Acceptance and Use of Mobile Technology for Health Self-Monitoring in Lung Transplant Recipients during the First Year Post-Transplantation

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Keywords
Mobile applications, telemedicine, self-care, lung transplantation, patient compliance

Summary

Objectives: To describe lung transplant recipients (LTRs') acceptance and use of mobile technology for health self-monitoring during the first year post-transplantation, and explore correlates of the use of technology in the 0 to 2, >2 to ≤6, >6 to ≤12, and 0 to 12 months.
Methods: Secondary analysis of data from 96 LTR assigned to use Pocket PATH®, a smartphone application, for daily health self-monitoring in a randomized controlled trial. Use of Pocket PATH was categorized as low, moderate, and high use. Proportional odds models for ordinal logistic regression were employed to explore correlates of use of technology.
Results: LTR reported high acceptance of Pocket PATH at baseline. However, acceptance was not associated with actual use over the 12 months (p=0.45~0.96). Actual use decreased across time intervals (p<0.001). Increased self-care agency was associated with the increased odds of higher use in women (p=0.03) and those less satisfied with technology training (p=0.02) in the first 2 months. Higher use from >2 to ≤6 months was associated with greater satisfaction with technology training (OR=3.37, p=0.01) and shorter length of hospital stay (OR=0.98, p=0.02). Higher use from >6 to ≤12 months was associated with older age (OR=1.05, p=0.02), lower psychological distress (OR=0.43, p=0.02), and better physical functioning (OR=1.09, p=0.01). Higher use over 12 months was also associated with older age (OR=1.05, p=0.007), better physical functioning (OR=1.13, p=0.001), and greater satisfaction with technology training (OR=3.05, p=0.02).
Conclusions: Correlates were different for short- and long-term use of mobile technology for health self-monitoring in the first year post-transplantation. It is important to follow up with LTR with longer hospital stay, poor physical functioning, and psychological distress, providing ongoing education to improve their long-term use of technology for health self-monitoring.

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1. Introduction

Lung transplantation has been accepted as a standard treatment for persons with end-stage lung diseases to improve their survival and quality of life [1–3]. However, lung transplant recipients (LTR) experience lower 1– and 5-year survival rates compared to other solid organ transplant recipients [4, 5], which may be due to their high risk for complications, such as infection and rejection, especially during the first year post-transplantation [5–7]. Therefore, LTR are highly encouraged to perform daily health self-monitoring in order to detect early signs of complications [8], and seek prompt treatment to reduce morbidity and mortality [9].

Electronic systems for self-monitoring of pulmonary function, vital signs, and respiratory symptoms by LTR have been shown to be valid and reliable for detecting complications [10, 11] and reducing the overall cost of post-transplant medical care [12]. However, most of these systems do not involve patients in data interpretation and recipients' use tends to decrease over time [12, 13]. Recently, mobile technology has been increasingly adopted in the health care field and shown to be convenient for patient health self-monitoring [14-17]. Pocket Personal Assistant for Tracking Health (Pocket PATH®) is a smartphone application developed with customized programs for LTR to monitor health indicators, view trends in values overtime and receive decision support about when and what to report to their transplant coordinators [18, 19]. A randomized controlled trial (RCT) of Pocket PATH compared to usual care found that Pocket PATH was superior in promoting self-management behaviors including adhering to the medical regimen, performing self-monitoring and reporting condition changes to clinicians [19]. However, correlates of acceptance and use of this mobile technology by LTR are unknown. The current study was conducted to identify potential correlates of use of mobile technology for LTR health self-monitoring using data for the Pocket PATH study.

Previous barriers to performance of home self-monitoring by LTR were reported as forgetfulness, lack of time, and poor health status [13, 21]. In addition, health beliefs and perceived support from clinicians influenced their performance [22, 23]. Few studies have applied technology acceptance theories to examine correlates of acceptance and actual use of technology systems for health self-monitoring by LTR. Furthermore, although previous studies identify that the patients' use of technology may decrease over time [13, 15], no study has explored the correlates of short- and long-term use of mobile technology in LTR. Such information is important for clinicians to identify subgroups of LTR who may be at high risk for lower use of technology for health self-monitoring, and to develop tailored, timely interventions to assist them to engage in health self-monitoring over time.

The Unified Theory of Acceptance and Use of Technology (UTAUT) [24] was developed by integrating the constructs common to previous theories including the Technology Acceptance Model (TAM) [25]. The UTAUT has been widely used to explain patients' behavior of using information technology systems and validated by a variety of studies, including the use of health monitoring system by home care patients [24, 26–27]. Previous studies suggest that the context of health care needs to be considered when selecting variables into the model to determine the patients' intention to use and actual use of health information technology [26]. Therefore, based on the context of LTR health self-monitoring and the variables available from the parent Pocket PATH study, a modified UTAUT, as shown in ►Figure 1, was used in this study to guide the selection of potential correlates of use of mobile technology, and mainly focused on technology acceptance, including perceived usefulness (PU), perceived ease of use (PEU), and intention to use (IU), and facilitating conditions that were generally described as the potential conditions that facilitate performing the behaviors [29]. Facilitating conditions were operationalized in this study as (1) clinical characteristics and health status (length of hospital stay, re-hospitalization, hospital discharge destination, psychological distress, and health-related quality of life physical component summary) [29-33], (2) health control beliefs [22, 23], (3) self-care agency [34], and (4) environmental factors (quality of recipient and family caregiver relationship and satisfaction with technology training) [29, 32, 35]. In addition, age, gender, and experience with technology, were explored as potential moderators of the relationships between predictors of IU and use of mobile technology; and relationships between facilitating conditions and use of mobile technology.

2. Objectives

Using Pocket PATH as an exemplar of a mobile health technology, the purposes of this study were to (1) describe acceptance and use of mobile technology for health self-monitoring during the first year after lung transplantation, (2) identify possible correlates of use of mobile technology in the time intervals of 0 to 2 months, > 2 to ≤ 6 months, > 6 to ≤ 12 months, and 0 to 12 months post-transplant, and (3) explore possible mediation effects of IU between PU or PEU and use of technology in each time interval, and moderation effects of age, gender, and technology use experience on relationships between predictors and IU or use of technology.

3. Methods

3.1 Study Design and Sample

A cross-sectional correlational design was used with secondary analysis of existing data from 96 LTR who were randomized to the Pocket PATH intervention for health self-monitoring. In the parent study participants were recruited from the acute cardiothoracic unit of the University of Pittsburgh Medical Center from December 2008 to December 2012. LTR were included if they were at least 18 years of age, stable enough to be transferred to the acute cardiothoracic unit, and able to read and speak English. LTR were excluded if they had a prior transplant, were not able to be discharged from the hospital, or were likely to have limited involvement in their own post-transplant care.

3.2 Procedures

LTR were given the Pocket PATH application on a smartphone (HTC Pure with Window Mobile 6.5), which had a 3.2-inch touchscreen, full onscreen QWERTY keyboard, and an extra stylus for data entry. The primary features of Pocket PATH included direct data entry of health indicators, both logged and graphical displays of data over time, and automatic feedback messages generated when critical values are entered. A full description of features of Pocket PATH and core elements of the Pocket PATH intervention were introduced and published elsewhere [18]. Before hospital discharge, 88 LTR (91.7%) received approximately 30-60 minutes of technology training about using the device for health self-monitoring by one of two trained nurse interventionists. The remaining 8 LTR (8.3%) had the training session at their second or sixth month home visit due to their poor health status. There were no statistically significant differences in socio-demographic and clinical characteristics between those 88 and 8 participants. During the training session, LTR were instructed to enter all self-monitoring values of spirometry, temperature, blood pressure, symptoms, and weight into the daily checklist of the Pocket PATH application. Data recorded in the device were date- and time-stamped and viewed with critical values indicated on graphs. No prompts were sent to remind LTR to use the application. However, the application was programmed to generate automatic feedback messages when critical values of health indicators were entered into the device, reminding LTR to take action, including reporting the critical values to transplant clinicians [18, 35]. Self-monitoring data were automatically transmitted to the research site server every 24 hours. Data were not shared directly with clinicians, because the trial was intended to assess LTRs' performance of self-management, including LTRs' reporting critical health indicators immediately to the transplant coordinators [18, 36]. A User Support Manual and a toll-free number were given to LTR to call for help with technical problems.

3.3 Measures

Measures were assessed at four time points: baseline (prior to discharge or at 1 week post-discharge), 2 months, 6 months, and 12 months post-discharge by experienced data collectors who were blinded to treatment condition.

Use of Pocket PATH for Health Self-monitoring. Use of Pocket PATH during each time interval (0 to 2, > 2 to ≤ 6, > 6 to ≤ 12, and 0 to 12 months post-transplant) was calculated by the number of days self-monitoring was performed during each time interval divided by the number of participation days in the same time interval (re-hospitalization days were excluded) and expressed as a percentage.

Acceptance Factors: Intention to Use (IU), Perceived Usefulness (PU), and Perceived Ease of Use (PEU). IU, PU and PEU were measured using the Technology Acceptance Subscales, with item wording modified for the Pocket PATH technology, as directed by Davis and colleagues [24, 25]. Internal consistency reliability of the original scales was reported with Cronbach's alphas of 0.96 for IU, 0.90 for PU, and 0.92 for PEU [24]. Scores for PU (4 items) and PEU (4 items) range from 4 to 28, with each item response ranging from 1=very unlikely to 7=very likely; and scores for IU (1 item) range from 1=strongly disagree to 7=strongly agree, after reversely coding. Higher scores indicate higher perception and higher intention. As the technology acceptance measures were discovered and added after the parent trial was underway, acceptance data were not collected in the first 30 LTR.

Clinical Characteristics and Health Status. Data for *length of hospital stay (LOS)*, *re-hospitalization,* and *hospital discharge destination* were obtained from medical record review by consensus between two independent abstractors. LOS was measured in days, re-hospitalization was coded as "yes" or "no" to indicate whether the person was ever re-hospitalized during the indicated time interval, and discharge destination was dichotomized into two levels, "home" vs. "any facility other than home".

Psychological Distress was assessed by the Anxiety and Depression subscales of the Symptom Checklist 90-Revised [37]. In previous studies, the test-retest reliability for the checklist ranged from 0.80 to 0.90 [37], and Cronbach's alpha for the two subscales ranged from 0.80 to 0.88 in LTR [38]. The severity of anxiety and depression was measured at baseline, and 2, 6, and 12 months post-transplant. Both anxiety and depression scores range from 0 to 4 with higher scores indicating more distress.

Physical Component Summary (PCS), one of the summary measures of health-related quality of life from the Medical Outcomes Study Short Form (SF-36) v2 [39], was calculated using transformed T-scores ranging from 0 to 100, with higher scores indicating better physical functioning in the previous four weeks. Cronbach's alpha for the PCS in LTR was reported as 0.83 [20]. PCS was measured at 2, 6, and 12 months post-transplant.

Health Control Beliefs. Health control beliefs were measured at baseline using two subscales of the Multidimensional Health Locus of Control scale assessing the extent to which LTR believed that their health outcomes were primarily their own responsibility (*Internality*) or the responsibility of their health professionals (*Externality*). Subscale scores range from 6 to 36 with higher subscale scores indicating greater internality or externality. Cronbach's alpha for the two subscales ranged between 0.67 and 0.78 in samples, including LTR [40-42].

Self-care Agency. *Self-Care Agency* was assessed at baseline and 2, 6, and 12 months using the Perception of Self-Care Agency scale [43], with higher scores indicating greater perception of one's ability to engage in self-care activities at each time point (scores range from 53 to 265). In studies of LTR, the Cronbach's alpha was reported as 0.95 [34].

Environmental Factors. *Quality of Recipient-Caregiver Relationship* was assessed at baseline using an adaptation of the Dyadic Adjustment Scale [44]. Previous studies of LTR reported Cronbach's alpha of 0.86 [34] and 0.94 [20]. This study used the sum score of the first 15 items for analysis, because these items apply to any type of recipient-caregiver relationship. Scores range from 15 to 75 with higher scores indicating higher relationship quality.

Satisfaction with Technology Training. Satisfaction with training was assessed by the After-Scenario Questionnaire (ASQ) [45], a 3-item, 7-point Likert scale. In previous studies, Cronbach's alpha ranged from 0.90 to 0.96. Scores range from 1 to 7 with higher scores representing greater satisfaction.

Socio-demographic Factors. Socio-demographic factors were assessed at baseline and included age, gender, race, marital status, education, employment, and income. The questionnaire also assessed previous experience in using a cell phone, personal digital assistant (PDA), other hand-held device (e.g., MP3, digital camera, etc.), and computer. A new variable, *Experience with Technology,* was generated to represent general prior experience with technology by summing scores of frequency of use of each technology.

3.4 Data Analysis

Statistical analyses were conducted by using IBM® SPSS® Statistics (version 22.0, IBM, Inc., Chicago, IL). Missing data were assessed by the amount and patterns of missingness. Since data missingness was more than 5% and missing at random, multiple imputation with 5 imputations was used to impute missing data. Analysis results were pooled across datasets completed via imputation and reported in this study.

3.4.1 Data transformations

Use of Pocket PATH for Health Self-monitoring data were highly skewed (U-shaped or J-shaped distribution) and could not be normalized by common data transformation. Because the ceiling effects present in U- or J-shaped curves can lead to incorrect model selection and biased parameter estimation [46], categorizing the variables is considered a better way to analyze this type of data [47]. Literature supports that (1) when LTR had at least 25% adherence to the electronic spirometry system, the net medical savings covered the cost of home monitoring [16]; and (2) LTR with high adherence rates (> 75%) to an electronic home-monitoring program showed a trend toward better survival [9]. Therefore, in this study, use of Pocket PATH was categorized into three groups: low use (0% ≤ percentage of days used ≤ 25%), moderate use (25% < percentage of days used ≤ 75%), and high use (75% < percentage of days used ≤ 100%), and resulted in sufficient numbers in each category.

IU, PU, and PEU data were highly skewed (J-shaped distribution), with the mean (SD) of PU and PEU as 26.3 (2.2) and 26.2 (2.5), respectively, and the median of IU as 7. PU and PEU were dichotomized as low perception (≤ 24, rating each of 4 items less than or equal to 6 on average) vs. high perception (> 24, rating each of 4 items greater than 6 on average). IU was dichotomized at the median as low intention (< 7) vs. high intention (= 7) [47].

Physical Component Summary (PCS) and Self-care Agency. For variables measured over time, such as **PCS** and **Self-care Agency,** mean scores were calculated and used for analysis. The mean PCS scores were calculated for each time interval of 2–6, 6–12, and 2–12 months. The mean self-care agency scores were calculated for each time interval of 0–2, 2–6, 6–12, and 0–12 months. Both scores were normally distributed.

Psychological Distress. Since the Anxiety and Depression subscales were highly correlated (r=0.684 to 0.740, p<0.001) and use the same scaling, a new variable, *Psychological Distress*, was computed by summing the mean anxiety and depression scores for each time interval [48]. The summed scores range from 0 to 8 with higher scores indicating more psychological distress. The mean psychological distress scores were calculated for each time interval of 0–2, 2–6, 6–12, and 0–12 months. The distribution of scores was non-normal.

Satisfaction with Technology Training data were highly skewed (J-shaped distribution). The variable was dichotomized based on the median value 7 as less satisfaction (< 7) vs. greater satisfaction (= 7) [47].

3.4.2 Statistic Analysis

Descriptive statistics, such as mean, standard deviation, frequencies, and percentages, were used to characterize the sample and examine acceptance and use of Pocket PATH for health self-monitoring. The Friedman test was used to assess the change of actual use over time, following by *post hoc* analysis with pairwise Wilcoxon signed-rank tests, using a Bonferroni adjustment (where the testwise level of significance was set at 0.017). Relationships between potential predictors and the use of Pocket PATH in each time interval were explored by univariate (single predictor) and multivariate (multiple predictors) ordinal logistic regression analyses assuming proportional odds. Only predictors with $p < 0.25$ in univariate analyses were included in the multivariate analysis [49, 50]. Final parsimonious models were generated using backward selection ($p < 0.05$). Significance level was set at $p < 0.10$ for the exploration of mediation (simple mediation modeling) [51] and moderation effects.

4. Results

4.1 Description of the Sample

The summary of demographic and clinical characteristics is shown in ►Table 1. Participants in this study were on average 57 years old. Most were male, white, either currently married or living with a partner, unemployed, had more than a high school education, and reported that their current household income met their basic needs. They had moderate experience with technology, with an average of 30 days of length of hospital stay. About half were re-hospitalized at some point during the first year.

4.2 Acceptance of Pocket PATH at Baseline

Of the 66 participants (69%) who completed the Technology Acceptance Subscales, 56 (85%) rated "strongly agree" with IU, 53 (80%) and 54 (82%) had high ratings of PU and PEU (rating > 24), respectively. The pooled results, combined over the results from the five datasets completed via imputation, indicated that IU was not significantly predicted by either PU ($p = 0.07$) or PEU ($p = 0.10$).

4.3 Use of Pocket PATH at Each Time Interval

Since 5 participants started self-monitoring at the end of second month, 3 started self-monitoring at the end of the sixth month, 1 died during the > 2 and ≤ 6 months interval, and 3 died and 2 re-hospitalized in the > 6 and ≤ 12 months interval, the number of participants with self-monitoring data in each time interval was: 88 (0–2 months), 92 (> 2 and ≤ 6 months), and 90 (> 6 and ≤ 12 months). As shown in ►Figure 2, approximately half (48%) of the LTR showed high daily use of Pocket PATH (>75% days used) in the first 2 months. However, this percentage decreased to 28% in > 2 to ≤ 6 months and 19% in > 6 to ≤ 12 months. Conversely, the percentage of low use (≤ 25% days used) increased from 22% to 34% and 58% in the three time intervals, respectively. Use of Pocket PATH for daily health self-monitoring decreased over time (Chi-Square=58.08, $p < 0.001$). Significant decreases for the use of Pocket PATH were found from the first 2 months to the > 2 to ≤ 6 months ($Z=-4.13$, $p < 0.001$), from the > 2 to ≤ 6 months to the > 6 to ≤ 12 months ($Z=-5.40$, $p < 0.001$), and from the first 2 months to the > 6 to ≤ 12 months ($Z=-5.74$, $p < 0.001$).

4.3.1 Correlates of Use of Technology during 0–2 Months

Based on univariate analyses, the multivariate model of use of Pocket PATH included the 6 candidate predictors of age, gender, LOS, self-care agency, quality of recipient-caregiver relationship, and satisfaction with technology training. ►Table 2 shows the final parsimonious modeling results. Two significant two-way interactions were found between self-care agency and gender (OR = 0.94, 95% CI=[0.88–0.99], $p = 0.03$), and between self-care agency and satisfaction with technology training (OR = 0.93, 95% CI=[0.87–0.99], $p = 0.02$). The graph plots of the interactions showed that women and those less satisfied with technology training increased their use of Pocket PATH as their self-care agency increased.

4.3.2 Correlates of Use of Technology from > 2 to ≤ 6 Months

The multivariate model started with seven screened predictors: age, gender, LOS, psychological distress, physical functioning, self-care agency, and satisfaction with technology training. As shown in ►Table 2, final results included a marginally significant interaction between age and mean psychological distress (OR = 0.96, 95% CI=[0.93–1.00], $p = 0.05$). The plot of the interaction showed that with the increase of psychological distress, younger LTR (less than one standard deviation below the mean age of 57 years) tended to increase their use of Pocket PATH, while older LTR (greater than one standard deviation below the mean age) tended to decrease their use of Pocket PATH. Results also showed that LTR with greater satisfaction with technology training (OR = 3.37, 95% CI=[1.30–8.75], $p = 0.01$), and less LOS (OR = 0.98, 95% CI=[0.96–0.99], $p = 0.02$) significantly increased their use of Pocket PATH at > 2 to ≤ 6 months.

4.3.3 Correlates of Use of Technology from > 6 to ≤ 12 Months

The multivariate model started with 10 screened predictors (age, experience with technology, LOS, re-hospitalization, psychological distress, physical functioning, internality, externality, self-care agency, and satisfaction with technology training). As shown in ▶Table 2, the final parsimonious model only included three significant predictors. Age (OR = 1.05, 95% CI=[1.01–1.09], $p = 0.02$), psychological distress (OR = 0.43, 95% CI=[0.21–0.88], $p = 0.02$), and physical functioning (PCS) (OR = 1.09, 95% CI=[1.02–1.16], $p = 0.01$) were significant independent predictors of use of Pocket PATH at > 6 to ≤ 12 months. No significant interactions were found.

4.3.4 Correlates of Technology Use from 0–12 Months

Eight candidate predictors (age, LOS, re-hospitalization, psychological distress, physical functioning, internality, self-care agency, and satisfaction with technology training) were included in the 0 to 12-month multivariate model. Final parsimonious modeling results (▶Table 2) indicated that age (OR = 1.05, 95% CI=[1.01–1.09], $p = 0.007$), satisfaction with technology training (OR = 3.05, 95% CI=[1.16–8.02], $p = 0.02$), and physical functioning (OR = 1.13, 95% CI=[1.06–1.21], $p = 0.001$) were significant predictors of use of Pocket PATH over the total 12 months. No significant interactions were found.

4.4 Mediation and Moderation Effects

4.4.1 Intention to Use (IU) as a Mediator of PU and PEU on Use of Pocket PATH for Health Self-monitoring

None of three factors, IU, PU, and PEU, was found to have a significant relationship with the use of Pocket PATH for health self-monitoring during any of the time intervals ($p = 0.45$~0.96).

4.4.2 Age

Age did not moderate the relationship between PU and IU, or between PEU and IU ($p \geq 0.10$). However, age did show a trend to moderate the relationship between psychological distress and use of technology for the > 2 to ≤ 6 month interval ($p = 0.08$), and the relationships between quality of recipient-caregiver relationship and use of technology for both > 6 to ≤ 12 months ($p = 0.08$) and 0 to 12 months ($p = 0.07$).

4.4.3 Gender

Gender was not found to moderate any of the relationships between PU and IU, and between PEU and IU ($p \geq 0.10$).

4.4.4 Experience with Technology

Experience with technology did not moderate the relationship between PEU and IU ($p \geq 0.10$), but it showed a trend to moderate the relationship between re-hospitalization and use of technology from > 6 to ≤ 12 months ($p = 0.08$) as well as the relationship between internality ($p = 0.05$) and externality ($p = 0.08$) on use of technology from 0 to 12 months.

5. Discussion

This study described technology acceptance at baseline and actual use of mobile technology (Pocket PATH) for health self-monitoring during the first year post-lung transplantation, and explored correlates of actual use at each time interval. LTRs' actual use of Pocket PATH for health self-monitoring was significantly decreased over time in 12 months. This finding is consistent with the patterns of use of home electronic spirometry systems by LTR [12, 13] and use of mobile health services by other populations, such as overweight adults [15], indicating that sustained use of mobile technology for health self-monitoring is an issue, and appropriate strategies may need to be developed to encourage LTRs' engagement, such as receiving reinforcement messaging prompts from health care providers [52].

Upon receiving training for using Pocket PATH, LTR reported high intention to use mobile technology. However, perceived usefulness (PU), perceived ease of use (PEU), and intention to use (IU) at baseline did not predict actual use at any time interval, indicating IU was not supported as a mediator between PU or PEU and use of mobile technology. As recipients' acceptance of mobile technology for health self-monitoring was measured at baseline, it is unknown whether recipients changed their perceptions after they actually used the technology for self-monitoring. Since the recipients needed to manually enter multiple health indicators into the device every day, it was possible that the burden to perform self-monitoring influenced their initial perceptions and intention to use. It may be important to assess the recipients' perceptions of use of mobile technology for health self-monitoring over time, in order to provide just-in-time support for sustained use. Previous studies of technology acceptance mainly focused on the exploration of relationships within IU, PU and PEU [32], and reported positive relationships between them [28, 36, 53, 54]. Fewer studies explored their relationships with actual use of technology for health self-monitoring [27, 55]. One study [55] has reported similar results that perceived usefulness did not predict use of a smartphone application for self-monitoring of physical activity in a sample of 50 healthy adults. Findings of the current study confirmed the influence of health status, psychological distress, and satisfaction with technology training on actual use of mobile technology for health self-monitoring.

Previous studies reported that both better and poorer health status are associated with use of technology [13, 56-58]. Specifically, LTR who felt too sick or too well discontinued using a home electronic monitoring system because they did not want a reminder of their deteriorating status or they saw no need to use the system for monitoring [21]. The current study found that poor health status was associated with lower use of technology. Although the negative effect of LOS on use of Pocket PATH tended to be small, it implies that poor general health status pre-discharge is associated with a decreased use of mobile technology for health self-monitoring in > 2 to ≤ 6 months. Similarly, the positive effect of physical functioning indicates that LTR with worse physical health status may explain the lower use of technology in > 6 to ≤ 12 months and for the total 12 months.

Previous studies reported that psychological distress is common after lung transplantation [59, 60] and an important predictor of non-adherence to treatment and performance of self-care in LTR [5, 34]. In this study, psychological distress was an independent predictor of lower use of technology in > 6 to ≤ 12 months. In addition, the influence of psychological distress on use of technology for health self-monitoring differed by age, specifically, younger LTR tend to use technology more with the increase of psychological distress. However, this finding may need to be further confirmed in future studies.

Satisfaction with technology training was a strong predictor of use of technology during the first 6 months and for the total 12 months. LTR with stronger satisfaction with technology training were more likely to be in the higher use of technology group. This may be because during the training session, the Pocket PATH intervention provided encouragement to LTR to become activated partners in their self-management including the use of the device for daily health self-monitoring. In the first 2 months, the relationship between satisfaction with technology training at baseline and use of technology was moderated by their perceived self-care agency, which reinforces the importance of recipient agency in their health self-monitoring. The impact of satisfaction with technology training at baseline waned over the later time period (> 6 months), which was perhaps due to lack of ongoing reinforcement for being activated in their use of technology for health self-monitoring.

There were a few limitations in this study. First, this study was conducted in one transplant center. However, our sample characteristics match those reported for other lung transplant population [5]. Second, measures of technology acceptance (IU, PU, and PEU) were added after the trial was underway, and data were not available for the first 30 participants in this study. However, univariate analyses did not find any associations between three technology acceptance variables and actual use of technology in 66 LTR. Since IU, PU, and PEU were not included in the final models, the missing of acceptance measures from the first 30 LTR did not affect the identification of correlates in final analysis models. In addition, multiple imputation was applied to handle missing data and similar results were reported between the original and pooled analysis. Third, a relatively small sample size in this study may not be able to provide enough power to reveal relationships between variables.

However, the performance of univariate analyses helped to decrease the number of independent variables in the multivariate models. The final parsimonious models only included significant predictors. Third, categorization of the variable of use of technology, and dichotomization of a few other variables, such as IU, PU, PEU, and satisfaction with technology training, to overcome their high skewness may have caused further loss of information and inaccurate representation of the original measures. However, categorizing the variable is considered a better way to analyze U- or J-shaped distributed data [47]. Lastly, this study was a secondary analysis, using data that were available from the parent trial. Some concepts of the UTAUT, such as social influence and voluntariness of use, would need to be explored in the future.

Findings from this study add to our understanding of acceptance and use of technology to promote self-monitoring after lung transplantation. For example, facilitating conditions related to the context of health self-monitoring, such as health status, health control beliefs, self-care agency, and environmental factors, were included in the conceptual model to help understand complex behavioral patterns in LTR, which should be considered an appropriate adaptation of the UTAUT model to fit the clinical context [61]. In addition, predictors of both short- and long-term use of mobile technology in 12 months were explored, revealing variation in predictors of use of mobile technology for health self-monitoring in each time interval.

6. Conclusions

This study examined LTRs' acceptance and use of mobile technology for health self-monitoring and identified correlates of short- and long-term use of technology in 12 months post-transplantation. LTRs' acceptance of mobile technology at baseline did not predict their actual use over time in this study. Future studies may need to be conducted to assess whether and how LTRs' perception of technology use changes over time, especially to explore the determinants of such changes, in order to provide targeted solutions.

LTRs' actual use of mobile technology for health self-monitoring significantly decreased over time in 12 months. The identification of correlates of short- and long-term use of technology may inform the development of tailored, timely interventions to help LTR engage in self-monitoring performance. For example, satisfaction with technology training and higher self-care agency were strongly associated with the higher use of technology, especially in the first few months post-transplantation, suggesting that providing ongoing reinforcement of training and encouragement for LTR to play an active role in their health self-management may be beneficial. The consistent assessment of LTRs' physical and psychological status is important for health care providers to identify those who are at high risk for lower use of technology for health self-monitoring, so that targeted supportive interventions can be provided. Although the association of age and gender of LTR with their use of mobile technology for self-monitoring tends to be small in this study, their significant interactions with other correlates warrant future exploration.

As mobile technology is progressing at a rapid rate, it can be challenging for the research study to keep pace with technological developments [18]. Advanced technical system design and application programming are expected to lead to further refinement of the mobile application, to satisfy lung transplant recipients' needs for support for sustained use of mobile technology for health self-monitoring to improve their quality of life and survival.

Clinical Relevance Statement

Knowledge of the correlates of use of mobile technology for health self-monitoring identified in this study may contribute to better identification of who are most likely to adopt mobile technology and the optimal time to introduce patients to the technologies for health self-monitoring. Further, it is important to provide ongoing encouragement for patients to be engaged and play an active role in their long-term self-management, especially for those with deteriorated physical and psychological health.

Conflicts of Interest

All authors declare that they have no conflicts of interest in the research.

Protection of Human Subjects Protections

The parent study (NIH, NINR, R01 NR010711, PI: Annette DeVito Dabbs) has been approved and renewed by the University of Pittsburgh Institutional Review Board (IRB, PRO08070401). Since the current study only used de-identified data for secondary analysis, University of Pittsburgh classified this study as exempt (PRO15010376).

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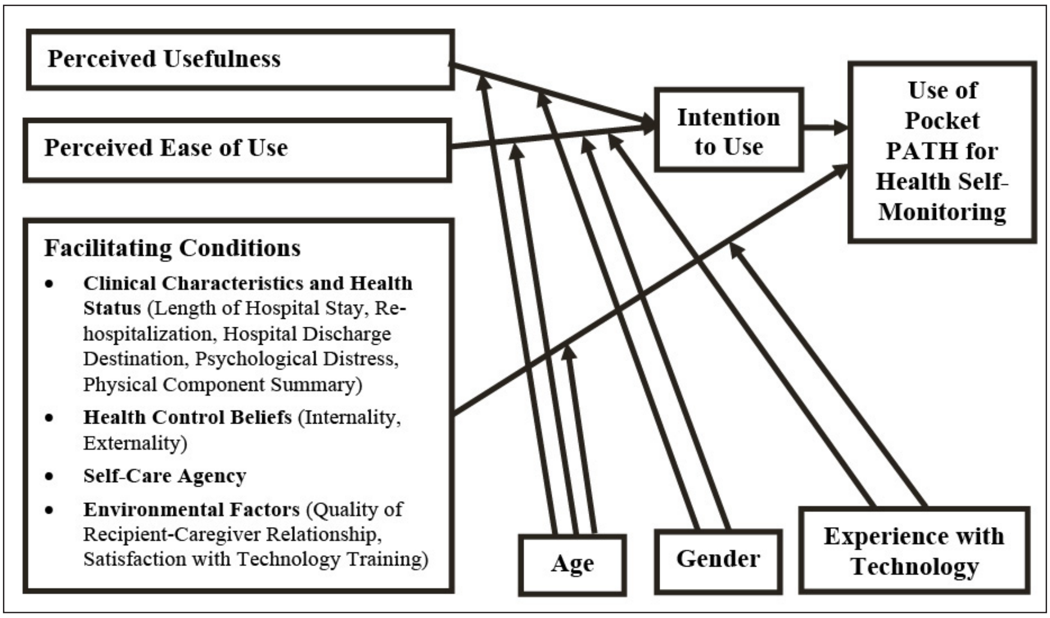

Fig. 1 Conceptual Model for Acceptance and Use of Pocket PATH for Health Self-Monitoring in Lung Transplant Recipients (adapted from the Unified Theory of Acceptance and Use of Technology)

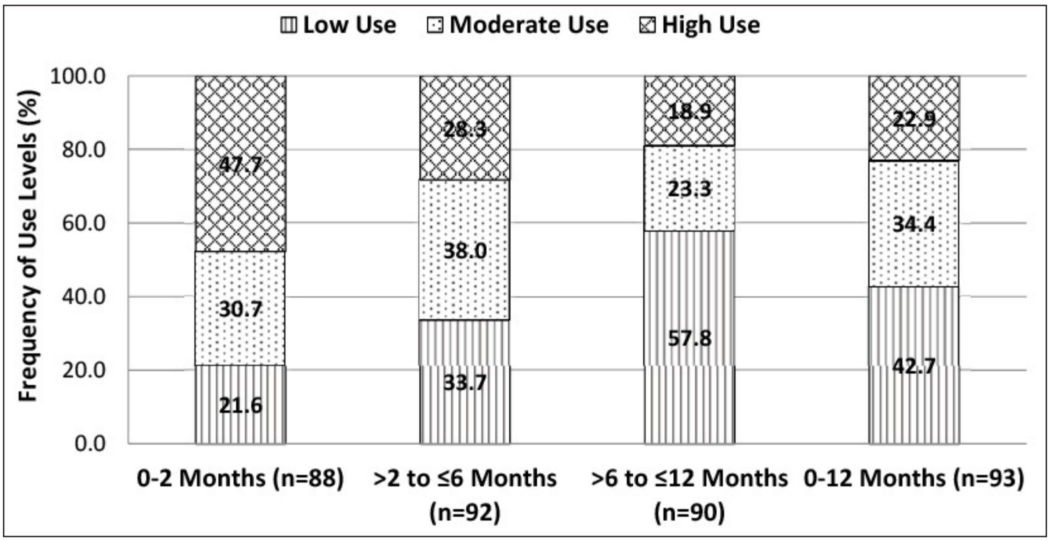

Fig. 2 Use of Pocket PATH for Health Self-Monitoring during the First Year Post-Transplantation

Table 1 Summary of Sample Characteristics (N=96)

Category	Characteristic	Mean (SD)	Range
Demographic-Characteristics	Age (years)	57 (14)	18–74
	Experience with Technology	5 (2)	1–8
		n	%
	Gender (male)	49	51
	Race (white)	89	93
	Marriage (married or living with a partner)	71	74
	Employment (unemployed)	81	84
	Education (> high school)	54	56
	Income (basic needs met)	85	89
Clinical Charac-teristics	Characteristic	Mean (SD)	Range
	LOS (days)	30 (23)	9–134
	Length of ICU stay (days)	9 (11)	1–49
		n	%
	Underlying disease (obstructive/COPD)	41	43
	Type of transplant (double)	78	81
	Post-op ventilator needs (< 48 hours)	66	69
	Re-intubated (No)	81	84
	Return to ICU (No)	83	87
	Discharge destination(home or local residence)	87	91
	Re-hospitalization (Yes)		
	• 0 to 2 months	52	54
	• > 2 to ≤ 6 months	53	55
	• > 6 to ≤ 12 months	46	48

Notes: ICU: Intensive Care Unit; LOS: Length of Stay (in hospital); SD: standard deviation.

Table 2 Multivariate Ordinal Logistic Regression for Screened Predictors of Use of Pocket PATH

Predictor	*b*	*p*	OR	95% CI	*b*	*p*	OR	95% CI
0 to 2 Months	**Original Results# (n=86)**				**Pooled Results## (n=88)**			
Gender (Male)	1.58	0.001	4.85	1.85–12.63	1.54	0.002	4.66	1.77–12.22
ASQ (High)	1.07	0.05	2.92	1.01–8.48	1.39	0.01	4.01	1.38–11.54
PSCA	0.13	0.001	1.14	1.06–1.22	0.13	0.001	1.14	1.05–1.23
Gender*PSCA	-0.05	0.07	0.95	0.90–1.01	-0.07	0.03	0.94	0.88–0.99
ASQ*PSCA	-0.08	0.01	0.92	0.86–0.98	-0.08	0.02	0.93	0.87–0.99
> 2 to ≤ 6 Months	**Original Results# (n=89)**				**Pooled Results## (n=92)**			
Age (years)	0.03	0.06	1.03	1.00–1.06	0.03	0.05	1.03	1.00–1.06
ASQ (High)	1.16	0.02	3.18	1.21–8.41	1.22	0.01	3.37	1.30–8.75
LOS (days)	-0.03	0.005	0.97	0.95–0.99	-0.03	0.02	0.98	0.96–1.00
PsychoDistress	-0.74	0.01	0.48	0.27–0.85	-0.79	0.01	0.45	0.25–0.83
Age*PsychoDistress	-0.04	0.05	0.96	0.93–1.00	-0.04	0.05	0.96	0.93–1.00
> 6 to ≤ 12 Months	**Original Results# (n=81)**				**Pooled Results## (n=90)**			
Age (years)	0.05	0.02	1.05	1.01–1.09	0.05	0.02	1.05	1.01–1.09
PsychoDistress	-0.57	0.09	0.57	0.30–1.09	-0.86	0.02	0.43	0.21–0.88
PCS	0.10	0.004	1.11	1.03–1.18	0.09	0.01	1.09	1.02–1.16
0 to 12 Months	**Original Results# (n=78)**				**Pooled Results## (n=93)**			
Age (years)	0.04	0.01	1.04	1.01–1.08	0.05	0.007	1.05	1.01–1.09
ASQ (High)	1.02	0.03	2.77	1.08–7.11	1.12	0.02	3.05	1.16–8.02
PCS	0.105	0.0004	1.11	1.05–1.18	0.12	0.001	1.13	1.06–1.21

Notes. ASQ: Satisfaction with Technology Training; CI: Confidence Interval; LOS: Length of Hospital Stay; OR: Odds Ratio; PCS: Physical Component Summary; PSCA: Self-Care Agency; PsychoDistress: Psychological Distress.
#: Results from original dataset; ## Pooled results across five multiple imputation datasets.

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