, we analyzed 908 participants (45.42% female, average age 73.74 years, 25.37% frail). The K-means cluster analysis identified three internet use patterns: "less use" ($n = 478$), "social use" ($n = 261$), and "functional use" ($n = 169$). Logistic regressions with less use as a reference showed a negative relationship between social use and frailty (adjusted OR, 0.54; 95% CI, 0.35–0.84). The stratified analysis revealed significant relationships between social use and frailty only in males aged 65–74 years and females ≥ 75 years. A relationship was not observed between functional use and frailty.

Conclusions We confirmed the segmentation of internet use patterns and its associations with frailty in older populations, noting age-sex differences. The heterogeneity in the association between internet use and frailty provides evidence for the incorporation of digital technology into health care for older adults, highlighting its role in enhancing social interaction. These findings are cross-sectional, which limits causal inference. Further longitudinal study is needed.

Keywords Internet use, Frailty, Social factor, Aged, Digital health, Japan

*Correspondence:
Yaya Li
li.yaya@sahs.med.osaka-u.ac.jp
Mai Kabayama
kabayama@sahs.med.osaka-u.ac.jp
[1]Department of Health Sciences, Graduate School of Medicine, Osaka University, Osaka 565- 0871, Japan
[2]Health and Welfare Center, Toyono Town 563-0103, Osaka, Japan
[3]Graduate School of Medicine, Strategic Global Partnership & the X(Cross)-Innovation Initiative, Osaka University & Osaka University Hospital, Osaka 565-0871, Japan

Background

The empowering effects of digital technology development on healthy aging has become a topic of interest in recent years. The use of technologies, such as the internet, have been recognized as an emerging social factor of health [1], and health systems are exploring how internet resources can be connected to community-based health policies. However, due to digital divide, limited evidence is currently available for older populations. Furthermore, while previous studies examined the effects of internet use on various health issues, such as depression, loneliness, cognitive function, and physical activity [2–4], the relationship between internet use and frailty remains unclear. To our knowledge, only one report has shown independent protective effects of online activities on frailty in postmenopausal women [5]. However, how different internet use patterns relate to frailty among older adults remains underexplored.

Frailty often manifests as physical, psychological, and social vulnerability, leading to an increased risk of adverse health outcomes, such as disability and mortality [6]. It is regarded as a pre-disability stage and is preventable or reversible through effective interventions [7]. Therefore, the prevention of frailty is a public health issue that is being prioritized in Japan, which has a super-aged society. While a digital divide persists (with an overall internet usage rate of 97.5% among those aged 20–64 compared to 60.9% among those aged 65 and above), internet use has grown most rapidly among older population in recent years [8]. This trend enhances the feasibility of studying digital health factors in this population and emphasizes the necessity of understanding how internet technology may empower older individuals to prevent frailty.

Internet use patterns exhibit significant variation, encompassing social engagement, information searching, online entertainment, e-shopping, and e-learning. The latest report reveals that the most common internet activities among older Japanese internet users are sending and receiving emails, searching for information, and using social networking services such as free calling apps. In contrast, social networking service use is the most common activity among individuals aged under 50 years [8]. Hypothetically, these diverse patterns may have different effects on frailty. For example, online social activities may help reduce social isolation, mental stress, and other factors associated with frailty [9–11]. Information platforms may be linked to higher health literacy [12]. On the other hand, we must consider possibility of variations of "internet paradox" on frailty. It's reported that prolonged online social life may reduce face-to-face interactions, contribute to depression, and lower life satisfaction [13, 14]. Frequent searching online information may connect with mental stress [15, 16].The heterogeneity of internet use behaviors among older adults necessitates a comprehensive segmentation analysis for developing targeted interventions. Moreover, the prevalence of frailty and non-internet users is higher among rural area, which raise concerns that rural older adults may face a new kind of health inequality driven by the digital divide [17, 18]. The present study aimed to determine internet use patterns among rural older adults in Japan and to investigate the relationship between these distinct internet use patterns and frailty.

Methods

Samples

We conducted a postal survey of 1,800 community-dwelling older adults ≥ 65 years in a rural town in the north of Osaka, Japan, between February and March 2021. Participants received an anonymous self-reported paper questionnaire with reply envelopes by postal mail. Samples were randomly selected using age- and sex-based stratified random sampling with a stratified sampling ratio of 20% from the Basic Resident Registration System. In total, 1,288 questionnaires were valid (response rate 71.6%). We excluded individuals requiring long-term care, living in nursing homes, or those who did not answer questions on internet use, leaving 908 individuals to analyze.

Ethics

The present study was approved by the Osaka University Clinical Research Review Committee (number: 20369). Participants provided written informed consent to participate in the study.

Frailty

Frailty was measured using the Kihon Checklist (KCL) developed by the Ministry of Health, Labor, and Welfare, Japan. KCL is considered as a type of deficit model [19]. It contains 25 items divided into seven domains: instrumental activities of daily living, physical function, nutrition, oral function, social domain, cognitive domain, and depression. Each item is scored as either present or absent, and we summarized a total KCL score (the range: 0–25 points) for participants with no missing items. In this study, we used the widely accepted KCL cut-off score of ≥ 8 to define a frail status [20]. This cut-off value has been validated for its effectiveness in identifying frailty as well as predicting the risk of dependency and mortality in Japan [19, 20].

Internet use patterns

In the present study, we designed a 6-point scale (never, < one day/week, one day/week, 2–3 days/week, 4–5 days/week, and 6–7 days/week) to collect information on the average weekly frequencies of eight internet activities

in the previous month. These activities included sending e-mail, texting/video calls via social messaging apps, health information searching, COVID-19-related information searching, medical services usage, online learning, online shopping, and online entertainment. Details of the questionnaire items in English are provided in Supplementary data (Text S1). The scale demonstrated good reliability (Cronbach's alpha > 0.7) and inter-item correlations were weak (Spearman's ρ less than 0.7 with most less than 0.4). We standardized all the eight inputs before applying a K-means clustering analysis to identify patterns of internet usage. To assess the optimal number of clusters, multiple clustering analyses (k = 2–8) were conducted. Based on the Euclidean distance and interpretability of clusters, three patterns of internet usage were identified: 'Less Use', characterized by minimal activity; 'Social Use', characterized by significant engagement in social activities; and 'Functional Use', characterized by extensive engagement in information searching, online entertainment, and online shopping (see Fig. 1, discussed in detail in the Results section). As a supplementary data, we reported the distribution of varied frequencies of each item across the clusters in Table S1.

Statistical analysis

All analyses were conducted using STATA version 17 MP. We identified the basic characteristics of the three patterns of internet usage, which were confirmed using the k-means cluster analysis. We compared characteristics among three internet use clusters using a *t*-test for continuous variables and the chi-squared test for categorical values. We then used unadjusted and adjusted logistic regression models to assess the relationships between the three clusters (with 'less use' as the reference group) and frailty. In adjusted models, we adjusted for variables associated with frailty based on summaries from previous research [21]. Covariate adjustments included age, sex (male/female), subjective family economic status (not wealthy, normal, wealthy), living alone (yes/no), work (yes/no), physical activity (≥ once a week/never), smoking (yes/no), and multimorbidity (none/one/two or more conditions, including hypertension, diabetes, dyslipidemia, heart disease, cerebrovascular disease, and respiratory disease). Additionally, we conducted stratified analyses by sex and age (65–74 years, ≥ 75 years). To minimize any estimation bias from missing data, we used multiple imputation by a chained equation as a sensitivity analysis. We generated 20 imputed datasets, replicated analyses of each imputed dataset and pooled the results obtained using Rubin's rule [22] (Table S2).

Results

Internet use patterns

Three internet use clusters were identified, as shown in Fig. 1, which presents z-scores for the frequency of various internet activities within each cluster in a heat map format. Cluster 1, named "Less use", comprised 52.6% of the analyzed sample and exhibited the lowest frequency across all input internet activities (below the overall mean). Cluster 2, named "Social use" (28.7%), generally scored higher z-scores than Cluster 1, with z-scores for sending e-mails and texting/video calls via social messaging apps were the highest across activities and clusters. Based on previous studies, we named this cluster

Factors	Cluster 1 (n = 478)	Cluster 2 (n = 261)	Cluster 3 (n = 169)
(1) Sending e-mail	-0.61 ± 0.53	0.75 ± 0.93	0.54 ± 0.99
(2) Texting/video calls via social messaging apps	-0.58 ± 0.47	0.70 ± 1.01	0.42 ± 1.05
(3) Health information searching	-0.48 ± 0.36	-0.19 ± 0.59	1.59 ± 1.07
(4) COVID-19-related information searching	-0.57 ± 0.52	0.04 ± 0.86	1.47 ± 0.58
(5) Medical service usage	-0.18 ± 0.50	-0.10 ± 0.63	0.53 ± 1.70
(6) Online learning	-0.21 ± 0.15	-0.05 ± 0.76	0.56 ± 1.84
(7) Online shopping	-0.42 ± 0.45	0.06 ± 0.94	0.97 ± 1.29
(8) Online entertainment	-0.36 ± 0.57	0.22 ± 1.12	0.60 ± 1.30
Name labelled	**Less use**	**Social use**	**Functional use**

Note. All variables were standardized.
The table is color-coded according to the color legend on the right side, indicating trends from the minimum (yellow) to the maximum (blue) values of means.

Fig. 1 Results of cluster analysis: means and standard deviations of clustering criteria

Table 1 Characteristics of participants based on three internet use clusters

	Overall (*n* = 908)	Clusters			*p* value[a]
		Cluster 1 "Less use" (*n* = 478)	Cluster 2 "Social use" (*n* = 261)	Cluster 3 "Functional use" (*n* = 169)	
Mean age, y (SD)	73.74 (5.74)	75.24 (5.82)	72.22 (5.22)	71.88 (5.11)	< 0.001[bc]
Aged ≥ 75 y, n(%)	358 (39.91%)	238 (50.64%)	81 (31.27%)	39 (23.21%)	< 0.001[bc]
Sex, females, n(%)	407 (45.42%)	230 (48.63%)	116 (45.14%)	61 (36.75%)	0.030[c]
Frail, n(%)	207 (25.37%)	128 (30.55%)	37 (15.55%)	42 (26.42%)	< 0.001[bd]
Subjective family economic status					0.003[bc]
Not wealthy	226 (25.08%)	141 (29.81%)	53 (20.38%)	32 (19.05%)	
Normal	491 (54.50%)	253 (53.49%)	145 (55.77%)	93 (55.36%)	
Wealthy	184 (20.42%)	79 (16.70%)	62 (23.85%)	43 (25.60%)	
Work, n(%)	213 (23.67%)	89 (18.90%)	69 (26.54%)	55 (32.54%)	< 0.001[bc]
Living alone, n(%)	94 (10.41%)	50 (10.55%)	26 (10.00%)	18 (10.65%)	0.967
Smoking	62 (6.86%)	35 (7.35%)	16 (6.15%)	11 (6.55%)	0.815
Physical activity, n(%)	614 (67.77%)	301 (63.24%)	196 (75.10%)	117 (69.23%)	0.004[b]
Multimorbidity, n(%)					0.726
None	337 (38.51%)	179 (39.17%)	102 (40.32%)	56 (33.94%)	
One condition	332 (37.94%)	170 (37.20%)	93 (36.76%)	69 (41.82%)	
Two or more conditions	206 (23.54%)	108 (23.63%)	58 (22.92%)	40 (24.24%)	

[a] The t-test for age in years and Pearson's chi-squared test for other variables. [b] Significant difference: Cluster 1 vs. Cluster 2. [c] Significant difference: Cluster 1 vs. Cluster 3. [d] Significant difference: Cluster 2 vs. Cluster 3

Table 2 Logistic regression results for the relationship between internet use patterns and frailty

Models	Cluster 1 "Less use"	Cluster 2 "Social use"	Cluster 3: "Functional use"
Crude (*n* = 816)	1.00 (Reference)	**0.42 (0.28,0.63)**	0.82 (0.54,1.23)
Adjusted[a] (*n* = 774)	1.00 (Reference)	**0.54 (0.35,0.84)**	1.03 (0.65,1.63)
Stratified by sex and age			
Overall males (*n* = 432)[b]	1.00 (Reference)	**0.54 (0.31,0.94)**	0.74 (0.41,1.35)
Males aged 65–74 years (*n* = 254)[b]	1.00 (Reference)	**0.41 (0.19,0.92)**	0.73 (0.33,1.63)
Males ≥ 75 years (*n* = 178)[b]	1.00 (Reference)	0.67 (0.29,1.55)	0.99 (0.36,2.73)
Overall females (*n* = 342) [b]	1.00 (Reference)	**0.46 (0.21,0.97)**	1.69 (0.79,3.61)
Females aged 65–74 years (*n* = 220)[b]	1.00 (Reference)	0.71 (0.27,1.85)	2.38 (0.94,6.04)
Females ≥ 75 years (*n* = 122)[c]	1.00 (Reference)	**0.25 (0.06,0.997)**	0.74 (0.14,3.80)

[a] Adjusted for age, sex, living alone, subjective family economic status, work, multimorbidity, smoking, physical activity. [b] Adjusted for age, living alone, subjective family economic status, work, multimorbidity, smoking, physical activity. [c] Adjusted for age, living alone, subjective family economic status, work, multimorbidity, physical activity. Values highlighted in bold indicate a significant difference at a $p < 0.05$ level

as "social use" as email and texting/video calls were considered as social technology, indicating a pattern focused on social connectivity [23]. In Cluster 3 ("Functional use", 18.6%), z-scores for each activity were above the overall mean. Within this cluster, the highest frequencies were observed in activities related to information searching, followed by online shopping and entertainment activities like watching YouTube or online game.

Participant characteristics

Table 1 shows descriptive characteristics and significant differences across the clusters. Cluster 1 ("Less use") had a significantly higher percentage of older adults (52.64%), particularly those ≥ 75 years (50.64% in Cluster 1 vs. 31.27% in Cluster 2 and 23.21% in Cluster 3), and more females (48.63% in Cluster 1 vs. 36.75% in Cluster 3). Additionally, Cluster 1 had fewer individuals with wealthy (16.70%) and working status (18.90%) than the other clusters. It also included more frail individuals (30.55%) and fewer physically active people (63.24%) than Cluster 2 ("Social use"). The only significant difference observed between Clusters 2 and 3 ("Functional use") was in the prevalence of frailty, with Cluster 3 showing a higher proportion (26.42% in Cluster 3 vs. 15.55% in Cluster 2).

Associations between internet use patterns and frailty

Table 2 shows the relationships between internet use clusters and frailty, alongside the results from sex- and age-stratified analyses. In comparison with the "Less use" group (Reference), the "Social use" group (Cluster 2) had lower odds of frailty (odds ratio [OR], 0.42; 95%

confidence interval [CI], 0.28–0.63), whereas the "Functional use" group did not show a significant association (OR, 0.82; 95% CI, 0.54–1.23). After adjusting for age, sex, socioeconomic status, health status, and lifestyle factors, the negative relationship between "Social use" and frailty remained significant (OR, 0.54; 95% CI, 0.35–0.84). Stratified analyses revealed that this relationship was consistent across sexes, with correlations between "Social use" and frailty in both males (OR, 0.54; 95% CI, 0.31–0.94) and females (OR, 0.46; 95% CI, 0.21–0.97). However, further age-group stratification indicated that the relationship between "Social use" and frailty was only present in males aged 65–74 years (OR, 0.41; 95% CI, 0.19–0.92) and females ≥ 75 years (OR, 0.25; 95% CI, 0.06–0.997). As a sensitivity analysis, we replicated the models from Table 2 using multiple imputed data and obtained similar results (Table S2).

Discussions

The present study examined internet use as a health factor in an older population. We specifically aimed to identify whether and which type of internet use was associated with frailty in older adults. We identified three patterns of internet use: "less use", "social use", and "functional use". Among them, "social use" was independently associated with a lower prevalence of frailty compared to "less use", while 'functional use' was not significantly associated with frailty. Furthermore, this relationship was consistent across sexes, but exhibited age-related heterogeneity. To the best of our knowledge, this is the first study to examine the association between internet use and frailty status in community-dwelling older adults, including sex- and age-based heterogeneities in this association.

The results showing the protective association of internet use with frailty is consistent with a similar study on postmenopausal middle-aged and older women, which reported the non-use of internet services as a predictor of frailty; however, older men were not included in this study [5]. Another study reported that internet use exerted protective effects against frailty in individuals > 70 years in Spain; however, this relationship was not independent of potential confounders [24]. These studies collectively assumed that the internet's empowerment in preventing frailty may be attributed to an active, internet-based social life. However, further evidence to support this hypothesis was not provided. The present study contributes additional support for a social pathway linking internet use to frailty. The results obtained herein suggest that the protective effects of internet use against frailty are not simply a matter of presence or absence. Among the various patterns of usage, social use is specifically associated with a lower prevalence of frailty. To verify stability, we performed multiple logistic regressions using the functional use group as a reference group (Table S3) and the results obtained consistently revealed a negative relationship between social use and frailty. We identified similar studies, although few, on other health-related topics in older adults. One study reported that the social purpose of a phone, not entertainment purposes, was associated with reduced loneliness [25], while another study compared seven specific types of internet use between 2013 and 2016 and showed that only communicating with friends or family predicted a lower risk of depression [10].

While the causal pathways linking the social use of digital technology and frailty have not yet been established, we propose several mechanisms: social, psychological, and physical pathways. The effects of internet use on physical and mental health may be mediated through social connections [23]. Digital technology, such as the internet, transcends geographical and physical limitations, facilitating the maintenance or expansion of social networks. Therefore, internet use may empower individuals to grasp the benefits of social capital derived from digital development. For example, online social contact has been reported to reduce loneliness and decrease social isolation [26–28], all of which are well-known risk factors for frailty [29, 30]. Similarly, psychological factors affect frailty in older individuals [31], and the positive effects of digital technology use on depression have been widely reported [3, 23, 32]. Furthermore, studies have suggesting a boosting effect of digital technology use on self-esteem and social efficiency in older adults [33], which may have a positive impact on frailty [34]. It is important to note that a strong relationship has been reported between cognitive function and frailty, particularly physical frailty [35]. Internet use in daily life has recently shown to be associated with cognitive function [2, 36]. However, it' worth noting that one criticism of internet use is its possibility to increase the risk of social isolation in the real world [37]. Some studies suggest that internet use for social interaction (rather than as an escape from the real world) is beneficial for health [38]. Similarly, excessive internet use has been associated with a higher prevalence of depression and cognitive decline, highlighting the importance of moderation [14, 39]. In Japan, older adults generally have low levels of internet use [40], and the internet users in our data were not heavy users (generally low frequencies; see Table S1). Future research considering the extent of internet use and its complex relationship with real-world social networks is needed.

Sex- and age-based heterogeneities revealed a negative relationship between social internet use and frailty that was more obvious among young-old males (aged 65–74 years) and old-old females (≥ 75 years). This may be explained by changes in social networks throughout

the course of life and sex differences in the social division of labor. In Japan, men in the 'young-old' stage (65–74 years) are often transitioning to retirement (Retirement age: 60-65 years in Japan). This transition may be particularly significant for men, as they typically have higher workforce participation rates but lower engagement in informal social networks compared to women in Japan [41, 42]. Therefore, old Japanese men appear to benefit from online social networking because it provides a compensatory role to meet their needs of maintaining a social network during the retirement transition and post-retirement periods; however, men in the 'old-old' stage (≥ 75 years) enter a later stage of life where the effects of declining physical abilities become more apparent. On the other hand, women generally have higher social needs in many cultural contexts, making the social deficits due to physical restrictions or shrinking social networks more significant during the 'old-old' stage. The social network shrinks in later life stages due to aging and health issues [43]. A previous study reported that Japanese women benefited more than men from bridge social capital [44]. Online social interactions may help females ≥ 75 years to connect with diverse social networks.

The impact of online information gathering on health outcomes is not consistent [45]. Some studies highlighted positive impacts on health literacy, health behavior, and physical health [12, 46], whereas others reported that online information searches caused anxiety [16, 47]. The present study, conducted in Japan during the COVID-19 pandemic, found no relationship between functional use and frailty. This result may have been affected by psychological stress due to the pandemic, as reported in a previous study [48]. An excessive focus on online information seeking may exacerbate its negative effects on the psychological status. Frail individuals also exhibit higher anxiety levels than non-frail individuals, potentially leading to increased online information-seeking behavior. Additionally, a small percentage of the functional use group engaged in entertainment activities, which may be linked to sedentary behavior [49]. The present results also demonstrated that fewer individuals engaged in physical activity in the functional use group than in the social use group.

The present study has several strengths. It is the first to obtain evidence from the oldest population of Japan, a super-aged society. Furthermore, our survey had a high response rate of 71.6%, providing a high level of representativeness. Although there were missing responses on internet use and frailty scales, we obtained consistent results based on multiple imputations, which supports the reliability of the present results. However, there are also several limitations that need to be addressed. Since this was a cross-sectional study, we cannot establish causality. Moreover, our sample comprised older people who were not using long-term care services; therefore, the results obtained may only be generalized to self-reliant older adults in the community. In addition, data were obtained from one area in the second largest city in Japan; therefore, the sample lacks representativeness, making it difficult to generalize to the entire older people in Japan. Similarly, the study sample included only Japanese, and the KCL assessment tool used to identify frailty is primarily applied in Japan. These factors may limit the generalizability of our findings to other countries and populations. Another limitation is that the survey may have some recall bias. It should also be noted that "social use" in this study refers to messaging and video calls via social messaging apps (e.g., LINE), which may present social interactions within close social networks. We are unable to extend our results to broader online social networks such as using of social networking sites (e.g., Facebook), or media sharing apps (e.g., Instagram), and their potential associations with frailty. Different types of social relationships may have varied impacts on health [50]. While Facebook and Instagram usage remains relatively low among older adults in Japan [40], further research involving specific types of online social use is suggested. Lastly, our classification is based on the cluster analysis of frequencies of internet activities and lacks further differentiation regarding their purposes of use. More detailed data of internet use are needed in future studies.

Conclusions

This cross-sectional study explored the association between internet use patterns and frailty among community-dwelling older adults. Social internet use, but not functional use, was associated with reduced odds of frailty. The association varied based on sex and age, highlighting the potential of technology in promoting social engagement for older population. These results provide timely evidence for incorporating digital technology into health care and highlight the potential in promoting social engagement for older adults. However, these findings are cross-sectional, further longitudinal study is needed to determine the mechanisms.

Abbreviations

KCL Kihon Checklist

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12877-025-05708-z.

Supplementary Material 1

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Author contributions
Study conception-YL. Study design-YL, KG, SK, RS, KK, MK. Data collection-YL, KG, SK, RS, KK, MK, Data analysis and interpretation-YL, MK. Drafting of the manuscript-YL. Critical revision of the manuscript-KM. Funding-YL, MK. Administrative and technical support- KG, MK, KK, MK. Final approval of the version to be published- YL, KG, MK, SK, RS, KK, MK.

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Data availability
The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate
The study was approved by Osaka University Clinical Research Review Committee (approval number 20369). Informed consent was obtained from all participants before analysis. No human participants, human data or human tissue involved in this study.

Consent for publication
Not applicable.

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Competing interests
The authors declare no competing interests.

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