Assessing Digital Health Equity in Implementation of Virtual Rehabilitation After Total Knee Arthroplasty Among Older Adults in the U.S.: A Case Example

by

Ziqi Zhang

Department of Global Health

Duke University

Date: 04/26/2021

Approved:

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Janet Prvu Bettger, Advisor

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Shenglan Tang

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Joseph Egger

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Thesis submitted in partial fulfillment of

the requirements for the degree of

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ABSTRACT

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Abstract

Background: Digital divide among elderly people is an emerging problem. With more adoption of technology in the health care field, we should be aware of the health inequity generated by the adoption of digital health as the norm after COVID-19 crisis.

Objectives: The primary aim of this study is to evaluate the participants' comfort with technology (self-reported digital literacy) prior to using VERA, a digital health platform for exercise therapy. The secondary aim is to examine the association of patient characteristics and digital literacy with the acceptability, treatment adherence, accuracy of exercises performed, and change in exercise over 90-day intervention.

Methods: This cohort study used secondary data from the VERITAS clinical trial (clinicaltrials.gov identifier: NCT02914210). The research analyzed socio-demographics, digital health determinants, and process outcomes at 90-days. Descriptive statistics were conducted, Prevalence Ratio (PR) was used as a measure of association.

Results: Participants who were older in age and had less than 16 years of education were less comfortable with technology. Less comfort with technology prior to starting therapy was not associated with lower acceptability, adherence, accuracy, nor change in days per week exercised over 90 days. We found that having a preexisting condition of neurological disorders was associated with lower self-reported adherence.

Conclusion: Age and education are related to comfort using technology. We should take them into consideration at the digital health design stage. Besides, we didn't find unequal use of VERA with the process outcomes among different strata, which means by personalized health intervention and improved usability, people who have disadvantages can also adopt technology to achieve better health. By advocating the human-centered design, digital health can benefit more people to achieve health equity on a large scale.

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Introduction

Health equity is the leading topic of contemporary public health. (Dover & Belon, 2019). It is important since health is the fundamental human right. Healthy People, the U.S. public-private initiative that sets national goals and targets, highlighted the mission of achieving health equity to improve health and well-being before 2030 (CDC 2020). However, the trajectory toward reaching these goals was disrupted by the COVID-19 public health crisis. Quickly many health facilities had to transit services to be delivered as virtual health care to maintain patient access. Digital health is defined as "the field of knowledge and practice associated with the development and use of digital technologies to improve health" (Crawford & Serhal, 2020). Through digital systems like wearable devices, electronic systems (eHealth) and mobile apps (mHealth), digital health could be a solution for equal access to health resources.

Rehabilitation care is considered an essential health service for health insurance and universal health coverage and is estimated to be needed by 2.4 billion people worldwide (IHME, 2021). Rehabilitation is defined as a series of interventions to reduce disability and optimize functioning(WHO, 2019). Traditional in-person visits to physiotherapists have deficiencies: there are limited specialists and facilities for patients, the rehabilitation program is costly in the United States, and in-person care can be inconvenient especially after surgery. Long time spent waiting at appointments and indirect healthcare spending like transportation can also impede patients' from receiving appropriate services(Crowley et al. 2020; Syed, Gerber, and Sharp 2013). To address these barriers, innovative and flexible digital health alternatives can provide access to rehabilitation and improve patients' adherence to recommended therapeutic regimens. Previous studies (Zampolini et al., 2008) showed home telerehabilitation, a subset of telemedicine using advanced telecommunication technologies, can address barriers to patient access to physiotherapy. New interventions like telemonitoring systems allow independent home-based rehabilitation combining information and sensor technology(Nascimento et al. 2020). It can help patients receive timely and objective feedback on exercise performance and functional outcomes. Because physical therapy exercises can be repetitive, maintaining patients' interests and adherence can be difficult, more therapists explore the use of virtual reality (VR) for rehabilitation treatment (Maresca et al., 2018). VR, the artificial environment created by a computer to simulate reality, is used as a form of training, which patients can interact with (Rogers et al., 2019). The pilot research found that VR could facilitate recovery on both motor and cognitive level after stroke. It has many advantages including the ability to engage individuals to set a personalized recover goal, flexibility in adjusting the difficulties of tasks, and the embedded reward systems to help maintain patients' compliance (Rogers et al., 2019).

An innovative virtual physiotherapy program was designed combining care coordination managed by experienced telehealth therapists and a cloud-based virtual telehealth platform called Virtual Exercise Rehabilitation Assistant (VERA™) system. VERA tracks activity, performance, exercise quality, and adherence of patients. It has 3 main functions, including quantifying patients' pose and motion by 3D tracking technology, providing visual and audible instructions by a virtual training coach, and offering immediate visual and audible feedback to patients. Individuals receive personalized digital therapy regimens programmed into the system through the clinician interface before the surgery. Patients have weekly video visits to evaluate progress and adjust the regimen accordingly. In the past research, a clinical trial demonstrated that this care coordination model using VERA was cost-effective and non-inferior compared with traditional physiotherapy for patients after total knee arthroplasty (TKA), also known as total knee replacement (Prvu Bettger et al., 2020). However, the technology assessment focused on effectiveness without discussing digital health equity and participants' perceptions of using the technology could limit the potential of implementation in practice (Enam et al., 2018).

The Digital Health Equity Framework developed by Crawford and Serhal (Crawford & Serhal, 2020) integrated Dover and Belon's Health equity Measurement Framework (HEMF) (Dover & Belon, 2019) with digital determinants of health to evaluate digital health equity. According to the previous research (Azzopardi-Muscat & Sørensen, 2019; Brewer et al., 2020), innovative health technology can both reduce and produce social inequities. It decreases inequity by improving people's access to health resources, but the influence can vary regard to different personal, contextual factors, which enlarge the gaps between people. Examining participation in the trial through a digital health equity lens can share insights on the impact of social stratification on access to digital healthcare and outcomes of utilizing digital health resources.

With the increasing adoption of telehealth after COVID-19 pandemic, we sought to explore digital health equity related to the VERITAS clinical trial that leveraged a virtual platform for physiotherapy as part of a post-surgical approach to care management. Since all patients in the trial were provided with the equipment and broadband cellular network access, with both the device and wireless access provided, we are focusing on the implementation process, which is the equal capability and outcomes to use VERA platform. More specifically, our primary aim was to describe the patient characteristics associated with comfort using technology prior to using VERA. The secondary aim is to evaluate if comfort with technology is associated with acceptability of the treatment approach, exercise adherence and accuracy, and change of physical activity over 90 days. A digital health equity lens will help structure the analysis of the broad scale of variables.

Methods

Study design

The study is a cohort study using secondary data derived from the VERITAS clinical trial (clinicaltrials.gov identifier: NCT02914210) intervention group, the database consists patients' electronic health records, baseline and follow-up questionnaires, and performance tracked in the VERA platform.

Participants and study size

The VERITAS trial examined the effectiveness of a virtual exercise therapy facilitated at home compared with traditional care with physiotherapy in person. The study sites recruited 153 patients to the virtual intervention group (out of 306 patients who enrolled in the trial) from November 1, 2016 to November 23, 2018, and they are followed-up through March 12, 2019 (Prvu Bettger et al., 2020). The patients enrolled in the trial are TKA patients who were aged above 18 years and were expected to discharge to home after surgery. The patients were excluded from this retrospective study if they were lost to follow-up or were missing data for any of our dependent variables listed below. This secondary analysis included 129 participants in total of the 153 eligible.

Dependent Variables

Comfort with use of technology

Comfort with technology is the primary factor in technology adoption. People who are uncomfortable with technology would find it difficult to access digital health. The indicator is measured at baseline (study enrollment prior to surgery) with a survey and asked as "how comfortable are you with a smartphone, tablet or iPad, or computer". It is a 5-point scale from 1 as very comfortable to 5 as very uncomfortable. In the analysis, we defined a score above 2 are not completely comfort with technology. The categories are based on the sample size; after the change, the sample size between 2 groups would be more balanced and we have more power in statistical analysis.

Acceptability

Acceptability is defined as "the perception of the innovation is agreeable, palatable or satisfactory" (Proctor et al., 2011). Acceptability comprises multiple components including affected attitude, burden, ethicality, intervention coherence and opportunity costs (Sekhon et al., 2017). In this study, we stratify acceptability to 2 categories based on the recommendation score 0-10. The recommendation score was from the 3-month follow-up question, which is an implication of the Net Promoter Score (NPS), a management tool frequently used to measure the customer likelihood to recommend a product (Koladycz et al., 2018). Respondents who scored 9 or 10 are defined as “promoters”, those who rated 7 or 8 are “passives” and those at 6 or below are “detractors”. To analyze the various feature of the people with distinctly perceived acceptability, we dichotomized the score to high acceptability and relatively low acceptability, more specifically, recommendation score 9 or 10 means high acceptability and below 8 as relatively low acceptability.

Adherence

Adherence to treatment is essential to achieve good health outcomes. It is an indicator to measure the total number of sessions and weeks that patients were in treatment. We used episode adherence and self-reported treatment adherence in this study to measure the therapeutic exercises completed of what was prescribed, descriptive analysis was conducted to measure the episode adherence in different groups. For the *self-reported treatment adherence*, it is a dichotomized variable reported by participants after 90-day intervention by answering the question that if they completely follow prescription or not. If the participant answered “yes”, we record “1” as completely follows the episode, vice versa. For *episode adherence*, it is a continuous variable reported as the percentage of following prescribed treatment recorded electronically by VERA, it is an objective variable, and the maximum value is 1.0.

Episode accuracy

Accuracy of accomplishing the exercise ensures the quality of treatment. When using VERA, the individual will receive an immediate feedback from VERA on the performance of the exercise. It is measured as percent of exercises performed exactly as guided by the virtual coach in the VERA platform. For each exercise, participants receive the evaluation from VERA on the precision of their performance. Episode accuracy is the average of accuracy in the whole prescribed episode period. The maximum value of this measurement is 1 and we treat it as a continuous variable. Hypothesis test was used to analyze the statistical significance in difference between groups.

Exercise days per week

Exercise days per week measures the frequency of participants' physical exercise. It reflects the effectiveness of the intervention. It is asked as "How many days per week do you engage in moderate to strenuous exercise? This is defined as activity during which you break a sweat, but still are able to carry on a conversation." The question is both asked at baseline and 90 days after intervention. We analyzed the change after 90-day intervention.

Digital Equity Lens to Data Analysis

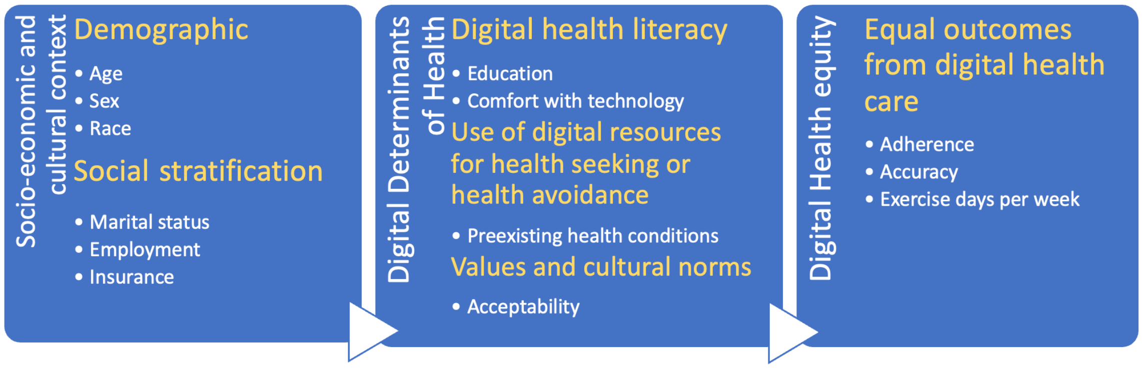

Figure 1 Conceptual models of variables on digital health equity

To structure the analysis process, the Digital Health Equity Framework (DHEF) (Crawford & Serhal, 2020) was used to guide the organization of data to describe the social, cultural, and digital determinants of health equity (Figure 1). To summarize, the framework contains the three domains. In the first domain it includes 2 constructs: demographic and social stratification. It is important in health equity since a person's social status will determine the opportunity to access health resources and vulnerabilities to health-related risk (Crawford and Serhal 2020). The second domain is digital determinants of health, which includes 3 constructs as digital health literacy, used of digital resources, and values and cultural norms. Digital health literacy is the determinants of engagement with technology, the use of digital resources for health seeking or health avoidance is related with the pre-existing conditions, which can shape the patients' access to digital health and the quality of intervention. The third construct is values and cultural norms, it can impact participants' digital health related beliefs. This construct is difficult to measure directly, we used perceived acceptability of VERA as the indicator. Eventually, the last domain of digital health equity is represented by the equal health outcomes from digital health care. To measure this construct, we used adherence, accuracy, and 90-day change of exercise days per week to evaluate use of VERA platform. In the DHEF model, these 3 domains have interrelationship: digital health determinants as intermediate factors reinforce the social-economic and cultural context stratification, eventually leads to the impact on digital health equity.

Statistical methods

We conducted descriptive analysis on socio-demographic and clinic characteristics. Also, we explored the association between the participants' characteristics and comfort with technology, acceptability, adherence, accuracy and change of exercise days per week. Mean with standard deviation were calculated for continuous variables, categorical variables were presented with frequencies and percentage. We dichotomized some categorical variables to avoid too small sample size in individual cells. To measure the relationship between two variables, two-sample t-test is used for the normal distribution data with sample size more than 30, Wilcoxon Rank Sum test was performed instead if the criteria was not met. Moreover, for categorical independent variables, Chi-square test of homogeneity was used. To further measure the association between independent variables and comfort with technology and acceptability, prevalence ratio and the 95% confidence interval (CI) were calculated. We then repeated this approach to examine acceptability of using the platform and self-reported adherence to the prescribed regimen. This research is an exploratory analysis and there wasn't evidence of confounding variables, therefore, we didn't adjust any covariates. The analyses were conducted with STATA 16.0.

Result

In Table 1, We found that people who enrolled in intervention cohort of the VERITAS trial are older retired population with a mean age of 65 years, they are highly educated, the average participants completed 15.5-years of education (college-level). 40.3% of the participants are male. The race of the participants is mostly white (86.7%). In terms of socioeconomic characteristics, more than half of the participants are married (77.5%), not working (57.4%), and have government health insurance (58.9%). All participants have some kind of preexisting conditions, and the musculoskeletal disorder has the highest prevalence as 91.5% among the cohort. Most of them (59.4%) are very comfortable with technology. For acceptability, among 129 participants of the trial, 105 (82%) rated high, while only 23 people rated low acceptability as score below 8. In terms of the outcomes, 87.6% of the participants reported to follow the VERA prescription, the episode adherence is 0.7 ± 0.3 and episode accuracy is 0.9 ± 0.2. In average, people exercise 2.4 days per week before the intervention, the number increased to 3.2 days per week after the intervention.

Table 1 Overall patients' characteristics

Variables		Values	Overall (N=129) N (%) Mean+/-SD
Demographic	Age	Years	65.3 ± 7.8
	Sex	Male	52 (40.3%)
		Female	77 (59.7%)
	Race	White	111 (86.7%)
		Black	13 (10.2%)
		Other	1 (0.8%)
		Multiple	3 (2.3%)
	Race**	white	111 (86.7%)
		Non-white	18 (14.0%)
Social stratification	Marital status	Married	100 (77.5%)
		Separated/divorced	15 (11.6%)
		Widowed	7 (5.4%)
		Single/never married	7 (5.4%)
	Marital status**	Married	100 (77.5%)
		Others	29 (22.5%)
	Employment	Employed full/ part-time outside of the home	49 (38.0%)
		Employed full/ part-time as a telecommuter or from home	6 (4.7%)
		Not working, unemployed, unable to work, or retired	74 (57.4%)
	Employment**	Employed	55 (42.6%)

		Unemployed	74 (57.4%)
	Primary health insurance	private	53 (41.1%)
		Medicare	62 (48.1%)
		Medicaid	5 (3.9%)
		Non-Medicaid state plan	3 (2.3%)
		Military	6 (4.7%)
	Primary health insurance**	Government insurance	76 (58.9%)
		Private insurance	53 (41.1%)
Digital health literacy	Education	Number of Years completed	15.5 ± 4.1
	Comfort with use of technology (tablet, Apple iPad, smartphone, or computer)	Very comfortable	76 (59.4%)
		Somewhat comfortable	41 (32.0%)
		Neutral	3 (2.3%)
		Somewhat uncomfortable	5 (3.9%)
	Comfort with use of technology	Very comfortable with use of technology	76 (59.4%)
		Not completely comfortable	52 (40.6%)
Use of health resources	Preexisting condition	Cardiovascular and circulatory diseases	74 (57.4%)
		Neuropsychiatric disorders	20 (15.5%)
		Respiratory diseases	24 (18.6%)
		Musculoskeletal disorders	118 (91.5%)
		Visual and hearing impair	58 (45.0%)
Values and cultural norms	Perceived acceptability	Score (10.0)	9.1 ± 2.1
	Perceived acceptability	High acceptability	105 (82.0%)
		Low acceptability	23 (18.0%)
	VERA use	Episode Adherence	0.7 ± 0.3
		Episode Accuracy	0.9 ± 0.2

Outcomes of digital health care	Self-reported PT	follow the vera prescription	113 (87.6%)
		Not completely following the vera prescription	16 (12.4%)
	Exercise days per week	Before intervention	2.4 ± 2.2
		After intervention	3.2 ± 2.5

** are dichotomized variables

Table 2 measures the association of patients' characteristics and comfort with technology, PR>1 means the people are more comfortable with technology. In terms of the effect size, we found that the older participants and those who has less than 16-year education tend to be less comfortable with technology. Besides, we found that female and unemployed participants showed relative lower comfort with technology. Comparing to those who don't have certain kind of preexisting disease, most of the participants are less comfortable with technology especially those with neurological disorders.

Table 2 Estimate of Prevalence Ratio for comfort with technology

Variables		Values	Very Comfortable (N=76) N (%) Mean+/-SD	Less Comfortable (N=52) N (%) Mean+/-SD	PR	95%CI	p-value
Demo-graphi-c	Age	Years	63.0±0.9	68.2±1.0			0.0002
	Age	<65 years (REF)	37 (66.1%)	19 (33.9%)			0.174
		⩾65 years	39 (54.2 %)	33 (45.8%)	0.82	(0.60,1.09)	
	Sex	Male (REF)	34 (66.7%)	17 (33.3%)			0.172
		Female	42 (54.6%)	35 (45.5%)	0.82	(0.62,1.08)	
	Race	Non-white (REF)	11 (64.7%)	6 (35.3%)			0.792
		white	64 (58.2%)	46 (41.8%)	0.89	(0.61, 1.32)	
Social stratify-cation	Marital status	Others (REF)	19 (65.5%)	10 (34.5%)			0.444
		Married	57 (57.6%)	42 (42.4%)	0.88	(0.64,1.20)	
		Unemployed (REF)	39 (52.7%)	35 (47.3%)			0.072

	Employment	Employed	37 (68.5%)	17 (31.5%)	1.30	(0.98,1.72)	
	Primary health insurance	Government insurance (REF)	42 (55.3%)	34 (44.7%)			0.252
		Private insurance	34 (65.38%)	18 (34.6%)	1.18	(0.89,1.57)	
Digital health literac-y	Education	Number of Years completed	15.9 ± 0.4	14.9 ± 0.7			0.176
	Education	<16 years (REF)	27 (44.3%)	34 (55.7%)			0.0009
		⩾16 years	49 (73.1%)	18 (26.9%)	1.65	(1.20,2.27)	
Use of digital resour-ces	Preexisting condition	Cardiovascular and circulatory diseases	40 (54.1%)	34 (46.0%)	0.81	(0.61,1.08)	0.151
		Neurological disorders	8 (40.0%)	12 (60.0%)	0.64	(0.36,1.11)	0.055
		Respiratory diseases	13 (54.2%)	11 (45.8%)	0.89	(0.60,1.33)	0.564
		Musculoskeletal disorders	72 (61.5%)	45 (38.5%)	1.69	(0.76,3.75)	0.104
		Visual or hearing impairment	34 (58.6%)	24 (41.4%)	0.98	(0.73,1.30)	0.874

Table 3 is the estimate of PR for acceptability using VERA. PR>1 means the people rated higher acceptability score. By categorizing the high acceptability and relatively low acceptability group, we didn't find participants' characteristics are related with the acceptability. For the demographic variables, we see similar perceived acceptability between age<65 and age⩾65 group (PR=1.00, 95%CI (0.67,1.49)). Female, white, married, employed people has relatively higher acceptability. Participants who have private health insurance rated lower in acceptability score. For the education, comparing to those with less than 16 years of education, people with higher education of more than 16 years have much less acceptability score. People who followed the vera prescription rated higher acceptability score. Also, compared with people without certain preexisting disease, those who have cardiovascular and circulatory diseases, neurological disorder, musculoskeletal disorders, visual or hearing impairment, rated higher acceptability. Participants who have respiratory disease rated less acceptable using VERA. Lastly, people who are very comfortable with technology rated lower acceptability.

Table 3 Estimate of Prevalence Ratio for Acceptability of Using VERA

Variables		Values	High acceptability score (≥9) (N=106) N (%)	Relatively low acceptability score (≤8) (N=23) N (%)	PR	95%CI	p-value
Demographic	Age	years	65.2 ± 7.3	64.7 ± 10.5			0.786
		<65 years (REF)	46 (82.1%)	10 (17.9%)			0.994
		⩾65 years	60 (82.2%)	13 (17.8%)	1.00	(0.85,1.18)	
	Sex	Male (REF)	41 (78.9%)	11 (21.2%)			0.418
		Female	65 (84.4%)	12 (15.6%)	1.07	(0.90,1.27)	
	Race	Non-white (REF)	13 (76.5%)	4 (23.5%)			0.507
		White	92 (82.9%)	19 (17.1%)	1.06	(0.82,1.43)	
Social stratification	Marital status	Others (REF)	23 (79.3%)	6 (20.7%)			0.648
		Married	83 (83.0%)	17 (17.0%)	1.05	(0.85,1.29)	

	Employment	Unemployed (REF)	60 (81.1%)	14 (18.9%)			0.708
		Employed	46 (83.6%)	9 (16.4%)	1.03	(0.88,1.21)	
	Primary health insurance	Government insurance (REF)	64 (84.2%)	12 (15.8%)			0.469
		Private insurance	42 (79.3%)	11 (20.8%)	0.94	(0.79,1.11)	
Digital health literacy	Education	years	15.5 ± 4.2	15.9 ± 3.9			0.140
		<16 years (REF)	53 (86.9%)	8 (13.1%)			0.185
		⩾16 years	53 (77.9%)	15 (22.1%)	0.90	(0.76,1.05)	
Use of digital resources	Preexisting condition	Cardiovascular and circulatory diseases	62 (83.8%)	12 (16.2%)	1.05	(0.89,1.24)	0.579
		Neurological disorders	17 (85.0%)	3 (15.0%)	1.04	(0.85,1.28)	0.719
		Respiratory diseases	19 (79.2%)	5 (20.8%)	0.96	(0.76,1.19)	0.670
		Musculoskeletal disorders	99 (83.9%)	19 (16.1%)	1.32	(0.84,2.08)	0.107

		Visual or hearing impairment	48 (82.8%)	10 (17.2%)	1.01	(0.86,1.19)	0.875
Values and cultural norms	Comfort with use of technology	Not completely comfortable (REF)	45 (86.5%)	7 (13.5%)			0.272
		Very comfortable	60 (79.0%)	16 (21.1%)	0.91	(0.78,1.07)	

Table 4 is the estimate of PR for self-reported adherence. From the results, we didn't find demographic characteristics related with the self-reported adherence. People who married, employed, and has private insurance showed higher adherence to VERA. Those who has more than 16-year education and very comfortable with technology reported higher adherence. We found apart from cardiovascular and circulatory disease, most patients with preexisting conditions had lower self-reported adherence to VERA, especially those who has neurological disorders (PR=0.71, 95%CI (0.51,0.98)).

Table 4 Estimate of Prevalence Ratio for Self-reported Adherence

	Variables	Values	Completely Follow VERA (N=113) N (%)	Not Completely Follow VERA (N=16) N (%)	PR	95%CI	p-value
Demographic	Age	years	65.1 ± 7.9	65.8 ± 8.2			0.772
		<65 years (REF)	49 (87.5%)	7 (12.5%)			0.977
		⩾65 years	64 (87.7%)	9 (12.3%)	1.00	(0.88,1.14)	
	Sex	Male (REF)	46 (88.5%)	6 (11.5%)			0.807
		Female	67 (87.0%)	10 (13.0%)	0.98	(0.86,1.12)	
	Race	Non-white (REF)	16 (94.1%)	1 (5.9%)			0.694
		White	96 (86.5%)	15 (13.5%)	0.92	(0.80,1.06)	
Social stratification	Marital status	Others (REF)	24 (82.8%)	5 (17.2%)			0.354
		Married	89 (89.0%)	11 (11.0%)	1.08	(0.90,1.29)	

	Employment	Unemployed (REF)	62 (83.8%)	12 (16.2%)			0.178
		Employed	51 (92.7%)	4 (7.3%)	1.11	(0.98,1.25)	
	Primary health insurance	Government insurance (REF)	65 (85.5%)	11 (14.5%)			0.431
		Private insurance	48 (90.6%)	5 (9.4%)	1.06	(0.93,1.20)	
Digital health literacy	Education	years	15.6 ± 4.3	15.4 ± 2.4			0.985
		<16 years (REF)	52 (85.3%)	9 (14.8%)			0.443
		⩾16 years	61 (89.7%)	7 (10.3%)	1.05	(0.92,1.20)	
Use of digital resources	Preexisting condition	Cardiovascular and circulatory diseases	65 (87.8%)	9 (12.2%)	1.00	(0.88,1.15)	0.923
		Neurological disorders	13 (65.0%)	7 (35.0%)	0.71	(0.51,0.98)	0.0009
		Respiratory diseases	20 (83.3%)	4 (16.7%)	0.94	(0.78,1.14)	0.497
		Musculoskeletal disorders	103 (87.3%)	15 (12.7%)	0.96	(0.79,1.17)	1.000
		Visual or hearing impairment	50 (86.2%)	8 (13.8%)	0.97	(0.85,1.10)	0.665

Values and cultural norms	Comfort with use of technology	Not completely comfortable (REF)	43 (82.7%)	9 (17.3%)			0.174
		Very comfortable	69 (90.8%)	7 (9.21%)	1.10	(0.95,1.27)	

Table 5 is the episode adherence among patients who used VERA platform, the data ranges from 0-1, the mean and SD are calculated for each category of the characteristics. Two sample t-test was performed for variables with sample size more than 30. Wilcoxon Rank Sum test was performed as non-parametric method if the criteria was not met. We found that participants who have government insurance showed higher episode adherence compared to those who have private insurance. (P=0.033) People who are older than 65 have the higher mean adherence comparing to the younger group. There is not a significant difference in adherence among sex, race, marital status, and employment. We didn't find adherence varied in different education groups. Preexisting conditions have limited impact on adherence. Whether patients are comfortable with technology VERA didn't show a correlation with adherence. The mean adherence for high acceptability group (mean=0.71) is much higher than that of lower acceptability group (mean=0.63). People who self-reported completely following VERA prescription have higher adherence, which approves the quality of self-reported data.

Table 5 Episode adherence among participants used VERA

Variables	Values	No. of Observations	Mean	SD	p-value
Adherence	Total	129	0.70	0.28	

Age	<65 years	56	0.65	0.30	0.068
	⩾65 years	73	0.74	0.26	
Sex	Male	52	0.71	0.28	0.741
	Female	77	0.69	0.28	
Race	White	111	0.70	0.27	0.936
	Non-white	17	0.66	0.35	
Marital status	Married	100	0.72	0.27	0.257
	Non-married	29	0.62	0.32	
Employment	Employed	55	0.69	0.28	0.901
	Others	74	0.70	0.28	
Primary health insurance	Government insurance	76	0.74	0.25	0.033
	Private insurance	53	0.63	0.32	
Education	<16 years	61	0.69	0.32	0.730
	⩾16 years	68	0.70	0.25	
Preexisting condition	Cardiovascular and circulatory diseases	74	0.68	0.30	0.422
	Neurological disorders	20	0.68	0.25	0.352
	Respiratory diseases	24	0.70	0.30	0.983
	Musculoskeletal disorders	118	0.69	0.29	0.960
	Visual or hearing impairment	58	0.72	0.28	0.407

Comfort with use of technology	Very comfortable with use of technology	75	0.69	0.29	0.678
	Others	52	0.71	0.27	
Acceptability of VERA	High acceptability (≥9)	105	0.71	0.28	0.200
	Relatively lower acceptability (≤8)	23	0.63	0.30	
Self-reported adherence	follow the vera prescription	113	0.72	0.27	0.024
	Not completely following the VERA prescription	16	0.56	0.31	

Table 6 is the episode accuracy recorded and evaluated by VERA platform. Two sample t-test was performed for variables with sample size more than 30. Wilcoxon Rank Sum test was performed as non-parametric method if the criteria was not met. From our result, it didn't show a significant difference in exercise performance between various sociodemographic groups in terms of age, sex, race, marital or employment status. There was no correlation between the accuracy and education, comfort with the use of technology, nor self-reported adherence. The preexisting condition would not affect the adherence either.

Table 6 Episode accuracy among participants used VERA

Variables	Values	No. of Observations	Mean	SD	p-value
Accuracy	Total	129	0.87	0.15	
Age	<65 years	56	0.88	0.14	0.562
	⩾65 years	73	0.87	0.16	
Sex	Male	52	0.85	0.19	0.241
	Female	77	0.89	0.13	
Race	white	111	0.88	0.14	0.883
	Non-white	17	0.84	0.24	
Marital status	Married	100	0.87	0.17	0.279
	Non-married	29	0.88	0.07	
Employment	Employed	55	0.90	0.08	0.083
	Others	74	0.85	0.19	
Primary health insurance	Government insurance	76	0.88	0.12	0.479
	Private insurance	53	0.86	0.19	
Education	<16 years	61	0.85	0.21	0.118
	⩾16 years	68	0.89	0.08	
Preexisting condition	Cardiovascular and circulatory diseases	74	0.86	0.19	0.377
	Neurological disorders	20	0.87	0.08	0.296

	Respiratory diseases	24	0.89	0.08	0.739
	Musculoskeletal disorders	118	0.87	0.16	0.394
	Visual or hearing impairment	58	0.86	0.18	0.487
Comfort with use of technology	Very comfortable with use of technology	75	0.87	0.16	0.877
	Others	52	0.87	0.14	
Acceptabilit y of VERA	High acceptability (≥9)	105	0.88	0.11	0.277
	Relatively lower acceptability (≤8)	23	0.83	0.27	
Self-reported adherence	Follow the vera prescription	113	0.88	0.14	0.177
	Not completely following the VERA prescription	16	0.82	0.23	

Table 7 explored the change of exercise days per week after 90-day intervention. Two sample t-test was performed for variables with sample size more than 30, Wilcoxon Rank Sum test was performed as non-parametric method if the criteria was not met. If there wasn't digital health inequity, we would find the similar level of change in exercise time before and after intervention among different strata. The result showed people who older than 65 has less change in exercise after intervention than those who are younger than 65. Male, white people who are married and unemployed showed less change. Participants had more than 16-year education increased exercise frequency per week after using VERA (mean = 1.05 days). People with preexisting conditions all increased their physical exercise, especially those with respiratory disorders. Participants who were very comfortable with technology increased exercise. For acceptability, we didn't find difference in change of exercise. Finally, the people who reported completely following the prescription had increased the exercise while those unadhered to VERA showed even less exercise frequency after intervention.

Table 7 Change after 90-day Exercise days per week

Variables	Values	No. of Observations	Mean	SD	p-value
Exercise	Days per week	128	0.78	2.58	
Age	<65 years	55	1.02	2.38	0.362
	⩾65 years	73	0.60	2.73	
Sex	Male	51	0.58	2.73	0.481
	Female	77	0.91	2.49	
Race	Non-white	17	0.94	2.78	0.758
	white	111	0.73	2.57	
Marital status	Others	29	1.21	2.14	0.311
	Married	100	0.65	2.70	

Employment	Others	73	0.67	2.70	0.595
	Employed	55	0.92	2.44	
Primary health insurance	Government insurance	75	0.83	2.56	0.799
	Private insurance	53	0.71	2.64	
Education	<16 years	60	0.47	2.32	0.203
	⩾16 years	68	1.05	2.78	
Preexisting condition	Cardiovascular and circulatory diseases	74	0.81	2.84	0.865
	Neurological disorders	19	0.66	2.85	0.529
	Respiratory diseases	24	1.21	3.30	0.244
	Musculoskeletal disorders	117	0.89	2.50	0.381
	Visual or hearing impairment	58	0.82	3.10	0.869
Comfort with use of technology	Not completely comfortable	52	0.39	2.57	0.160
	Very comfortable	75	1.05	2.59	
Acceptability of VERA	Relatively lower acceptability (≤8)	23	0.63	0.30	0.240
	High acceptability (≥9)	105	0.71	0.28	

Self-reported adherence	Not completely following the vera prescription	15	-0.23	1.90	0.085
	follow the vera prescription	113	0.91	2.64	

Discussion

Overall, from our result, we find that participants who are older and have lower education are less comfortable with technology, which emphasizes the age and literacy may result in the disparity of using VERA platform. As mentioned by most researchers, elderly people are more reluctant to adopt technologies (Abbey & Hyde, 2009), which is consistent with our findings. In the meantime, the exercise days per week changed less in the age⩾65 group comparing to age<65 group. It emphasized the unequal effectiveness of health intervention with regard to age. This result is consistent with research with Quan-Haase et al. indicating that the elderly generally feels uncomfortable, unsafe and unconfident about using technology(Quan-Haase et al., 2016). However, by analyzing the process indicator like adherence and accuracy of the technology, we found the older age group can use the platform as well as age<65 groups. From the health equity perspective, it could mean that it meets the vertical equity that unlike individuals receive personalized treatment, thus showing the similar implementation outcomes.

Apart from age, we found the people who have higher education are more comfort with technology. Literatures(Fang et al., 2019) support this founding indicating the lack of literacy is the key boundary of access to technology. Neves and Amaro found that the elderly people's use of information and communication technology is related with their education level(B. Neves, 2012). Kania-Lundholm and Torres did an focus interview among older adults aged 66-89 also found the education and socio-economic status influence people's use of technology.

For our secondary aim, we found comfortable using technology does not necessarily lead to higher acceptability of the technology. Considering acceptability consists multiple components, we should be aware that the attitudinal factors like health beliefs on the effectiveness of technology, opportunity costs can also impact the perceived acceptability. (Best et al., 2015) Understanding the difference between use/non-use requires the careful observation of the nuance in technical, personal and cultural contexts (B. B. Neves et al., 2018), which could be explored in further research.

In this study, we find most of the participants rated acceptability score above 9, we consider the reason could be VERA is well adopted by the participants and highly acceptable for most of the users, or we have bias in the research. Considering the potential bias, we could have selection bias that patients who were recruited to the trial have higher acceptability than the general TKA patients. Because the data was collected in a clinical trial, the people were recruited only after they fully acknowledged the risk of the intervention and agreed upon the consent of using the platform. People who didn't accept VERA might refuse to be recruited to the trial at the beginning. Moreover, information bias could occur. The recommendation score we used to generate acceptability variable was collected in the follow-up investigation after 90-day of the intervention by phone. The participants could be reluctant to rate lower score considering the device were provided free of charge on technology and broadband network.

For the self-reported adherence and episode adherence provided from VERA platform, we didn't observe significant difference based on the stratification apart from preexisting conditions. From the Table 5 we find that those who reported completely following prescription are those who have higher adherence to VERA, which approves the quality of the self-reported data. Apart from that, we found having preexisting condition of neurological disorders is related with lower self-reported adherence. Friemel found that physical limitations could be a hurdle of using technology(Friemel, 2016), McMurtrey et al. indicated that "physical dexterity especially the manual dexterity and vision deterioration" are the main barriers for elderly people to adopt technology (McMurtrey et al., 2008). Neurological disorders like Alzheimer's disease might restrict the cognitive capability of patients and imped them from using the VERA platform.

In terms of the episode adherence and accuracy, the analysis didn't show a significant difference in terms of the social strata apart from the insurance category. The result could imply the benefit of personalized rehabilitation in achieving high adherence and accuracy regardless of the patient's stratification. The human-centered design of VERA system tracks activity, performance, exercise quality, and adherence of patients. It can help patients receive timely and objective feedback on exercise performance and functional outcomes and a variety of embedded reward structures to help maintain compliance. Besides, the therapy is prescribed based on individual recovery goal. Therefore, the adherence and accuracy were high. As for the difference of insurance, it indicates that insurance coverage and reimbursement might impact the participants' behavior. This implies the health system as a social determinant of health is essential in digital health equity promotion(Crawford & Serhal, 2020). Furthermore, policy often enlarge inequity unintentionally by unequal distribution of resources (Azzopardi-Muscat & Sørensen, 2019), as more resources flow to the people with a better health condition and higher capability to use them, relatively less to those who are disadvantaged.

We define sustainable as “continued use”(Lennox et al., 2018). It is specified as the current use of telehealth during COVID-19 and the continued use of VERA after the clinical trial. During this study, the implementation of VERA was severely impacted by COVID-19 for unable to install the device at patients’ homes. And one of the 4 sites in the initial clinical trial has terminated the service, so even if the device is used, the patients cannot connect with the physiotherapists they were initially designated. The environmental change has largely impacted the use of technology.

Limitation of the study

Even though we addressed some of the drawbacks and try to include as comprehensive measurements as possible, the study still has a few limitations. Firstly, the research has potential selection bias in the recruiting process. As mentioned above, our result shows that the recommendation score rated by the patient is mostly above 9, which may because those who did not accept VERA rejected to enroll in the trial at the beginning, there was a third of eligible patients declined to participate in the clinical trial initially(Prvu Bettger et al., 2020), which could mean those left are mainly patients who are comfortable with technology and has belief in using VERA as a potential substitute of traditional rehabilitation. This could result in a serious of change in the dependent variable like the acceptability of VERA, adherence and accuracy when performing the exercise.

Besides, some variables are difficult to measure. For instance, the self-reported measures are based on the perception of the participants, which can lead to the low quality of data. Apart from that, some variables are conceptual, we used indirect measurement as a substitute, but the exchangeability of the two variables might need more evidence. For instance, the implementation outcome acceptability is generated by dichotomizing recommendation score, however, acceptability comprises multiple components including affected attitude, burden, ethicality, intervention coherence and opportunity costs (Sekhon et al., 2017), which might not be the same as the component of recommendation score. Likewise, health beliefs of the intervention are difficult to measure, we used the indirect measurement, if they completely follow the VERA intervention, as a substitute, that could bring the same problem to the study.

Moreover, due to the travel constraint of COVID-19, variables related to digital health determinants are not measured thoroughly. For instance, the access to digital resources is not measured, the potential variables could be geographical location, access to internet, cost of technology. These variables are important to patients' use of the technology determining the internet connection, availability of the device maintenance, etc. Besides, digital health literacy is measured including education and comfort with technology, which could include more factors. As for the study design, there can be qualitative research on values and cultural norms, health system and policy level can be better studied, and questions about how to integrate the digital health resources into the community would be important to evaluate the appropriateness and sustainability in implementation.

In terms of the scope, the study has a relatively small sample size for evaluating the digital inequity using populational level variables, so this research is limited to a case example and can be a reference for the further study. Meanwhile, the short-term follow-up of the intervention prevents the researcher from evaluating the sustainability of the program. Moreover, the research didn't measure the horizontal equity, since all the participants receive intervention programed in the systems, we assume the similar participants who have similar conditions would receive the same intervention based on the prescription from clinicians.

To address the above-mentioned problems, a populational level digital health equity research could be conducted with more comprehensive measures using a mixed method combining qualitative research, more discussion on the barriers and facilitators in the health system and policy level will be needed.

Conclusion

Based on the results, we found age and education are related with comfort using technology. We should take them into consideration at intervention design stage. Besides, we didn't find unequal use of VERA with the process outcomes among different strata, which means by personalized health intervention and improved usability, people who have disadvantages can also adopt technology to achieve better health. By advocating the human-centered design, digital health can benefit more people to achieve health equity in a larger scale.

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