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Exploring the relationship of digital information sources and medication adherence

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ABSTRACT

We present a retrospective analysis of data collected in the United States from the 2015 National Consumer Survey on the Medication Experience and Pharmacists' Role in order to model the relationship between health information sources and medication adherence and perception. Our results indicate that while the digital age has presented prescription users with many non-traditional alternatives for health information, the use of digital content has a significant negative correlation with pharmaceutical adherence and attitudes toward medication. These findings along with previous research suggest that in order to fully realize the potential benefits of the digital age in regards to patient health, positive patient-provider discussions regarding information found online, efforts to improve general health literacy and improvements in the quality and accuracy of the information found are key. Given that higher reliance on digital content is correlated with younger age, the analysis suggests that proactive measures should be taken to educate younger prescription users about the merits and pitfalls of information seeking techniques as they pertain to health literacy.

1. Introduction

Nearly half of all Americans who use chronic prescription medications have some form of non-adherence [1]. Non-adherence to long-term chronic prescriptions causes poor health-related outcomes, and has been shown to increase the likelihood of disease progression, lead to higher utilization of healthcare services, increase the cost of care, and cause higher mortality rates. While the underlying causes of non-adherence are not completely understood, research has shown that they are in part driven by individual perception of, and attitudes toward, pharmaceutical interventions and the overall healthcare industry [2–8].

As our progress towards full ubiquitous computing continues to increase, so does the diversity of the health information sources pertaining to prescription medications. Whereas information regarding prescriptions was once sought almost exclusively from healthcare professionals, the internet, along with accompanying search, social media, and mobile technologies, allow users to gather pharmaceutical data and support from a plethora of outlets; resulting in a society that can be more proactive in regards to personal health information gathering, and subsequently feels empowered to form its own healthcare opinions [9]. The availability of such large amounts of data may also encourage individuals to form their own conclusions about the medications that have been prescribed without direct interactions with healthcare providers [10]. However, the open and unmediated nature of the internet raises questions and concerns over the quality and accuracy of the information provided [11–13]. This variability in the quality and accuracy of data along with the ease of accessibility and poor overall health literacy has lead to a population that is more susceptible to misinformation that could, potentially, negatively impact medication adherence if not properly informed [14–16].

In this paper we conduct a retrospective analysis of survey data from 16,369 participants to determine the impact of information source on chronic prescription medication adherence and perception. Our results suggest that chronic prescription medication adherence and overall beliefs surrounding prescription medication have a negative correlation with reliance on digital content for information regarding prescriptions. Additionally, our data suggests that digital information sources are more popular among younger prescription users, the group most at risk for non-adherence, underscoring the need for the healthcare community to engage in constructive conversations with patients regarding

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information found online, as well as promote effective information seeking techniques for health literacy at an early age.

2. Related work

There have been several studies centered on the use of pervasive technology in the search for health information and the impact that can result on patient views regarding their own health and prescription medicines. A systematic review of studies on the state of online health information found that 55 out 79 studies viewed the quality of information as problematic or questionable [11]. For example a study focusing on 100 of the most widely accessed websites that provide information on celiac disease found that 47 provided information that was less than 95% accurate. Regardless of accuracy, these sites provided inadequate information needed to form a clear understanding of the general concepts surrounding celiac disease 52% of the time [12]. Additionally a report released by the California HealthCare Foundation reports serious weaknesses and potential hazards in digital health information for consumers [13]. Compounding the poor state of online health information is the finding that only 12% of adults in the U.S. had proficient health literacy skills [14]. A 2004 report published by the Institute of Medicine: Committee on Health Literacy highlights that due to the complexities of most health-care related information more than 90 million U.S. adults have difficulty understand and acting upon health information, more than 300 studies indicate that health-related materials far exceed the average reading ability of U.S. adults and that competing sources of information intensify the need for improved health literacy [17]. In conjunction with a large portion of the population being unable to understand health information and make actionable decisions with that information studies have reported that patients typically use common search engines rather than medical search tools with short, commonly misspelled phrases when searching for information, increasing the likelihood that patients are not using the best possible information to shape these choices [18,19]. Additionally typical search habits result in finding correct and useful answers to health related questions on only 69% of searches conducted by adolescents, arguably the most technologically proficient age group [20]. This combination has lead to patients feeling overwhelmed and confused by information on the internet [21,22].

A U.S. study found that 60% of those that searched for information online felt that the information was the "same as" or "better than" that received from their doctor, and only 15% thought that the quality was "worse than" their doctor's information [10]. The combination of low health literacy skills and high perceived quality of unregulated information sources has the potential to create scenario where patients are making ill informed decisions regarding their medication, potentially leading to decreased prescription medication adherence. A similar study focusing on the use of search engines to find health information reported that internet users tend to be young college graduates and those living in higher income households, both groups that previous research has suggested are at an elevated risk for decreased adherence [23]. Additionally individuals who had more difficulty in comprehension of online material or who did not trust the material were less likely to discuss the information with their health care providers [15]. A study on Cyberchondria (online health-related information seeking that is fueled by anxiety about ones wellness) found that non-clinically health anxious individuals are prone to experiencing heightened health anxiety after online health related searches [16].

Further amplifying the risks of incorrect information and increased worry about individual health is the fact that few people go beyond the first two sites when reviewing search results [24]. Alarmingly, 45% of users don't check the source or author of their favorite health site, yet 44% state that the information they find online impacts their decisions about how to treat an illness or condition, which may result in patients becoming non-adherent, or discontinuing their medications without speaking to their healthcare provider [25]. Additionally, the ability to easily convince users of the quality or provenance of health information is evident when analyzing suggestions of marketing research firms. These organizations advise e-health companies that both search engines and banner ads are particularly effective at building an online following from those dealing with less debilitating diseases [26].

A recent study of drug company websites analyzing the availability of information to patients found that of 40 websites reviewed 38 had information labeled for health care professionals only. Of those, 24 of the 38 sites required users to verify that they were healthcare providers prior to granting access to this information [27]. The increase in the use of digital means to gather information along with the suppression of information, which allows patients to be fully informed about their medication, has the potential to create a scenario where patients feel as though they are better informed about their medication than their health care providers. In such a case physicians have been seen to acquiesce to patient requests regardless of their potentially negative impacts [28].

These related studies indicate that there is a widespread use of information technology to supplement, or even replace, the advice of health care professionals despite the lack of understanding by patients and the prevalence of inaccurate information found in these sources. However, the positive impacts digital sources can have on healthcare cannot be ignored, allowing patients to feel more in control of their own health, giving them access to online support communities, and fostering more effective communication between the provider and patient, when handled correctly. A literature review of 24 studies focusing on online support and resources for cancer patients, found that most studies reported positive psychosocial effects, such as improved info seeking abilities, better social support and fewer negative emotions from the use online resources. Additionally the study reported that the outcomes of online cancer support showed promise, however due to the lack of studies based on rigorous evaluation the evidence is inconclusive [29].

A Japanese study evaluating internet use for health related information reported that 68% of participants felt the internet improved their understanding of their disease, conditions or treatments, yet only 17% had told healthcare professionals about the health related information found from the internet [30]. A similar Australian study conducted regarding the internet usage of men with prostate cancer patients, suggests that the knowledge and support available on the internet has the potential to empower patients, remove inhibitions experienced in face-to-face encounters, and increase their sense of control over their disease. While participants interview for this study reported many positive effects of the internet a strong theme among all respondents was the fear or unwillingness to speak to healthcare professionals about the information they found on the internet [31]. This fear or unwillingness to discuss what is found on the internet with healthcare professionals has the potential to force patients to make decisions based on information that is either incorrect or they do not completely understand, creating a higher chance for negative health outcomes.

Despite these potential negative implications, when the patient-provider relationship is handled correctly the use of digital means can have a significant positive impact. A study of patients at three primary care osteopath medical clinics reported that 55% of respondents changed the way they think about their health as a result of information on the internet, 66% reported asking more questions during physicians visits, and 73% reported they had discussed these changes with their physician. A key factor to the positive effects of digital information found in this study, was the finding that 84% of respondents believed physicians were willing to discuss health information they found on the internet [9].

Recent technological advancements have radically altered the way humans go about everyday life, the search for relevant medical information is no exception. Several studies have highlighted the potential risks to this shift in gathering critical health related information, however there are significant gains that can be found if this information is gather and discussed properly. Where previous studies have identified the implications or overall use of these sources, the primary objective of this study was to evaluate the relationship between the source of data with the level of patient medication adherence.

3. Methods

This study analyzes data from the 2015 National Consumer Survey on the Medication Experience and Pharmacists' Role (NCSMEPR) [32]. The 2015 National Consumer Survey was conducted from July 2015 to December of 2015 using Qualtrics to provide participant panels, and enroll participants based on census statistics for geographic location, age, and gender. All communications to potential participants were delivered electronically via email. Participant stratification criteria were included to ensure a minimum of 500 respondents from each of the 50 states, as well as the District of Columbia. A total of 26,094 participants completed the study after discarding responses that were deemed to be incomplete. More detailed information regarding the NCSMEPR can be found in previous publications [33]. The study sample for this analysis includes US residents aged 18 years and older at the time of study completion. The sample dataset was derived by filtering the original dataset to include only those participants actively using a prescription medication and either using a digital medium or healthcare professional to gather information regarding their medications. Additionally, only respondents living within 200 miles of a pharmacy who also completed a demographic profile, providing information about age, sex, race, and income, were considered. Key summary statistics describing the sample used in our analysis are detailed in Table 1.

The analysis presented here focuses on the influence of age on participant information seeking method and the subsequent changes in patient prescription medication adherence and beliefs regarding medicine. Participant medication adherence was determined using the 8-item Morisky Medication Adherence (MMAS-8) scale, which is a self-reported medication adherence scale that consists of 8-items. Previous research has demonstrated that the MMAS-8 is both a reliable and valid measure of adherence to chronic medications and has established correlation of MMAS-8 scores with measured adherence levels, as well as, its correlation to clinical outcomes, like blood pressure control [34–36]. The MMAS-8 scale ranges from 0 to 8, with a score of 0 being related to the lowest adherence score and 8 being the highest possible adherence score. A score of 0 to less than 6 indicate poor adherence, a score of 6 to less than 8 indicate moderate adherence, and a score of 8 indicates high adherence [35].

Additionally participant perception about their medications was analyzed based on an abbreviated version of the Beliefs about Medicine Questionnaire (BMQ) [37,38]. The BMQ comprises two sections: the BMQ-Specific, which assesses the participants beliefs about their personal medications, and the BMQ-General, which assesses the participants general belief about medications. The total BMQ comprises of 18 items; however, an abbreviated version of the questionnaire was included in the data collected, which comprised of 11 total items, including items from both the BMQ-Specific and BMQ-General sections. The abbreviated BMQ was used in the original survey to reduce participant burden. The abbreviated version included in the survey has not been validated against the original scale; however, the included items are all found within the original scale. Individual responses were used to establish participant views on harm, overuse, life saving ability, and burden related to prescription medications. A 7-point Likert scale was used to determine participant agreement with the included statements. Participant overall health was determined using a four point scale with 1 being the lowest overall health. The rate of recent hospitalization was determined with a Yes/No question, with 0 corresponding to No and 1 corresponding to Yes.

The cohorts used for analysis in this study were created based on participant responses to a survey question instructing participants to select up to three of the sources they rely on most often for obtaining information regarding medicine. Participants that only used digital content such as Government-Sponsored (PubMed Health), Health Organization (mayoclinic.com), Information Company (About.com, WebMD), or Pharmaceutical Company (Lipitor.com) websites, Social Media (Youtube, Wikipedia, PatientsLikeMe.com), Search Engines (Google, Bing), or smart phone apps were placed in the digital medium cohort. While participants that only consulted a healthcare professional (Physician, Pharmacist, or Other Healthcare Professional) were placed in the healthcare professional group. Participants that gathered information from both sources were placed in to cohorts based on the number of digital sources they relied on. Participant demographics and characteristics, medication adherence and primary information medium were reported using descriptive statistics. The interaction between information source, adherence and medication burden belief, medication life saving belief, medication overuse belief, medication harm belief, household income, education level, age were examined. Additionally the beliefs of each cohort may be influenced by the source of their healthcare information therefor the difference in beliefs

Table 1
Demographics of participants separated based on Digital Only, 2 Digital Sources, 1 Digital Source and Healthcare Professional information source cohorts.

Variables	Digital Only	2 Digital Sources	1 Digital Source	Healthcare Professional Only	Significance
Total Participants	2430 (14.8%)	2934 (17.9%)	3800 (23.2%)	7205 (44.0%)	
Mean Age (S.D.)	39.9 (14.9)	43.40 (16.7)	50.6 (15.6)	49.6 (16.8)	< 0.005
Age Group					
18–29	724 (29.8%)	754 (25.7%)	443 (11.7%)	1091 (15.1%)	< 0.005
30–41	743 (30.6%)	764 (26.0%)	739 (19.5%)	1424 (19.8%)	< 0.005
42–53	452 (18.6%)	509 (17.4%)	821 (21.6%)	1467 (20.4%)	< 0.005
54–65	315 (13.0%)	463 (15.8%)	939 (24.7%)	1486 (20.6%)	< 0.005
Over 65	196 (8.1%)	444 (15.1%)	858 (22.6%)	1737 (24.1%)	< 0.005
Income					
Income At or Below $40,000	1070 (44.0%)	1153 (39.3%)	1647 (43.3%)	3291 (45.7%)	< 0.005
Income Between $41,000 and $100,000	1115 (45.9%)	1415 (48.2%)	1771 (46.6%)	3080 (42.8%)	< 0.005
Income Over $100,000	245 (10.1%)	366 (12.5%)	382 (10.1%)	834 (11.6%)	< 0.005
Education					
High School Degree or Less	505 (20.8%)	503 (17.1%)	744 (19.6%)	1831 (25.4%)	< 0.005
Some College To Bachelors Degree	1622 (66.8%)	2040 (69.5%)	2554 (67.2%)	4531 (62.9%)	< 0.005
Advanced Degree	303 (12.5%)	2040 (13.3%)	2554 (13.2%)	4531 (11.7%)	0.05
Sex					
Male	681 (28.0%)	725 (24.7%)	925 (24.3%)	2162 (30.0%)	< 0.005
Female	1749 (72.0%)	2209 (75.3%)	2875 (75.7%)	5043 (70.0%)	< 0.005
Race					
White	1900 (78.2%)	2391 (81.5%)	3268 (86.0%)	6130 (85.1%)	< 0.005
Non-White	530 (21.8%)	543 (18.5%)	532 (14.0%)	1075 (14.9%)	< 0.005

between each cohort was analyzed.

Two main groups of analyses were run. First, an Analysis of Variance (ANOVA) model with Adherence Score as the outcome variable, and Information cohort ad various demographic variables (Age, Income, Education Level, and Gender) as predictor variables. Follow up Tukey HSD comparisons were be made for each cohort if information source cohort was significant in the original ANOVA model. Second, a Multivariate ANOVA (MANOVA) with a matrix of belief variables (such as Self Responsibility, Harm, Life Saving, and Burden) as an outcome and demographic variables as well as whether or not the subject was recently hospitalized were run. Univariate ANOVAs with each belief variable were run and each univariate model was followed up with Tukey HSD pairwise comparisons for variables in which information source group was statistically significant.

4. Results

A total of 16,677 of the 26,173 participants reported taking between 1 and 30 prescription medications, of these participants a total of 16,369 met the inclusions criteria, stated in the methods section. Based on participants answers 6734 were “mixed use” participants, gathering their information regarding prescription medications from both digital sources and healthcare professionals, with 2934 using utilizing two digital information sources and 3800 utilizing 1 digital information source, 2430 obtained their information from only digital means and 7205 obtained their information exclusively from healthcare professionals.

The demographic makeup of the cohorts varied significantly with digital medium users having an average age of 39.9 years old compared to 43.4, 50.6 and 49.6 for the 2 digital sources, 1 digital source and healthcare professional cohorts. The distribution of participant preferred information gathering source varied significantly with age, 24% of age 18–29 cohort preferred using only digital means, compared to the 6.1% of the over 65 population. The opposite trend was observed for the choice of healthcare professionals as the primary source for information gathering with the 18–29 age cohort accounting for only 36.2% of cohort population, compared to 53.7% for those over 65. Difference also existed in income, education, sex and ethnicity; Table 1 provides further demographic information for each cohort.

The mean MMAS-8 adherence score for the entire study population was 5.6 (SD = 2.0). For each study cohort the average MMAS score was examined, as well as the percentage of participants that fell into certain adherence criteria. The distribution of participants and average adherence scores varied significantly between the cohorts (Table 2). Participants that utilized only digital means had an average adherence score of 4.95 (SD = 2.15), compared to 5.34 (SD = 2.04), 5.73 (SD = 1.96) and 5.89 (SD = 2.0) for the 2 digital sources, 1 digital source and healthcare professional cohorts, respectively. Additionally a significantly larger portion of digital only users classified as low adherence (MMAS < 6) (digital 62.4%, 2 digital sources 57.2%, 1 digital source 48.2% and healthcare only 44.2%). This was further reflected in the high adherence classification (MMAS = 8) with only 12.6% of digital users falling into this classification compared to 17.0%, 21.6% and 26.5% for the 2 digital sources, 1 digital source and healthcare professional cohorts, respectively.

Adherence scores for digital users were similarly lower, as the reliance on digital means increased, across all demographic factors considered. When comparing participants from the same age groups, income groups, education level, sex and ethnicity, increases in the reliance on digital information sources correlated with lower adherence scores (Table 3). Additionally the healthcare professional cohort, which did not use any digital means, had the highest adherence.

A baseline main effects ANOVA on Adherence score was built using Age, information source, Income, Education Level and Gender. A second model with all two-way interactions with Age was also built, and a third model which added all two- and three-way interactions including Gender were also built. The three models were compared using an F test that revealed that Age interaction model was significantly more predictive than the main effects model (p = 0.0008), and the model with both Age and Gender interactions was significantly more predictive than the model with only Age interactions (p = 0.0021), and was therefore chosen to be analyzed. Age and gender interactions were chosen based on previous studies indicating that age and gender strongly affect adherence [39].

The chosen model was significantly predictive of Adherence Score (F (22,16346) = 110.3, p < 0.0005, Adj. R^2 = 0.1281). The information source cohorts differed significantly in Adherence Score (F (3,16346) = 58.371, p < 0.000), and the interaction between information source and Gender was also significant (F (3,16346) = 2.772, p = 0.0399) which indicates that the observed effect differs between Genders. Information source by Age Interaction was not significant (p = 0.19523). Full results are listed below (Table 4).

The significant effect of information source was followed up with Tukey HSD pairwise comparisons which revealed significant differences in all pairwise comparisons except between the two mixed use cohorts (1 vs. 2 professional resources, p = 0.132).

The second model run was a MANOVA with Burden, Life Saving, Over Prescribed, Overall Health, Self Responsibility, Harm, and Savior as the outcome variables and Age, Information Source, Income, Education Level, Recent Hospitalization, and Gender as predictors.

The omnibus model was significantly predictive (F (8,16360) = 1409, p < 0.0005, Adj. R^2 = 0.406), with a significant difference between information source cohorts (Pillai's Trace = 0.24615, approximate F = 74.110, p < 0.000). Follow up univariate ANOVAs were conducted for each outcome variable, and all were statistically significant (corrected using Bonferroni's correction, $\alpha = 0.00625$). Tukey's HSD pairwise comparisons were conducted for each univariate model, results are reported in Table 5.

Patient perception of their medications varied across the cohorts, with digital users consistently reporting more negative overall views regarding prescription medication. Digital users were significantly more likely to believe their medications caused more harm than good, medications were over prescribed by doctors, while also believing that

Table 2
Adherence rates between Digital Only, 2 Digital Sources, 1 Digital Source and Healthcare Professional information source cohorts.

	Digital	2 Digital Sources	1 Digital Source	Healthcare Professional	Significance
Average MMAS-8 Score (SD)[a]	4.95 (2.15)	5.34 (2.04)	5.73 (1.96)	5.89 (1.97)	< 0.005
Low Adherence N (%)[b]	1516 (62.4%)	1677 (57.2%)	1832 (48.2%)	3187 (44.2%)	< 0.005
Medium Adherence N (%)[b]	609 (25.1%)	759 (25.9%)	1148 (30.2%)	2106 (29.2%)	< 0.005
High Adherence N (%)[b]	305 (12.6%)	498 (17.0%)	820 (21.6%)	1912 (26.5%)	< 0.005

The MMAS (8-item) content, name, and trademarks are protected by US copyright and trademark laws. Permission for use of the scale and its coding is required. A license agreement is available from Donald E. Morisky, ScD, ScM, MSPH, MMAS Research LLC., 294 Lindura Ct. Las Vegas NV 89138–4632, USA; dmorisky@gmail.com.

[a] Significance reported as P values from Kruskall-Wallis comparing differences between groups.

[b] Significance reported as P values from chi-square difference test.

Table 3
Mean adherence scores and standard deviation among different demographic groups based on cohort groupings.

Variables	Digital	2 Digital Sources	1 Digital Source	Healthcare Professional
Age Group				
18–29	4.65 (2.14)	4.77 (2.05)	4.90 (2.10)	5.03 (2.03)
30–41	4.53 (2.19)	4.88 (2.07)	5.11 (2.08)	5.30 (2.10)
42–53	5.14 (2.11)	5.35 (1.98)	5.49 (1.98)	5.69 (1.99)
54–65	5.66 (1.83)	5.88 (1.78)	6.01 (1.77)	6.20 (1.82)
Over 65	6.14 (1.83)	6.52 (1.60)	6.62 (1.50)	6.84 (1.42)
Income				
Income At or Below $40,000	4.79 (2.15)	5.17 (2.05)	5.56 (2.01)	5.72 (2.04)
Income Between $41,000 and $100,000	4.99 (2.15)	5.40 (2.03)	5.84 (1.94)	5.99 (1.92)
Income Over $100,000	5.52 (2.07)	5.66 (1.98)	6.00 (1.76)	6.23 (1.80)
Education				
High School Degree or Less	4.81 (2.16)	5.31 (2.03)	5.77 (1.98)	5.89 (1.97)
Some College To Bachelors Degree	4.98 (2.14)	5.29 (2.02)	5.66 (1.97)	5.87 (1.96)
Advanced Degree	5.03 (2.18)	5.63 (2.12)	6.07 (1.86)	6.05 (2.01)
Sex				
Male	4.92 (2.17)	5.31 (2.00)	6.05 (1.87)	6.12 (1.91)
Female	4.97 (2.14)	5.35 (2.05)	5.63 (1.98)	5.80 (1.99)
Ethnicity				
White	5.09 (2.14)	5.44 (2.02)	5.81 (1.93)	6.00 (1.92)
Other	4.48 (2.13)	4.91 (2.08)	5.27 (2.09)	5.32 (2.13)

they could lead their lives normally without their medications. Participants who only consulted healthcare professionals had the highest overall perceptions toward medicine in every category except the belief that their life would be impossible without their medication. Patient perception of their overall health was also analyzed with users of only digital means reporting a significantly lower overall health than other cohorts, while the two cohorts that had consulted a healthcare professional in some capacity had roughly similar overall health perceptions. These difference in perception and overall health were despite there being no significant difference in the rate at which participants were recently hospitalized (Table 6). When comparing all perception based questions, participants in all cohorts were most likely to have a negative perception toward the over prescription of drugs which may have an additive effect when patients are not consulting healthcare professionals about the potential benefits of prescription medication.

5. Discussion

The internet and pervasive computing play an integral part in daily lives [40]. The access to information these sources provide allows individuals to gain knowledge that was previously reserved for experts in a given field. Increasing patient awareness about pharmaceuticals has long been a focus of the medical community therefore we would expect the use of digital means would have a positive impact on overall adherence [41,42]. However our analysis suggests that the use of digital means correlates with decreased medication adherence. Mean adherence scores decreased steadily as reliance on digital information sources increased, with information source having a significant impact on adherence with an effect size of 0.0106 ($p < 0.005$). This impact is exemplified in the average adherence scores of each group, with the digital only cohort reporting a mean adherence score of 4.95 compared to 5.89 for those that only consult healthcare professionals ($p < 0.005$). This significant difference in mean adherence score is also reflected in the number of participants classified as having low adherence (MMAS < 6) with 62.4% of the digital only cohort falling into this category compared to 57.2%, 48.2% and 44.2% for the 2 digital

Table 5
Results of Tukey HSD follow up comparisons for 8 univariate models. $p_{i,j}$ is the adjusted p-value for the comparison between groups i and j. 0-Only Digital, 1- 1 Professional Source, 2 - 2 Professional Sources, 3 - Only Professional.

	$p_{0,1}$	$p_{0,2}$	$p_{0,3}$	$p_{1,2}$	$p_{1,3}$	$p_{2,3}$
Burden	0.0250	< 0.000	< 0.000	0.135	< 0.000	0.0644
Life Saving	0.0720	< 0.000	0.997	0.001	0.023	< 0.000
Over Prescribed	< 0.000	< 0.000	< 0.000	0.167	< 0.000	0.003
Self Responsibility	< 0.000	< 0.000	0.999	0.006	< 0.000	< 0.000
Harm	< 0.000	< 0.000	< 0.000	0.011	0.2514	0.284
Savior	< 0.000	< 0.000	0.114	0.039	< 0.000	< 0.000
Overall Health	0.991	0.010	0.987	0.002	0.888	< 0.002

Table 4
ANOVA table for univariate model of adherence scores predicted by demographic variables. $\alpha = 0.05$

	Df	Sum Sq	Mean Sq	F value	Pr (> F)	Partial eta^2
Age	1	7485.17	7485.17	2067.65	0.0000	0.1123
Information Source	3	633.93	211.31	58.37	0.0000	0.0106
Household Income	1	461.65	461.65	127.52	0.0000	0.0077
Education Level	1	1.75	1.75	0.48	0.4864	< 0.0000
Gender	1	5.34	5.34	1.48	0.2244	0.0001
Age:Information Source	3	17.01	5.67	1.57	0.1952	0.0003
Age:Household Income	1	3.72	3.72	1.03	0.3107	0.0001
Age:Education Level	1	2.65	2.65	0.73	0.3926	< 0.0000
Age:Gender	1	60.09	60.09	16.60	0.0000	0.0010
Information Source:Gender	3	30.11	10.04	2.77	0.0399	0.0005
Household Income:Gender	1	21.84	21.84	6.03	0.0140	0.0004
Education Level:Gender	1	0.00	0.00	0.00	0.9996	< 0.0000
Age:Information Source:Gender	3	30.24	10.08	2.78	0.0393	0.0005
Age:Household Income:Gender	1	33.17	33.17	9.16	0.0025	0.0006
Residuals	16346	59174.77	3.62			

Table 6
Medication and Health perception differences between Digital Only, 2 Digital Sources, 1 Digital Source and Healthcare Professional information source cohorts.

Variables	Digital	2 Digital Sources	1 Digital Source	Healthcare Professional	Significance
Burden	3.85 (1.65)	3.99 (1.54)	4.12 (1.55)	4.19 (1.57)	< 0.005
Life Impossible	4.53 (1.78)	4.67 (1.66)	4.90 (1.62)	4.63 (1.68)	
Over Prescribed	3.30 (1.53)	3.45 (1.37)	3.52 (1.35)	3.61 (1.38)	< 0.005
Self Responsibility	5.78 (1.26)	5.91 (1.03)	6.03 (0.95)	5.82 (1.09)	< 0.005
Harm	4.47 (1.58)	4.86 (1.41)	5.02 (1.33)	4.96 (1.37)	< 0.005
Savior	5.09 (1.49)	5.29 (1.29)	5.42 (1.24)	5.21 (1.34)	< 0.005
Overall Health	2.31 (0.74)	2.32 (0.71)	2.40 (0.71)	2.35 (0.70)	< 0.005
Percentage of Population Recently Hospitalized	19%	20%	19%	18%	0.17

source, 1 digital source and healthcare professional cohorts, respectively ($p < 0.005$).

The bivariate analysis show several differences between each cohort. Among all demographic variables included in the models age demonstrated the largest impact on overall adherence with the 18–29 age group reporting a mean adherence of 4.82 (2.08) compared to 6.69 (1.5) for the 65 + age group. This large difference in adherence was additionally present in all cohorts used in this study with youngest and oldest subgroups reporting differences of 1.5, 1.75, 1.72 and 1.8 for the digital only, 2 digital source, 1 digital source and healthcare professional only groups, respectively. Despite the similar overall impact of age on adherence amongst all groups, the digital only cohort reported significantly lower adherence rates throughout all age groupings compared to those seen in the mixed use and healthcare professional cohorts.

These findings suggest a correlation between the use of digital information sources and decreased prescription medication adherence that is independent of age, though not gender. Additionally ethnicity appears to have an independent impact on overall adherence, with the White cohort reporting a significantly higher adherence regardless of information source usage. The significantly combination of a lower average age and more diverse makeup partially explains the lower adherence seen in the digital cohort [43,44]. Additionally in models attempting to control for the impact of demographic factors on overall adherence, information source utilization continuously showed statistical significance. Information source alone does not drive whether or not a patient will take their medication, there are many factors with complex interactions that drive this decision; however our findings suggest that it must be considered in efforts to increase patient adherence.

Analysis of patient medication perception revealed significant differences between the cohorts, with digital users reporting significantly more negative views than both mixed use cohorts and the healthcare professional cohort. Personal beliefs on any subject are derived from a complex interplay of individual knowledge, experience, and interactions with others, the beliefs surrounding prescription medication are no exception. While information source is not the only factor shaping these beliefs, the findings of this study show that increased usage of digital sources has a strong correlation with negative views on medication. A particularly worrying finding is the negative correlation between reliance on healthcare professionals for information and the believe prescription medications are over-prescribed. However there are positives to be found from the combination of information from healthcare professionals and digital means with the group using 1 digital source having the strongest beliefs in their self-responsibility for their own health, that medications are life-saving, do more good than harm, as well as the most positive view of their own overall health.

While the data captured in this study is not sufficient to determine whether these negative views and reduced overall adherence are a result of the use of digital means, or the reason that participants chose to use an increasing number of digital means for information gathering; it does indicate that information source must be considered when attempting to improve patient adherence and as a result overall patient health. In order to better understand the impact that information source has on adherence and patient beliefs longitudinal studies, with cohorts utilizing varying sources and combinations of sources, must be undertaken. Additionally studies analyzing the impact that patient indication, demographic factors and medication type have on the sources individuals rely on for education and information should be undertaken.

As our society continues to advance towards a fully connected world, the utilization of digital sources for information will continue to increase. There are many potential positive impacts to the democratization of information, particularly when it comes to patient health. Allowing patients to feel more empowered in their own health related decisions, increasing access to support groups, and creating a better educated populace on the importance of health-related decisions [9]. However in order to full harness these potential benefits several steps must be taken. First, the patient-practitioner relationship must be an open one, encouraging patients to engage in discussions about the information they find online, the decisions they make based on these findings and their overall impact on patient health. Second, improving overall patient health literacy must become a focus of both the education system and healthcare professional. Third, this data highlights the need to improve the quality and accuracy of online information sources, particularly.

6. Limitations

This study has a number of limitations the authors wish to describe. First, the study is based on a cross-sectional survey, which does not allow for the detection of the potential changes in patient behavior and beliefs that information sources usage may have caused or the detection of events that may have led to changes in information seeking behaviors. Second, electronic data collection was used, which requires individuals to have internet and computer access to enroll in the study. This may have been a limiting factor for both older populations and those living in more rural areas. Third, the data collected only allowed researchers to report correlations between individual factors and adherence. The nature of the data does not allow researchers to determine if each factor is causative in nature. Fourth, the survey did not collect detailed data on the individual conditions, prescription medications of participants, or overall patient morbidity. The authors acknowledge that the impact adherence has on overall patient health varies between conditions and this information would have allowed for more robust analysis. Fifth, each subgroup used for analysis varied in size and overall demographic makeup. Sixth, MMAS-8, is a self-reported adherence scale, which limits the researchers' ability to verify the accuracy of the levels of adherence reported. The MMAS-8 has been widely used and validated, but the self-reporting of adherence without incorporation of additional metrics has potential limitations.

7. Conclusion

The information age has caused a fundamental shift in the accessibility of knowledge, with over half of the global population having access to the internet. The widespread utilization of the internet has greatly aided in the democratization of knowledge, and while this can lead individuals to feel as though they are making educated and well-informed decisions, there is no guarantee on the quality of the information or full comprehension by the user. This is particularly true when considering complex health and medical information, which must be considered in the context of a wide array of factors. Several previous studies have shown that younger individuals are at risk for decreased prescription adherence. When these results are combined with our analysis showing that younger age groups are more inclined to rely on information sources that also correlate with lower adherence, it quickly becomes apparent that this demographic is especially at risk of succumbing to the negative health consequences that accompany the incorrect or inconsistent usage of medication.

While the analysis presented here focuses solely on the impact that pervasive technologies can have on medication adherence and viewpoints surrounding medications, future analysis interpreting the impact of the information age on a wide range of viewpoints surrounding participant health is needed. Geographic, psychological and health related factors also need to be investigated in order to develop a more complete picture on the influence that the cultural differences of regions have on overall medication adherence and information seeking behavior. This is especially critical in understanding adherence risk factors in rural or low-resource populations.

While the data in our study is unable to determine causation over correlation, it never the less highlight the importance of the patient-practitioner relationship. In order to improve the adherence and overall health of the general population, individuals must be urged to consult with health care professionals before any decisions regarding their health are made. Additionally, health care professionals must engage in conversations with their patients regarding the benefits of their medications and the information that can be found on the internet, social media, and mobile applications. Most importantly, the health community as a whole must make a concerted effort to improve the accuracy, readability, and reliability of the information made available through modern technology. In order to fully utilize the positives, and mitigate the potential negative impacts, of the digital age on patient health, the quality of information available must improve, health literacy education must improve and the patient-practitioner relationship must be open, collaborative, and supportive, encouraging patients to be involved in their own healthcare, research information in anyway possible and discuss healthcare related decisions with educated professionals.

Conflicts of interest

The authors declare that they have no conflicts of interest.

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