Can digital health technologies exacerbate the health gap? A clustering analysis of mothers' opinions toward digitizing the maternal and child health handbook

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ABSTRACT

Background: The use of mobile health has increased worldwide, but along with its increased utilization comes the risk of the digital divide, inequity in access to information and communications technologies, exerting greater influence on health inequity caused by socioeconomic determinants of health. There is a growing need to investigate whether the digitization of existing health interventions has a risk of worsening the health gap.
Methods: We investigated the attitudes of mothers and pregnant women toward digitization of the Maternal and Child Health Handbook (MCHH), a popular personal health record (PHR) used by almost every pregnant woman or mother in Japan, using a cross-sectional survey. We determined sociodemographic factors associated with favorable opinions toward digitization using a multivariate regression model. We then grouped the participants using partitioning around medoids clustering, a machine-learning approach, to interpret their varying attitudes toward digitization in light of their sociodemographic characteristics as well as their affinity toward the paper MCHH.
Findings: Higher income and educational level, older age, and less reliance on the MCHH were significantly associated with favorable opinion toward digitization. Clustering analysis identified four latent clusters. The cluster with the highest socioeconomic status (SES) was the most favorable toward digitization, while two clusters with the lowest SES, one of which relied heavily on the paper MCHH, were less favorable of digitization compared to the high SES cluster. The final cluster was comprised of mothers with the experience of raising multiple children and did not rely heavily on the MCHH.
Interpretation: Our study identified a socioeconomic divide in opinions toward digitization of an existing health intervention. A hasty digitization may result in an unbalanced uptake of the digitized health intervention among different social classes.

1. Background

Information and communication technologies (ICTs) are seen as an important catalyst for achieving the Sustainable Development Goals (Sustainable Development Goals Knowledge Platform, 2016). The uptake of ICTs have been increasing at an impressive rate, even in developing countries (Avgerou et al., 2016). The health care sector is no exception to the upward trend in the utilization of ICTs; a digital health

resolution adopted in the 71st World Health Organization (WHO) World Health Assembly recognized the potential of digital technologies to improve the accessibility, quality, and affordability of health services and thereby advance toward the attainment of the Sustainable Development Goals (The Seventy-first World Health Assembly, 2018).

In accordance with this resolution, numerous countries are promoting the uptake of digitized health services. In the United Kingdom, the National Health Service (NHS) has been promoting the uptake of a self-management application for Chronic Obstructive Pulmonary Disease (COPD) patients, myCOPD, since 2015 (Nather & Hicks, 2018). Japan's Ministry of Health, Labor, and Welfare announced in 2018 that health care provided through telemedicine would be covered by health insurance (Kadoya et al., 2020). The upward trend in the uptake of digital health is apparent not only in the developed countries but also in developing parts of the world; for instance, the United Nations Relief and Works Agency for Palestine Refugees in the Near East (UNRWA) released the electronic Maternal and Child Health Handbook application in 2017 (Nasir et al., 2020) and the electronic Non-communicable Diseases application in 2020 (United Nations ReliefandWorks Agencyin the Near East, 2019) in Middle Eastern countries and territories like Jordan, Syria, Lebanon, West Bank, and Gaza. Mobile health has been gaining even more attention with the emergence of the coronavirus disease 2019 (COVID-19) pandemic (Keesara et al., 2020). In March 2020, the United States Congress increased access to telemedicine in rural areas for beneficiaries of Medicare (Office U.S.G.P., 2020), followed by a bill that advocated for the increased coverage of telemedicine in the United States beyond the COVID-19 era (Congress.gov, 2020).

Amidst the wave of digitization in health care, many would expect that the digitization of health care services will reduce gaps in health. However, it also has the risk of doing just the opposite: digitization of health care services may leave marginalized people who don't have access to or are unwilling to use digital health services behind (Makri, 2019). In fact, previous studies have found that patients with low health literacy were less likely to use digital health tools or find them easy or useful (Mackert et al., 2016), and that patients of lower socioeconomic status (SES) were less likely to use the internet for health information (Din et al., 2019). The aforementioned WHO resolution on digital health makes no mention of the digital divide (The Seventy-first World Health Assembly, 2018; Makri, 2019), and the potential threats the digital divide pose on the health gap may be a risk that warrants more attention.

One area that has been gaining attention without its risks being discussed enough is the digitization of personal health records (PHRs). By empowering its users with their own health information as well as important health tips, PHRs have shown enormous potential in increasing health literacy and reducing gaps in health care (Hagiwara et al., 2013; Mori et al., 2015). However, it is becoming increasing important to realize that digitizing PHRs may in fact exacerbate the health gap, empowering only those who use the digital PHRs, making traditional PHRs obsolete, and leaving vulnerable populations behind.

Perhaps one of the most well-known, widespread, and popular PHRs in the world is the Maternal and Child Health Handbook (MCHH). Its uptake is nearly 100% in Japan, its country of origin, and has been mentioned in the law of the land since over 50 years ago. Currently, local municipalities are obliged by law to distribute the handbook to all pregnant women (Nakamura, 2010). Its presence is also recognized globally, with more than 20 countries worldwide having implemented the handbook (Nakamura, 2010). The handbook has become a necessity for mothers and pregnant woman not only as a source of health information but also as a tool to keep track of important health milestones from pregnancy to adolescence (such as vaccination records and results of health checkups), with multiple studies providing evidence that MCHH use leads to increased health-seeking behavior and improved health outcomes (Magwood et al., 2019; Mori et al., 2015). Because of its utility, almost all mothers and pregnant women bring the handbook to prenatal care checkups, child health checkups, vaccination

appointments, and their child's primary care visits. MCHH is no exception to the global wave of digitization of health services, with recent talks in Japan and internationally of digitizing the MCHH (the primary form of the MCHH currently used is the paper version, but the digital MCHH is increasingly utilized in select municipalities through collaborations with the private sector) (Kanagawa Prefecture, 2019; Nasir et al., 2020).

No study has evaluated the potential consequences of digitizing existing health interventions on the social determinants of health; our study will be the first to do so for a health intervention as widespread, popular, and effective as the MCHH. By characterizing mothers and pregnant women who currently use mobile phones unlikely or unwilling to use the digitized MCHH, we sought to evaluate the risk of a worsening health gap due to the digital divide in the setting of the digitization of a popular PHR.

2. Methods

2.1. Study design, questionnaire distribution and inclusion criteria

We distributed self-administered questionnaires to mothers and pregnant women from March to April of 2020. The questionnaires were distributed via a mobile application for pregnant women and mothers, which was developed in 2017 by the Japan Society of Obstetrics and Gynecology to provide valuable maternal and child health information to its 350,000+ users. The application is available in Japanese and is downloadable on smartphones for free in all regions of Japan, and provides helpful information in pregnancy and parenting. The questionnaires were distributed to all 108,154 active users of the application. Using this survey, we evaluated the relationship between socioeconomic status and opinion toward the digitization of the MCHH. By limiting the study participants to regular users of a mobile application, we were able to minimize the effects of access to mobile health on the participants' opinion toward utilization of digital health. Hence, our study was designed to answer the question "given there is equal access to digital technology, what are the effects of socioeconomic factors on opinions toward digitizing an existing health intervention?"

In addition to socioeconomic status and opinion toward digitization of the MCHH, the questionnaires contained questions on the participants' opinions toward the maternal and child health handbook as well as general questions on demographic information. We included in the study mothers and pregnant women whose answer to the question on the main outcome ("how much would you support the digitization of the MCHH?") was available.

2.2. Variables

We used the following variables in the analyses: age quintile of the participant (ordinal variable: 1, 0–20; 2, 21–25; 3, 26–30; 4, 31–35; 5, 36–40; 6, 41+ years old), age of the eldest child in years (age 0 if pregnant with first child), whether the participant was pregnant at the time of the study, number of children, annual household income quintile based on income quintiles from the Statistics Bureau of Japan (Ministry of Internal Affairs and Communications Statistics Bureau, 2020), and educational level of the participant (ordinal variable: 1, middle school; 2, high school; 3, junior college; 4, university; 5, graduate school). Additionally, participants were asked about the extent to which they read the MCHH (1, almost none; 2, about one-quarter, 3, about one-half; 4, about three-quarters; 5, almost all), and how much the participant was favorable of the digitization of the MCHH (answer to the question, "how much would you support the digitization of the MCHH?": 1, will favor the paper MCHH over digitized MCHH; 2, ambivalent (should be able to choose between the two/should use both/distribute paper MCH and use digitized MCH if necessary); 3, will favor digitized MCHH over paper MCHH).

Our main outcome was participants' opinion on the digitization of

the MCHH, rated on a scale from 0 to 3. We used the extent of MCHH reading as a measure of the extent to which the participant utilized the paper MCHH. Missing data were imputed using k-Nearest Neighbor imputation.

2.3. Statistical analyses

We conducted an ordinal logistic regression to identify factors associated with favorable attitudes toward digitization of the MCHH, rated on a scale from 1 to 3, 3 being the most favorable and 1 being the least favorable toward digitization. We then used partitioning around medoids (PAM) clustering, an unsupervised machine learning algorithm that divides a dataset into several groups, to identify latent subgroups within the study sample. PAM clustering is suitable for data containing mixed (both numeric and categorical) variables (Shamsuddin & Mahat, 2019). The optimal number of clusters was determined and verified using consensus cumulative density function (CDF) plots, elbow method, consensus matrix heatmaps (Wilkerson & Hayes, 2010), and t-distributed stochastic neighbor embedding (t-SNE), whose results are available in the supplement (van den Maaten & Hinton, 2008). We computed the basic characteristics of each subgroup identified from PAM clustering and conducted tests of significance to compare the clusters. P-values less than 0.05 were considered significant. All analyses were conducted using R version 3.6.3.

2.4. Ethical considerations

The study was approved by the ethics review board of the Aiiku Research Institute for Maternal-Child Health and Welfare (IRB number 2019–04).

Role of the funding source

3. Results

3.1. Basic characteristics and multivariate regression

A total of 7710 mothers and pregnant women met the inclusion criteria. There were 108,154 active users of the application at the time of the survey, giving a response rate of 7.1%. The basic characteristics of the study sample are shown in Table 1. The multivariate regression (Table 2) showed that higher income and education level, older age of the participant, and lesser extent of MCHH reading were significantly associated with favorable opinion toward digitization of the MCHH.

Table 1

Basic characteristics of the participants. Categorical variables are expressed as proportions and continuous variables are expressed as mean ± standard deviation. Opinion toward digitization of MCHH is expressed in three levels, 3 being the most favorable and 1 being the least favorable toward digitization, and the average level in each cluster is shown in the table. MCHH, maternal and child health handbook.

	All participants (n = 7710)
Opinion toward digitization	1.75 (0.50)
Extent of MCHH reading	2.84 (1.42)
Age quintile	3.79 (1.01)
Being pregnant	94.3%
Number of children	1.49 (0.77)
Age of eldest child	0.90 (1.29)
Income quintile	3.49 (1.06)
Educational level	3.23 (0.94)

Table 2

Regression for favorable opinion toward digitization of MCHH. P < 0.05 was considered statistically significant.

	All participants (n = 7710)			
	Coefficient	OR	95% CI	p-value
Extent of MCHH reading	−0.072	0.930	(0.899–0.963)	<0.001
Age quintile	0.077	1.089	(1.026–1.137)	0.004
Being pregnant	0.072	1.075	(0.874–1.317)	0.49
Number of children	−0.076	0.927	(0.829–1.036)	0.18
Age of eldest child	−0.048	0.953	(0.890–1.020)	0.17
Income quintile	0.176	1.193	(1.134–1.255)	<0.001
Educational level	0.068	1.070	(1.012–1.133)	0.02

3.2. Clustering analyses

Figs. S1–S4 show consensus matrix heatmaps, elbow method, consensus matrix heatmaps, and t-SNE plot, all of which were used to determine the adequate number of clusters (for details, see supplement). Using these results, we determined the optimal number of clusters to be four. Thus, we used PAM clustering to group the study sample into four subgroups.

The characteristics of each of the four clusters are presented in Table 3. Cluster 1 was composed of older mothers and pregnant women with multiple children, who likely were very experienced mothers who had already utilized the paper MCHH relatively extensively. The remaining clusters (cluster 2, 3, and 4) showed clear differences in SES; to delineate the characteristics of cluster 2 (the high SES cluster) compared to clusters 3 and 4 (the low SES clusters), we conducted tests of significance between clusters 2 and 3 and between clusters 2 and 4, whose results are shown in Table 4.

Cluster 2 was comprised of mothers with the highest SES among the

Table 3

Characteristics of each cluster. Clusters were identified via PAM clustering. The optimal number of clusters were determined using multiple statistical methods (Figs. S1–S4). Categorical variables are expressed as proportions and continuous variables are expressed as mean ± standard deviation. Opinion toward digitization of MCHH is expressed in three levels, 3 being the most favorable and 1 being the least favorable toward digitization, and the average level in each cluster is shown in the table. Chi-squared test was used to compare proportions and Kruskal-Wallis test was used to compare means. P < 0.05 was considered statistically significant. MCHH, maternal and child health handbook; PAM, partitioning around medoids.

	Cluster 1 (n = 2258)	Cluster 2 (n = 2051)	Cluster 3 (n = 1979)	Cluster 4 (n = 1422)	P-value
Opinion toward digitization	1.71 (0.50)	1.84 (0.49)	1.70 (0.50)	1.75 (0.51)	<0.001
% favorable toward digitization	2.3%	5.5%	1.9%	3.9%	
% ambivalent toward digitization	66.8%	73.3%	66.3%	67.2%	
% unfavorable toward digitization	30.9%	21.2%	31.7%	28.9%	
Extent of MCHH reading	3.20 (1.41)	2.17 (0.88)	4.15 (0.91)	1.39 (0.49)	<0.001
Age quintile	4.24 (0.88)	4.13 (0.87)	3.36 (0.98)	3.17 (0.89)	<0.001
Being pregnant	94.1%	95.0%	93.5%	94.9%	0.161
Number of children	2.43 (0.74)	1.09 (0.29)	1.11 (0.33)	1.08 (0.27)	<0.001
Age of eldest child	2.82 (0.39)	0.10 (0.36)	0.12 (0.36)	0.09 (0.34)	<0.001
Income quintile	3.43 (1.01)	4.34 (0.67)	3.12 (1.04)	2.91 (0.87)	<0.001
Educational level	3.02 (0.99)	3.84 (0.65)	3.07 (0.90)	2.90 (0.88)	<0.001

Table 4

Comparison between the high SES cluster (cluster 2) and the low SES clusters (cluster 3 and 4). Categorical variables are expressed as proportions and continuous variables are expressed as mean ± standard deviation. Opinion toward digitization of MCHH is expressed in 3 levels, 3 being the most favorable and 1 being the least favorable toward digitization, and the average level in each cluster is shown in the table. Fisher test was used to compare proportions and Wilcoxon rank-sum test was used to compare means. P < 0.05 was considered statistically significant. SES, socioeconomic status; MCHH, maternal and child health handbook.

	Cluster 2 (n = 2051)	Cluster 3 (n = 1979)	P-value	Cluster 2 (n = 2051)	Cluster 4 (n = 1422)	P-value
Opinion toward digitization	1.84 (0.49)	1.70 (0.50)	<0.001	1.84 (0.49)	1.75 (0.51)	<0.001
Extent of MCHH reading	2.17 (0.88)	4.15 (0.91)	<0.001	2.17 (0.88)	1.39 (0.49)	<0.001
Age quintile	4.13 (0.87)	3.36 (0.98)	<0.001	4.13 (0.87)	3.17 (0.89)	<0.001
Being pregnant	95.0%	93.5%	0.05	95.0%	94.9%	1.00
Number of children	1.09 (0.29)	1.11 (0.33)	0.03	1.09 (0.29)	1.08 (0.27)	0.29
Age of eldest child	0.10 (0.36)	0.12 (0.36)	0.03	0.10 (0.36)	0.09 (0.34)	0.10
Income quintile	4.34 (0.67)	3.12 (1.04)	<0.001	4.34 (0.67)	2.91 (0.87)	<0.001
Educational level	3.84 (0.65)	3.07 (0.90)	<0.001	3.84 (0.65)	2.90 (0.88)	<0.001

four clusters, who, compared to cluster 3 or 4 (the low SES clusters), had a significantly more favorable opinion toward digitization of the MCHH (Table 4). Cluster 3 likely contained mothers and pregnant women who primarily relied on the paper MCHH, given that their extent of MCHH reading was significantly larger than cluster 2 (4.15 vs 2.17, P < 0.001) and their opinion toward digitization was much less favorable than cluster 2 (1.70 vs 1.84, P < 0.001). Mothers and pregnant women in cluster 4, who had the lowest SES among the four clusters, did not have a favorable opinion toward the digitization of MCHH compared to cluster 2 (1.75 vs 1.84, P < 0.001) nor did they utilize the paper MCHH as much as cluster 2 (1.39 vs 2.17, P < 0.001).

4. Discussion

4.1. Principal findings

The study sheds light on a socioeconomic disparity in opinions toward digitization of a popular existing health intervention, even when its users have equal access to digital technology. Mothers and pregnant women who tended to favor the digitization of the MCHH were those with higher SES. Mothers and pregnant women with lower SES tended not to favor the digitization of the MCHH as much as those with higher SES; some of these mothers and pregnant women instead relied heavily on the paper MCHH.

4.2. Implications

4.2.1. Socioeconomic status and the uptake of digital health

Our results suggest that even when there is equal access to digital technology (which, according to economist Joseph Stiglitz, is an essential step to fighting inequity in the digital age) (Stiglitz, 2019), social determinants of health can pose a major threat in the uptake of digitized health interventions, implicating that socioeconomic status can impact the uptake of digital health through pathways independent of access to digital technology.

Previous studies from developing and developed nations have implicated that factors associated with access to digital health as the main obstacles of conquering the socioeconomic gap in health through digital technologies (Kim & Zhang, 2015; Nasir et al., 2020; Olu et al., 2019). A study in Jordan found the lack of access to the internet to be associated with limited uptake of an electronic MCHH (Nasir et al., 2020), and a study on Hispanics with low SES found that they relied heavily on public Wi-Fi for health information (Kim & Zhang, 2015). The present study provides a unique perspective in that it points to factors independent of access to digital health. A previous study showed that a digital divide in different socioeconomic classes exists because of how, not if, people use computers (Harris et al., 2017), but to the best of our knowledge, our study is the first to do so in the setting of an existing health care intervention. Therefore, simply reaching out to socioeconomically vulnerable groups with digital health interventions is unlikely to solve the health gap.

Future studies need to investigate the pathways through which the uptake of digital health can exacerbate the health gap by socioeconomic status. A previous qualitative study showed that low-SES adults used web browsers for health-related information rather than mobile applications, lacked the skills to effectively navigate mobile applications, and lacked the ability to comprehend and evaluate the quality of health-related information (Kim & Zhang, 2015). Perhaps a there is a need to directly convey health information to socioeconomically vulnerable groups, but this needs to be investigated in additional studies.

4.2.2. Addressing maternal and child health inequalities in the digital age

Inequalities due to social determinants of the health of the mother and the child are a pervasive issue (Cheng et al., 2015). Health disparities in children are often intergenerational (Lê-Scherban et al., 2018), and thus maternal and child health interventions are often crucial in addressing such disparities. In a world where the uptake of digital technology is becoming increasingly widespread, addressing the relationship between social factors and utilization of digital health in the setting of maternal and child health is an extremely important task.

Mothers and pregnant women of lower SES were less likely to adopt digital health technologies and may instead be dependent on conventional, paper PHRs. Digitizing PHRs in this setting may marginalize mothers and pregnant women of lower SES, thereby exacerbating the health gap. Perhaps the most appropriate option when it comes to digitizing an existing health care service may be to leave the conventional service (e.g. the paper MCHH) in place, leaving both options available. This was the case in the setting of the electronic MCHH in the Middle East, where the electronic MCHH was implemented but the paper MCHH was also kept in place (Nasir et al., 2020). Such interventions may be especially important in developing countries, where the digital divide may be more prevalent (Zhang, 2017). Furthermore, the digital divide has become more exposed with the COVID-19 pandemic, and the fact that there are few measures to address this warrants attention (Ramsetty & Adams, 2020).

4.2.3. Challenges of PHRs

Additionally, the present study sheds light on a major challenge faced by PHRs: often times, the hardest for PHRs to reach are those who are socioeconomically most vulnerable (Ancker et al., 2016), which is supported by our finding that mothers and pregnant women with the lowest SES tended to favor neither the paper MCHH nor the digitization of the MCHH. Reaching out to these mothers may require interventions other than PHRs, such as building a stronger provider-parent partnership in the care of the child (Yin et al., 2012).

4.3. Strengths and weaknesses of this study

To the best of our knowledge, our study is the first to evaluate the potential consequences of digitizing a popular existing health intervention on the social determinants of maternal and child health. By characterizing mothers and pregnant women with a focus on the

relationship between SES and opinions toward digitizing the MCHH, a popular PHR, we shed light on the potential risk of a worsening socio-economic gap in health due to the digital divide. With a large sample size and robust methods, the present study provides concrete evidence on an increasingly important topic in the digital age. Furthermore, we were able to point to pathways independent of access to digital technologies that can lead to health disparities among social classes.

However, our study should be interpreted in light of several limitations. We did not include potentially important factors in the analyses, such as the presence of a partner, support from parents, and availability of community resources. Addressing these factors may have led to better implications on the types of support that can provided to vulnerable pregnant women and mothers. Furthermore, based on the profiles of mothers and pregnant women sampled in our study, our study sample may be biased toward mothers and pregnant women who have better SES compared to the total population. This likely is due to the fact that we limited the study participants to regular users of a mobile health application; mothers and pregnant women who regularly use such an application likely have higher health literacy than the general population, and health literacy is known to be associated with SES (Kim & Zhang, 2015). Furthermore, that only smartphone users were able to participate in this study may limit the generalizability of this study, though in 2020, more than 94% of women in Japan aged 20–49 years owned a mobile phone, a percentage that has increased over the years and is larger in women than men (Ministry of Internal Affairs and Communications, 2020). Additionally, it is important to note that Japan is an advanced country in terms of maternal and child health services and digital health (Kadoya et al., 2020; Nakamura, 2010), which may also limit the study's generalizability to digitization of health services in other countries. Despite these limitations, our study does address important relative inequities among mothers and pregnant women in Japan, and has strong implications as aforementioned.

5. Conclusion

There is a socioeconomic disparity in opinions toward digitization of the MCHH, a popular PHR, even when there is equal access to digital technology. Mothers and pregnant women with lower SES, some of whom relied heavily on the paper MCHH, tended not to favor the digitization as much as those with higher SES. A hasty digitization may result in an unbalanced uptake of the digitized health intervention among different social classes.

Author statement

RG conceived the research idea, designed the questionnaire, carried out the analyses, drafted the initial manuscript, and reviewed and revised the manuscript. YW designed the study, gave critical feedback on the questionnaire design, and reviewed and revised the manuscript. ST coordinated the data collection and reviewed and revised the manuscript. AY, MS, and MN gave critical feedback on the research design and reviewed and revised the manuscript. YN supervised the study and critically reviewed the manuscript. All authors approved the final manuscript.

Contributors

RG conceived the research idea, designed the questionnaire, carried out the analyses, drafted the initial manuscript, and reviewed and revised the manuscript. YW designed the study, gave critical feedback on the questionnaire design, and reviewed and revised the manuscript. ST coordinated the data collection and reviewed and revised the manuscript. AY, MS, and MN gave critical feedback on the research design and reviewed and revised the manuscript. YN supervised the study and critically reviewed the manuscript. All authors approved the final manuscript.

Ethical considerations

The study was approved by the ethics review board of the Aiiku Research Institute for Maternal-Child Health and Welfare (IRB number 2019–04).

Data sharing

De-identified raw data used in this study can be made available to researchers from accredited research institutions who provide a legitimate research proposal and can conduct appropriate analyses. Access to data for authorized researchers is possible from the date of publication. Requests for data access should be sent to YN (yastisch@gmail.com). Those interested in research collaborations should contact RG (ryunosukegoto@gmail.com).

Declaration of competing interest

We declare no competing interests.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ssmph.2021.100935.

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