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Engineering Early Detection: Evaluating the Potential of Wearable Breast-Cancer Screening Devices Through Biomedical and Public-Health Frameworks

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Epidemiologic Impact of a Wearable Breast Ultrasound Device for Early Detection

Introduction

Breast cancer remains one of the most significant public health challenges worldwide and is the most commonly diagnosed cancer among women in the United States (Broeders 2012). Despite substantial advances in treatment, breast cancer mortality continues to be driven largely by stage at diagnosis, with early-stage disease associated with markedly higher survival rates than advanced-stage disease (Shapiro et al., 1988; Tabár et al., 2011). Decades of epidemiologic evidence from randomized controlled trials and population-based screening programs have demonstrated that early detection through screening leads to reduced breast cancer mortality, primarily by shifting diagnoses toward earlier, more treatable stages (Moss et al., 2020; Kalager et al., 2010; Paci, 2012).

Large screening trials; including the Health Insurance Plan (HIP) Study in the United States, the Swedish Two-County Trial, and the UK Age Trial have consistently shown 20–40% reductions in breast cancer mortality among women who participate in screening compared with those who do not (Shapiro et al., 1988; Tabár et al., 2011; Moss et al., 2020). Similar benefits have been observed in national screening programs in Norway, the Netherlands, Korea, and Japan, reinforcing the causal relationship between screening, earlier detection, and improved survival (Kalager et al., 2010; Broeders 2012). Collectively, these studies establish early detection and stage shift as validated surrogate outcomes for long-term mortality reduction in breast cancer epidemiology.

However, the population-level benefits of screening are not evenly distributed. Screening adherence remains suboptimal, particularly among younger women, women with dense breast tissue, and populations facing socioeconomic, cultural, or geographic barriers to care (Sprague et al., 2014). Mammography, the cornerstone of breast cancer screening, has reduced sensitivity in women with dense breasts and may be less effective in women under 50 years of age (Annette, 2005). These limitations contribute to higher rates of interval cancers and delayed diagnoses, undermining the full potential of screening programs to reduce mortality and exacerbating health disparities (Sprague et al., 2015).

Breast ultrasound has emerged as an important supplemental imaging modality capable of addressing some of these limitations. Multiple studies have demonstrated that ultrasound, when used in conjunction with mammography, increases cancer detection rates particularly for small, invasive cancers in women with dense breasts (Kevin et al., 2009; Brem F et al 2015). Automated breast ultrasound (ABUS) systems have further improved reproducibility and reduced operator dependency, making ultrasound more feasible as a scalable screening tool (Kelly et al., 2010). Systematic reviews and meta-analyses confirm that supplemental ultrasound identifies cancers that would otherwise be missed by mammography alone, although at the cost of increased false positives (Melnikow et al., 2016; Tagliafico et al., 2018).

While ultrasound has demonstrated diagnostic value, its population-level impact remains constrained by access, convenience, and adherence. Conventional ultrasound screening typically requires clinical visits, trained personnel, and specialized equipment, limiting its reach especially among populations already underserved by existing screening infrastructure (Sprague et al., 2014; WHO, 2014). These barriers highlight a critical gap between technological capability and real-world public health impact.

Recent advances in biomedical engineering have introduced the possibility of wearable breast ultrasound technologies, including flexible and conformable ultrasound patches capable of deep-tissue imaging (Du et al., 2023) and portable, patient-dedicated automated ultrasound systems (Park et al., 2023). These innovations suggest a future in which breast imaging could be performed more frequently, discreetly, and outside traditional clinical settings. A wearable, bra-shaped ultrasound device represents a novel approach that could potentially lower barriers to screening, increase screening frequency, and improve adherence; particularly among women who face discomfort, privacy concerns, or logistical challenges with conventional screening methods.

From an epidemiologic perspective, the potential public health value of such a device lies not in immediate demonstration of mortality reduction, but in its capacity to influence upstream determinants of cancer outcomes. Established screening trials demonstrate that increased participation and earlier detection lead to stage shift, which in turn reduces mortality (Shapiro et al., 1988; Tabár et al., 2011; Kalager et al., 2010). Therefore, improvements in screening adherence and early detection rates are recognized as valid surrogate endpoints for estimating long-term mortality impact (Paci, 2012; Moss et al., 2020). This indirect inference framework has been widely applied in cancer screening policy development, including the adoption of mammography, MRI screening in high-risk populations, and supplemental imaging strategies (Kuhl et al., 2005; Melnikow et al., 2016).

Importantly, the adoption of new screening technologies is not determined solely by diagnostic performance. Behavioral, cultural, and psychosocial factors; including physical comfort, modesty, privacy concerns, perceived cancer risk, and willingness to use or pay for new technologies play a decisive role in screening behavior (Sprague et al., 2014; Seely & Alhassan, 2021). Even highly sensitive screening tools fail to achieve population-level benefit if they are not acceptable or accessible to users. Understanding these factors is therefore essential for evaluating the real-world feasibility and epidemiologic impact of wearable breast ultrasound technologies.

Despite growing interest in wearable imaging devices, there is limited research examining how such technologies might influence screening behavior, acceptance, and potential population-level outcomes. No studies to date have directly assessed user perceptions of a wearable bra-shaped ultrasound device or evaluated its potential epidemiologic impact using behavioral and modeling approaches grounded in established screening evidence.

The present study addresses this gap by examining women's perceptions, comfort levels, cultural attitudes, privacy concerns, and willingness to adopt a wearable bra-shaped breast ultrasound screening device. Using survey data and an indirect epidemiologic inference framework, this study evaluates whether such a device could plausibly increase screening adherence and early detection, the key surrogate outcomes linked to reduced breast cancer mortality. By integrating behavioral data with established evidence from breast cancer screening trials and ultrasound research, this study aims to provide an early, evidence-based assessment of the potential public health value of wearable breast ultrasound technology and to inform future clinical testing, device development, and screening policy considerations.

Our research questions are as follows: *To what extent could a wearable bra-shaped ultrasound screening device improve early breast cancer detection and reduce screening disparities? How do user comfort, cultural attitudes, privacy concerns, and willingness to adopt the technology influence its feasibility and public-health impact?*

Methods

Study Design

This study employed a mixed-methods epidemiologic design integrating (1) a cross-sectional survey of women to assess perceptions and adoption-related factors for a wearable bra-shaped breast ultrasound device, and (2) a secondary synthesis of existing epidemiologic and screening literature to contextualize potential population-level impact. Because the device is not yet commercially available and clinical outcome data do not exist, the study applied an indirect epidemiologic inference framework, using validated surrogate outcomes such as screening adherence, early detection, and stage shift to estimate potential public-health implications.

Conceptual Framework

The study was guided by an epidemiologic framework linking technology access and acceptability to screening behavior, early detection, and downstream mortality outcomes. Established evidence demonstrates that increased screening participation and earlier stage diagnosis are causally associated with improved survival in breast cancer (Ohuchi, N., et al. (2016), Kelly, K. M., Dean(2010), Sprague, B. L., et al. (2021)). Accordingly, this study focused on upstream determinants user comfort, cultural attitudes, privacy concerns, and willingness to adopt that influence whether a wearable ultrasound device could plausibly improve screening adherence and early detection at the population level.

Survey Component

Participants and Recruitment

Participants were women aged 18 years or older who were students or faculty at the University of Oklahoma. Recruitment occurred via university email distribution lists using an IRB-approved recruitment message. Participation was voluntary, anonymous, and uncompensated. Eligibility criteria were limited to age and gender to capture a broad range of screening perceptions among women at varying levels of breast cancer risk.

Survey Instrument

Data were collected using a structured online questionnaire administered through Qualtrics. The survey was designed to assess key domains relevant to adoption and feasibility of a wearable breast ultrasound device, including:

1. Physical comfort with wearing a bra-shaped ultrasound device.
2. Perceived privacy and modesty concerns.
3. Cultural and familial attitudes toward breast health and screening.
4. Perceived anxiety reduction or reassurance related to device use.
5. Willingness to adopt the device for routine or supplemental screening.
6. Willingness to pay for or access the technology.
7. Perceived personal risk (e.g., family history of breast cancer).

Demographic variables included age group, student or faculty status, and prior experience with breast screening. All survey items were required to proceed through the questionnaire; however, participants could exit the survey at any point prior to submission.

Survey items primarily used Likert-scale responses, supplemented by categorical variables where appropriate. The instrument was reviewed for clarity and content validity prior to distribution.

Table1. Description and categorization of variables

Categorization	Name of Variable	Classification of Variable	Description (Selected Items / Measures)
Demographics	Gender	Categorical	Female (study limited to women)
	Age Group	Categorical	18–29 years; 30–49 years; ≥50 years
	University Status	Categorical	Undergraduate student; Graduate student; Faculty/Staff
	Prior Breast Screening Experience	Categorical	Ever had mammography or breast ultrasound (Yes/No)
	Family History of Breast Cancer	Categorical	First-degree relative with breast cancer (Yes/No/Unsure)
Comfort and Body Experience	Physical Comfort with Device	Likert-scale index	Comfort wearing a bra-shaped ultrasound device; comfort with skin contact; comfort with duration of wear
Privacy and Modesty	Privacy Concerns	Likert-scale index	Concerns about body exposure; data privacy concerns; comfort using device at home
	Modesty Concerns	Likert-scale index	Cultural or personal modesty related to breast imaging; comfort self-administering the device
Cultural and Social Context	Cultural Attitudes Toward Breast Health	Likert-scale index	Openness discussing breast health; family support for screening; cultural norms related to breast care
Psychosocial Factors	Perceived Anxiety Reduction	Likert-scale index	Belief that device use would reduce screening anxiety; reassurance from more frequent monitoring
	Perceived Breast Cancer Risk	Likert-scale index	Self-assessed risk of developing breast cancer
Technology Adoption	Willingness to Adopt Device	Likert-scale index	Likelihood of using the device for routine or supplemental screening
	Intended Screening Frequency	Categorical	Less often than current screening; same frequency; more frequent screening
Economic Feasibility	Willingness to Pay	Categorical	Not willing; <$100; $100–$300; >$300

Categorization	Name of Variable	Classification of Variable	Description (Selected Items / Measures)
	Access Preference	Categorical	At-home use; clinical setting; both
Outcome Variable	Adoption Intention (Primary Outcome)	Binary / Ordinal	Likely vs unlikely to adopt wearable ultrasound device

Notes: All attitudinal variables were measured using 5-point Likert scales (strongly disagree to strongly agree). Composite indices were created by averaging item scores within each domain. All survey items were required to proceed through the questionnaire; participants could exit the survey at any time prior to submission.

Outcome Measures

The primary outcome was *intention to adopt a wearable breast ultrasound device,* measured as self-reported likelihood of use for breast health monitoring or screening. Secondary outcomes included perceived acceptability, anticipated screening frequency, and perceived reduction of barriers associated with conventional screening methods.

Independent variables included comfort, privacy concerns, cultural attitudes, perceived cancer risk, and willingness to pay.

Statistical Analysis of Survey Data

Our data collection is ongoing, with 66 responses collected so far. Descriptive statistics will be used to summarize participant characteristics and survey responses. Associations between adoption intention and explanatory variables are evaluated using bivariate analyses and multivariable regression models, as appropriate. Regression analyses examined the relative contribution of comfort, privacy, cultural attitudes, perceived risk, and convenience to adoption intent.

All analysis will be conducted using standard IBM SPSS statistical software. Statistical significance assessed using a two-sided alpha level of 0.05.

Secondary Evidence Synthesis

To contextualize survey findings within the broader epidemiologic landscape, the study incorporated results from previously published randomized trials, population-based screening studies, systematic reviews, and modeling analyses related to breast cancer screening, ultrasound imaging, and early detection outcomes (Paci, E. (2012)). These studies were not re-analyzed at the individual-data level; instead, their findings were used to inform interpretation of how changes in screening behavior suggested by survey results could plausibly translate into

population-level outcomes (Ohuchi, N., et al. (2016), Kelly, K. M., Dean(2010), Sprague, B. L., et al. (2021))

Key parameters drawn from the literature included:

1. Established relationships between screening participation and stage at diagnosis
2. Evidence linking stage shift and reduced interval cancers to mortality reduction
3. Performance characteristics of ultrasound and automated breast ultrasound in dense breasts
4. Documented disparities in screening access and adherence

Epidemiologic Inference Approach

Because direct measurement of mortality reduction attributable to a wearable breast ultrasound device is not feasible at this stage, the study used model-based epidemiologic inference grounded in validated surrogate endpoints. Early detection rates, screening adherence, and stage distribution were treated as proximal outcomes, consistent with prior screening research and policy evaluations. Mortality impact will be discussed as plausible and projected, rather than measured, based on established causal pathways in breast cancer epidemiology (Ohuchi, N., et al. (2016), Kelly, K. M., Dean(2010), Sprague, B. L., et al. (2021))**.**

Ethical Considerations

The study protocol will be reviewed and approved by the University of Oklahoma Institutional Review Board. All participants provided informed consent electronically prior to survey participation. No identifiable information will be collected, and all responses will be analyzed in aggregate.

Methodological Limitations

This study relied on self-reported survey data, which may be subject to response bias. The sample is drawn from a single academic institution and may not be representative of all populations. Additionally, epidemiologic projections were based on secondary evidence rather than direct clinical outcomes. These limitations were addressed through conservative interpretation and explicit acknowledgment of assumptions.

Results

A total of 103 participants enrolled in the study, 66 participants completed the survey instrument at the time of analysis. Respondents represented undergraduate students, graduate students, and faculty/staff, spanning multiple age groups. Prior breast screening experience and family history of breast cancer were distributed across categories, allowing assessment of perceptions among women at varying baseline risk levels. All analyses presented below are descriptive and inferential within the context of an indirect epidemiologic inference framework. Descriptive statistics for the main composite variables are presented in Table 2.

Table 2. Descriptive Statistics for Main Composite Scores

Descriptive Statistics for Main Composite Scores

The MEANS Procedure

Variable	N	Mean	Std Dev	Minimum	Median	Maximum
comfort_score	66	72.26	26.98	0.00	80.00	100.00
willingness_score	66	75.97	17.80	23.20	79.00	100.00
culture_score	66	73.23	15.07	27.60	75.80	100.00
anxiety_score	66	49.85	19.65	1.00	50.50	86.33
reassurance_score	66	63.85	32.60	0.00	65.50	100.00

Reliability - Comfort Scale

The CORR Procedure

5 Variables:	comfort_physical comfort_clinic comfort_home concern_pain_r concern_privacy_r

Overall, participants reported moderately high levels of comfort and willingness toward the wearable breast ultrasound device. The mean comfort score was 72.26 (SD = 26.98), indicating that participants generally felt physically and socially comfortable using the device, although variability was relatively high.

- The willingness score had a mean of 75.97 (SD = 17.80), suggesting a strong overall openness to adopting the device for breast health monitoring. The median willingness score (79.00) further supports that most participants expressed favorable attitudes.
- The cultural and social acceptance score was also relatively high (M = 73.23, SD = 15.07), indicating that participants generally did not perceive strong cultural or social barriers to using the device.

- In contrast, the anxiety score was lower (M = 49.85, SD = 19.65), reflecting moderate concern levels associated with device use, e.g., fear of false alarms/health-related anxiety.
- The reassurance score had a mean of 63.85 (SD = 32.60), suggesting that many participants believed the device could help reduce anxiety by enabling earlier detection and more frequent monitoring, although responses varied widely.
- Across all composite measures, the full range of responses was observed (minimum values near 0, maximum values at or near 100), indicating substantial variability in participant perceptions. The comfort scale consisted of five items assessing physical comfort, usability in different settings, and concerns related to pain and privacy. Internal consistency was evaluated using reliability analysis. The results indicated that the items measuring comfort and body experience were appropriately grouped, supporting the use of a composite comfort score for subsequent analyses.

Table 3. Results of Statistical Analysis

Reliability - Willingness Scale

The CORR Procedure

5 Variables:	will_try will_regular will_adherence will_timehome prefer_trad_r

Simple Statistics

Variable	N	Mean	Std Dev	Sum	Minimum	Maximum
will_try	66	86.75758	18.99074	5726	9.00000	100.00000
will_regular	66	86.89394	19.48343	5735	6.00000	100.00000
will_adherence	66	73.30303	30.26853	4838	2.00000	100.00000
will_timehome	66	78.93939	26.91347	5210	0	100.00000
prefer_trad_r	66	53.95455	34.85196	3561	0	100.00000

Cronbach Coefficient Alpha

Variables	Alpha
Raw	0.682710
Standardized	0.730218

Cronbach Coefficient Alpha with Deleted Variable

	Raw Variables		Standardized Variables	
Deleted Variable	Correlation with Total	Alpha	Correlation with Total	Alpha
will_try	0.491619	0.626626	0.550059	0.660520
will_regular	0.539826	0.609509	0.589138	0.644728
will_adherence	0.629290	0.532651	0.609601	0.636324
will_timehome	0.532692	0.588846	0.595856	0.641979
prefer_trad_r	0.184845	0.779558	0.156192	0.801845

Pearson Correlation Coefficients, N = 66
Prob > |r| under H0: Rho=0

	will_try	will_regular	will_adherence	will_timehome	prefer_trad_r
will_try	1.00000	0.59859 <.0001	0.38668 0.0013	0.57902 <.0001	-0.01561 0.9010
will_regular	0.59859 <.0001	1.00000	0.43013 0.0003	0.52003 <.0001	0.09082 0.4683
will_adherence	0.38668 0.0013	0.43013 0.0003	1.00000	0.50290 <.0001	0.36655 0.0025
will_timehome	0.57902 <.0001	0.52003 <.0001	0.50290 <.0001	1.00000	0.05302 0.6724
prefer_trad_r	-0.01561 0.9010	0.09082 0.4683	0.36655 0.0025	0.05302 0.6724	1.00000

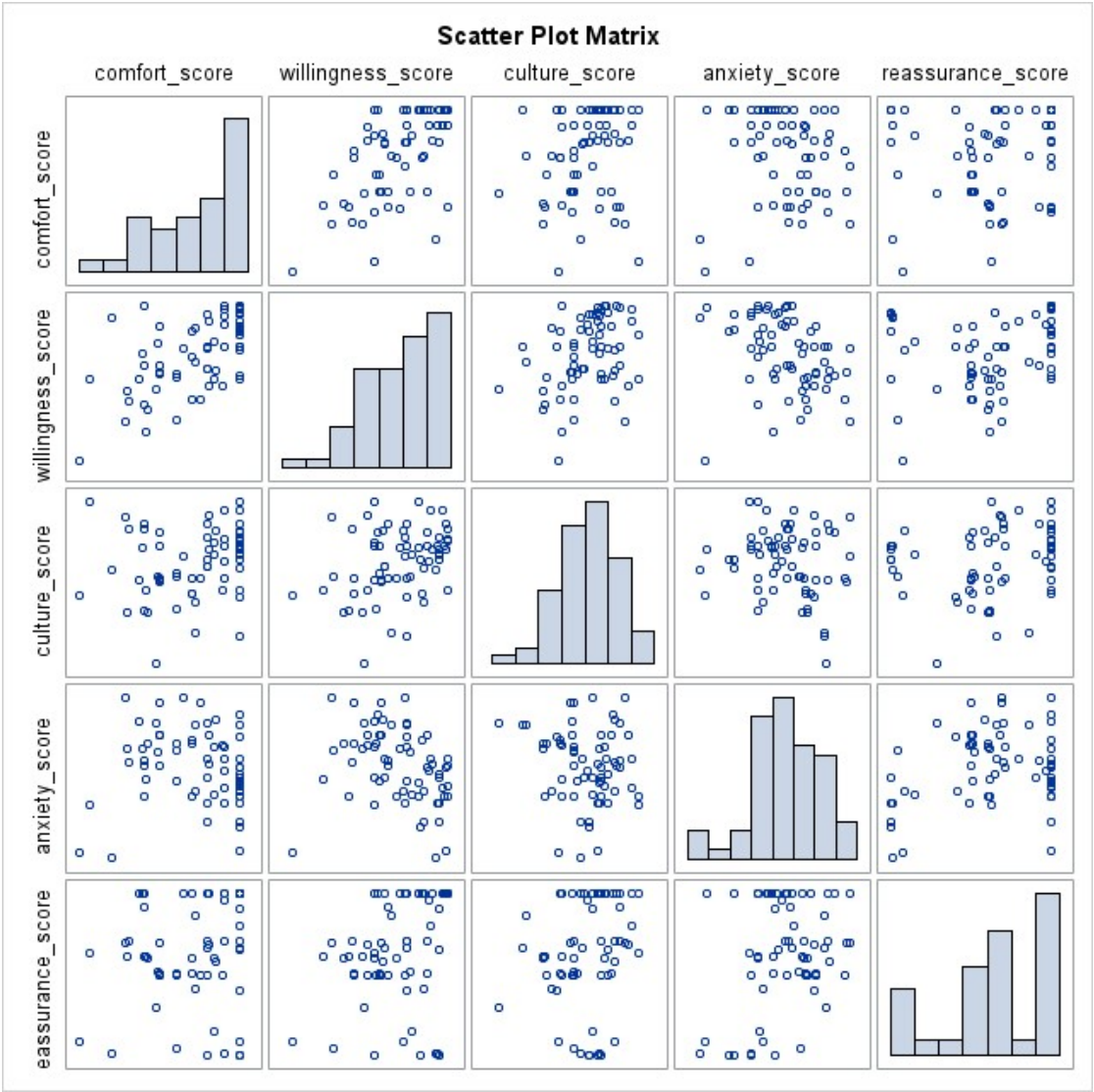
The willingness scale demonstrated acceptable internal consistency (Cronbach's $\alpha = 0.73$ standardized; $\alpha = 0.68$ raw). Most items were moderately correlated with the overall scale ($r = 0.49–0.63$). However, the reverse-coded item assessing preference for traditional imaging showed weak correlation with the total score ($r = 0.18$). Removing this item improved reliability ($\alpha \approx 0.80$), suggesting that it may reflect a distinct construct rather than willingness to adopt wearable technology (Table 3).

Independent samples t-tests were conducted to examine differences in willingness and comfort across awareness and prior imaging groups.

- There *was no significant difference in willingness scores based on awareness* of the wearable device ($t[64] = -0.13$, $p = 0.898$). Similarly, willingness did not differ significantly between participants with and without prior breast imaging experience ($t[64] = -0.36$, $p = 0.719$).
- Comfort scores were also not significantly different between awareness groups ($t[64] = -0.81$, $p = 0.419$). Tests of equality of variances indicated no violations of assumptions in any comparison.
- Although participants who were aware of the device showed slightly higher mean comfort and willingness scores, these differences were not statistically significant. Notably, the awareness group was very small ($n = 3$), limiting the reliability of these comparisons.
- Correlation analyses revealed *significant positive relationships among willingness-related items* ($r = 0.38–0.60$, $p < .001$), supporting the internal structure of the scale.
- At the composite level, comfort and cultural acceptance were positively associated with willingness, while anxiety showed a negative relationship. Reassurance demonstrated a modest positive association with willingness.

Scatter plot patterns (Figure 1) confirmed these trends, indicating that individuals who felt more comfortable and perceived fewer cultural barriers were more likely to report higher willingness to use the device, whereas higher anxiety was associated with lower willingness.

Figure 1. Scatter Plot Matrix



Comparison of Willingness Scores by Awareness

An independent samples t-test was conducted to examine whether awareness of the wearable breast ultrasound device was associated with differences in willingness to use the technology.

- Participants who were not aware of the device (n = 63) reported a mean willingness score of 75.91 (SD = 18.01), while those who were aware (n = 3) reported a slightly higher mean score of 77.27 (SD = 15.67). The mean difference between groups was −1.36, indicating only a minimal difference in willingness.

- The results of the t-test indicated that this difference was not statistically significant, $t(64) = -0.13$, $p = 0.898$. The Satterthwaite correction for unequal variances produced a similar result ($p = 0.896$), confirming the robustness of the finding.
- Levene's test (Folded F) showed no evidence of unequal variances between groups (F = 1.32, $p = 1.000$), supporting the assumption of homogeneity of variance. The 95% confidence interval for the mean difference (−22.53 to 19.82) was wide and included zero, further indicating the absence of a statistically meaningful difference.

Table 4. T-test of Willingness Score by Awareness

T-test: Willingness Score by Awareness

The TTEST Procedure

Variable: willingness_score

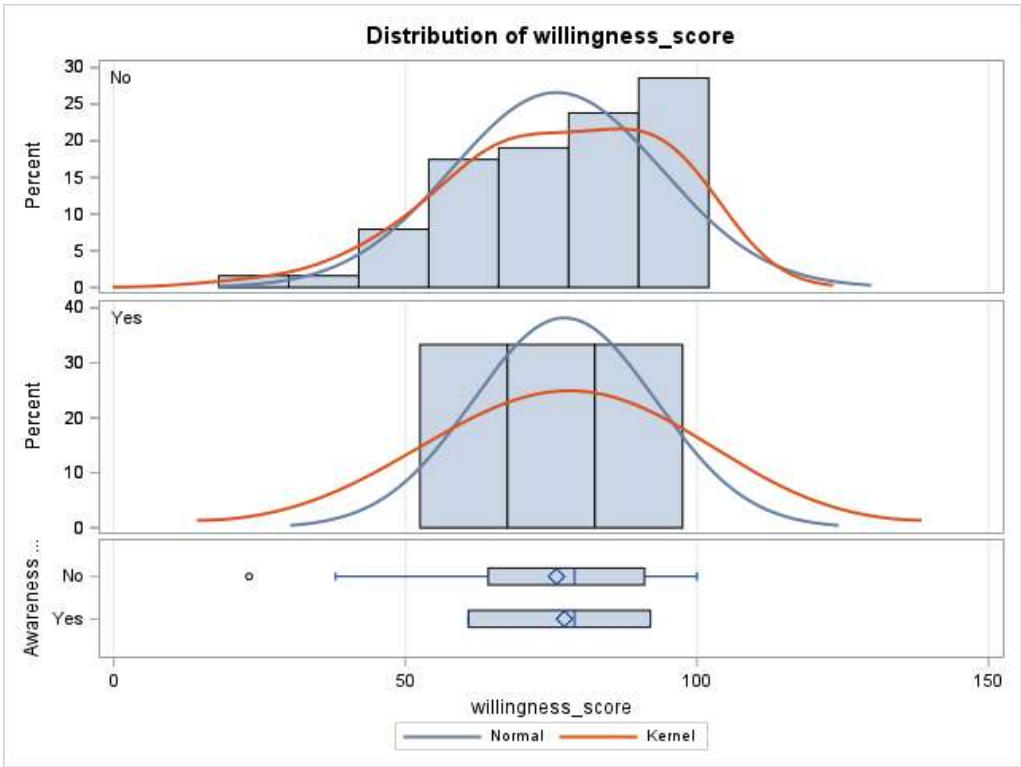
Awareness of Wearable Breast Ult	Method	N	Mean	Std Dev	Std Err	Minimum	Maximum
No		63	75.9079	18.0061	2.2686	23.2000	100.0
Yes		3	77.2667	15.6721	9.0483	60.8000	92.0000
Diff (1-2)	Pooled		-1.3587	17.9378	10.6001		
Diff (1-2)	Satterthwaite		-1.3587		9.3283		

Awareness of Wearable Breast Ult	Method	Mean	95% CL Mean		Std Dev	95% CL Std Dev	
No		75.9079	71.3732	80.4427	18.0061	15.3194	21.8444
Yes		77.2667	38.3351	116.2	15.6721	8.1598	98.4947
Diff (1-2)	Pooled	-1.3587	-22.5349	19.8174	17.9378	15.2970	21.6891
Diff (1-2)	Satterthwaite	-1.3587	-37.3918	34.6743			

Method	Variances	DF	t Value	Pr > |t|
Pooled	Equal	64	-0.13	0.8984
Satterthwaite	Unequal	2.2591	-0.15	0.8962

Equality of Variances				
Method	Num DF	Den DF	F Value	Pr > F
Folded F	62	2	1.32	1.0000

Distribution of Willingness Scores: Figure 2. Box Plots of Distribution of Willingness Scores



Visual inspection of the distribution plots revealed that willingness scores were generally skewed toward higher values in both groups, indicating a high overall level of acceptance of the wearable device.

- In the non-awareness group, scores were distributed across a wide range (approximately 23 to 100), with the majority of responses clustered between 60 and 100, suggesting generally favorable attitudes. A small number of lower scores were observed, contributing to a slight left-skew in the distribution.
- In the awareness group, willingness scores were also relatively high, with values approximately ranging from 60 to 92. However, due to the very small sample size (n = 3), the distribution in this group is not reliable for inferential interpretation.
- Boxplot comparisons showed substantial overlap between the two groups, with no clear separation in central tendency or spread (Figure 2). The non-awareness group exhibited greater variability and included at least one lower outlier, whereas the awareness group showed a narrower spread of values.

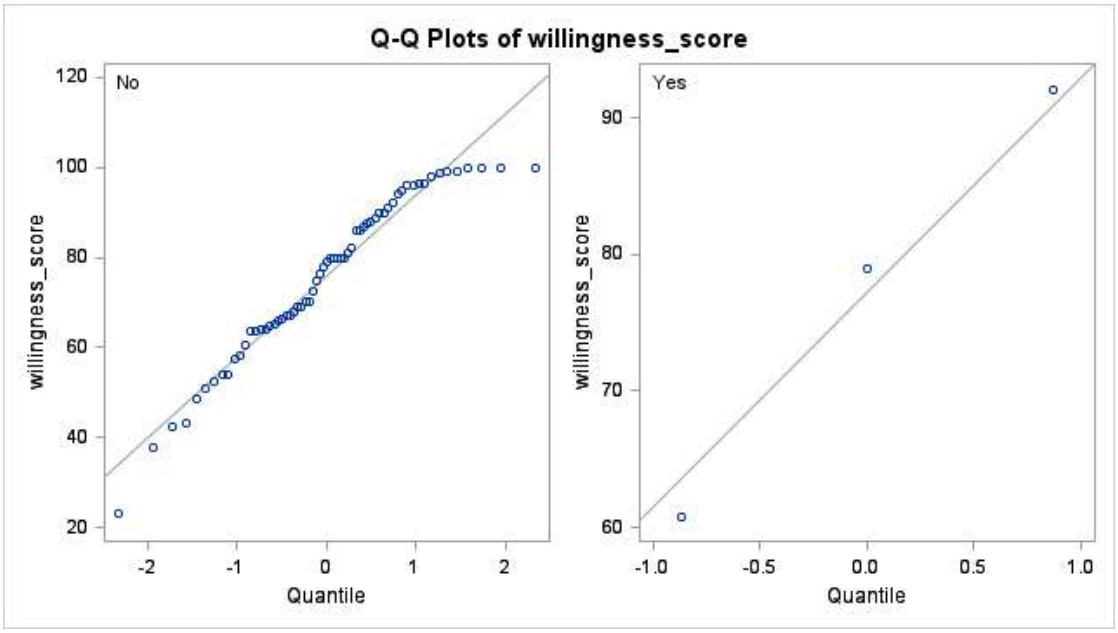
Assessment of Normality

Normality of the willingness score distribution was assessed using Q-Q plots.

- For the non-awareness group, the Q-Q plot demonstrated that most data points fell close to the diagonal reference line, indicating approximate normality in the central portion of the distribution. Some deviation was observed in the upper tail, where scores clustered near the maximum value (100), suggesting a potential ceiling effect. Despite this, the distribution was sufficiently normal for parametric testing, particularly given the relatively large sample size.
- For the awareness group, the Q-Q plot was limited by the extremely small number of observations (n = 3). Although the points appeared roughly aligned with the reference line, the sample size was insufficient to meaningfully assess normality. Overall, the analysis indicates that awareness of the wearable breast ultrasound device was not associated with a significant difference in willingness to use the technology. Both groups demonstrated relatively high willingness scores, and the observed difference between groups was minimal and not statistically significant.

While the assumptions of normality and equal variances were generally satisfied for the larger group, the extremely small size of the awareness group limits the reliability and generalizability of this comparison.

Figure 3. Q-Q Plots of Willingness Score



Limitations

Several limitations should be considered when interpreting the findings of this study. First, the sample was limited to students from the Norman campus and the Health Sciences Center, which restricts the generalizability of the results. Because participants were primarily drawn from a university population, the sample may not be representative of the broader public, particularly in terms of age distribution, educational background, and health awareness. As a result, the findings may not fully reflect attitudes toward wearable breast ultrasound devices across more diverse populations.

Second, the study relied on self-reported survey data, which may be subject to response bias, including social desirability bias and inaccurate self-assessment. Participants may have overestimated their willingness to adopt new health technologies or underreported concerns, potentially affecting the accuracy of the results.

Another important limitation is the small subgroup size for certain variables, particularly the awareness group ($n = 3$), which limits statistical power and reduces the reliability of group comparisons. This imbalance may have contributed to the lack of statistically significant differences observed in the t-test analyses.

Additionally, while the regression model explained a moderate proportion of variance in willingness, there may be other unmeasured factors, such as socioeconomic status, prior healthcare experiences, or trust in medical technology that were not included in the analysis but could influence adoption behavior.

To address these limitations, future research should aim to expand the sampling strategy beyond a single university setting. The next phase of this study will involve modifying the data collection approach to include a more diverse and representative population. Specifically, the survey will be distributed across the state of Oklahoma during the summer, with the goal of capturing a statewide perspective on perceptions of wearable breast ultrasound technology. Expanding the sample in this way will improve the external validity of the findings and provide a more comprehensive understanding of public attitudes toward this emerging screening approach.

Conclusion

This study provides early, evidence-informed support for the feasibility and potential public-health value of a wearable bra-shaped breast ultrasound screening device, using an indirect epidemiologic inference framework appropriate for technologies still in experimental development. Across 65 surveyed women at the University of Oklahoma, acceptability-related determinants of screening behavior including physical comfort, willingness to use the device at home, and intention to adopt if recommended by a clinician were generally favorable. Participants reported high comfort with wearing the device in both clinic and home settings and expressed strong willingness to use the device regularly if it could reduce late-stage breast cancer risk. Importantly, nearly three-quarters of respondents indicated they would be more likely to keep up with screening if wearable ultrasound were available, suggesting that the technology could plausibly improve screening adherence, a key upstream driver of early detection and stage shift.

The survey findings also highlight that barriers to adoption are not purely technical. While privacy and modesty concerns were present, they were moderate overall, and cultural barriers, such as reliance on family approval or fear of community judgment appeared limited within this sample. However, participants voiced meaningful concerns about device accuracy, false positives, emotional anxiety related to abnormal results, safety, and affordability. These concerns reflect well-established challenges in screening implementation: even highly sensitive modalities may fail to generate population-level benefit if they increase perceived harm, cost burden, or psychological distress. Therefore, the epidemiologic promise of wearable ultrasound depends not only on imaging performance but also on trust, accessible follow-up pathways, clear result communication, and equitable pricing.

When interpreted alongside biomedical engineering evidence, the reported acceptability is consistent with device designs that prioritize comfort, discreet use, and repeatable scanning. Engineering innovations such as conformable patches integrated into familiar garments and structured scanning mechanisms support the practical conditions needed for at-home imaging and may reduce reliance on clinical infrastructure. These design features directly address several adoption barriers raised in the survey, particularly those related to comfort, convenience, and privacy. In an indirect inference model, improvements in screening participation and frequency are treated as surrogate outcomes for stage shift an established intermediate pathway through which screening programs reduce breast cancer mortality (Shapiro et al., 1988; Tabár et al., 2011; Paci, 2012; Moss et al., 2020). Thus, the convergence of high user willingness and emerging technical feasibility strengthens the plausibility that wearable ultrasound could contribute to earlier detection and, ultimately, reduced mortality, especially among populations for whom conventional screening is less accessible or less acceptable.

At the same time, this study's conclusions must be interpreted in light of important limitations. The sample was drawn from a single academic community and may not reflect attitudes in rural

populations, lower-resource settings, older women at highest screening age, or cultural contexts where modesty and stigma may play a larger role. Findings were based on self-reported intentions rather than observed behavior, and the epidemiologic impact was inferred through surrogate endpoints rather than measured through clinical outcomes. These constraints are inherent to early-stage evaluation of emerging medical devices, but they underscore the need for cautious interpretation and prospective validation.

Future research should prioritize three directions. First, broader surveys and qualitative work should assess acceptability and barriers across diverse groups, including women with dense breasts, women under 50, rural communities, and populations with historically lower screening uptake. Second, pilot implementation studies are needed to test whether stated willingness translates into real-world use and whether wearable ultrasound changes screening frequency, follow-up adherence, and time-to-diagnosis. Third, modeling analyses should formally translate observed adoption probabilities into projected stage distribution and mortality outcomes under multiple scenarios (e.g., varying sensitivity, false-positive rates, adherence gains, and access constraints). Establishing safe clinical workflows for result interpretation and referral; and designing cost structures compatible with insurance coverage and low out-of-pocket burden will be critical for equitable translation.

In conclusion, the findings suggest that a wearable bra-shaped ultrasound device has meaningful potential to improve the feasibility of frequent breast monitoring and to reduce screening barriers related to access, convenience, and discomfort. By addressing upstream determinants of screening behavior, wearable ultrasound could plausibly increase adherence and early detection validated surrogate outcomes linked to mortality reduction thereby offering a promising strategy to reduce disparities in breast cancer outcomes. Continued multidisciplinary research integrating epidemiology, behavioral science, and biomedical engineering is warranted to evaluate this technology’s real-world impact and to guide responsible implementation.

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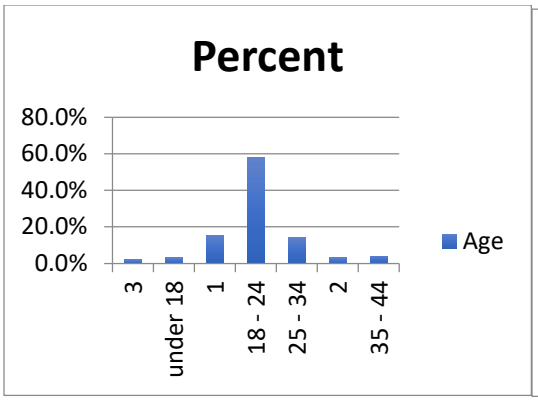
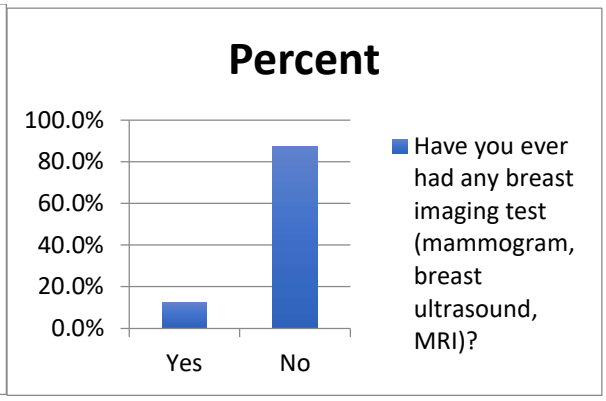
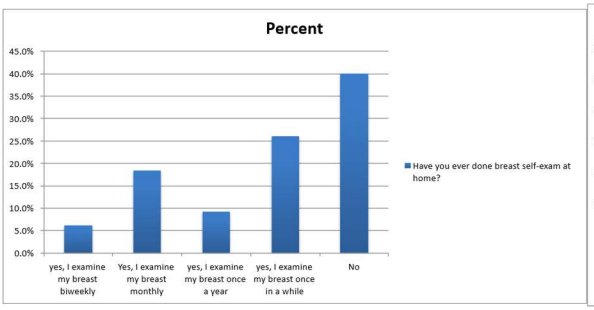
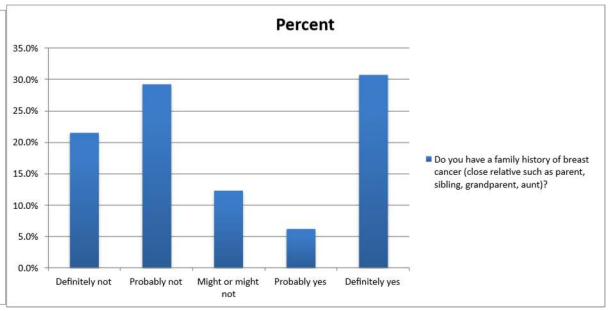
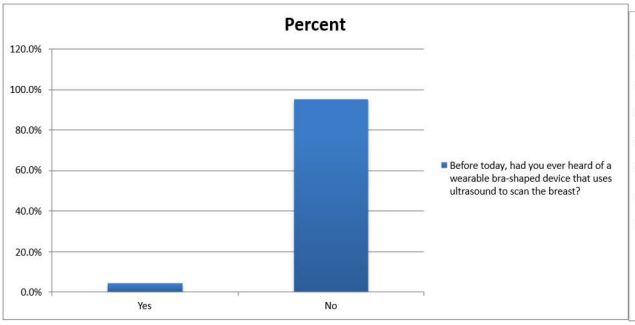
Appendix :The Survey Findings

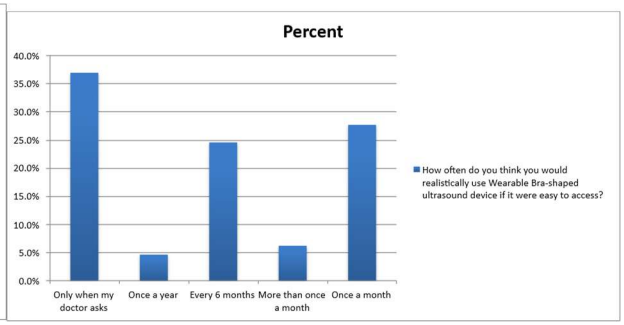


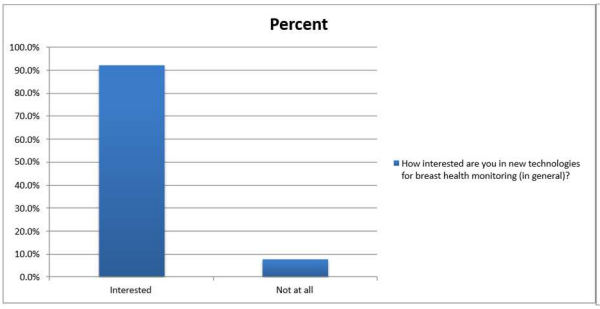


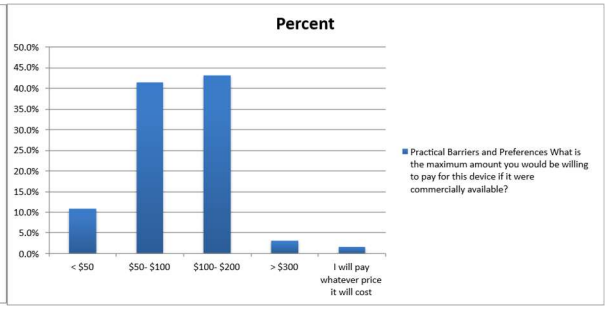












SAS OUTPUT:

T-test: Willingness Score by Imaging History

The TTEST Procedure

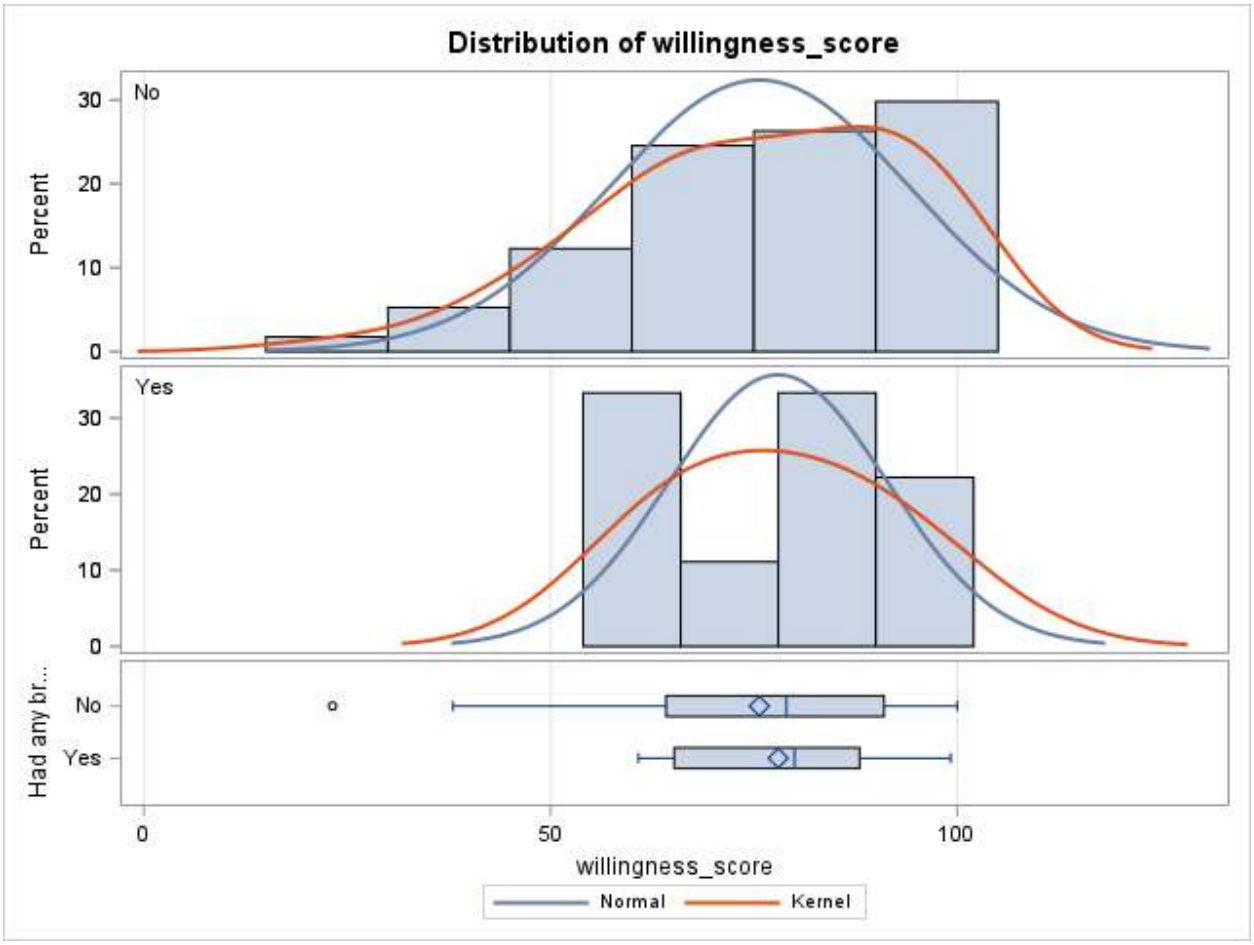
Variable: willingness_score

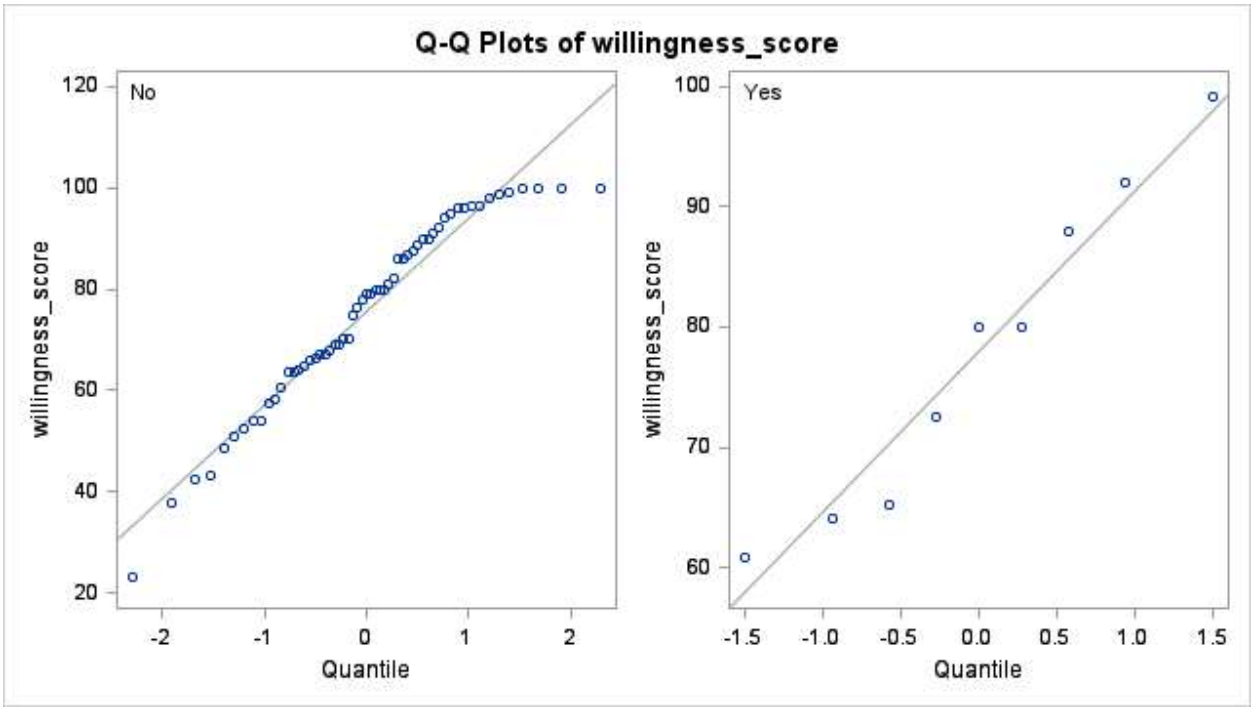
Had any breast imaging test Mamm	Method	N	Mean	Std Dev	Std Err	Minimum	Maximum
No		57	75.6526	18.4768	2.4473	23.2000	100.0
Yes		9	77.9778	13.4084	4.4695	60.8000	99.2000
Diff (1-2)	Pooled		-2.3251	17.9218	6.4283		
Diff (1-2)	Satterthwaite		-2.3251		5.0956		

Had any breast imaging test Mamm	Method	Mean	95% CL Mean		Std Dev	95% CL Std Dev	
No		75.6526	70.7501	80.5552	18.4768	15.5991	22.6663
Yes		77.9778	67.6712	88.2844	13.4084	9.0568	25.6874
Diff (1-2)	Pooled	-2.3251	-15.1671	10.5168	17.9218	15.2834	21.6697
Diff (1-2)	Satterthwaite	-2.3251	-13.3047	8.6544			

Method	Variances	DF	t Value	Pr > |t|
Pooled	Equal	64	-0.36	0.7188
Satterthwaite	Unequal	13.345	-0.46	0.6555

Equality of Variances				
Method	Num DF	Den DF	F Value	Pr > F
Folded F	56	8	1.90	0.3371


Distribution of willingness_score
No
Yes
Percent
30
20
10
0
Had any br...
No
Yes
0
50
100
willingness_score
Normal
Kernel


Q-Q Plots of willingness_score
No
Yes
willingness_score
Quantile
120
100
80
60
40
20
90
70
-2
-1
0
1
2
-1.5
-1.0
-0.5
0.0
0.5
1.0
1.5

T-test: Comfort Score by Awareness

The TTEST Procedure

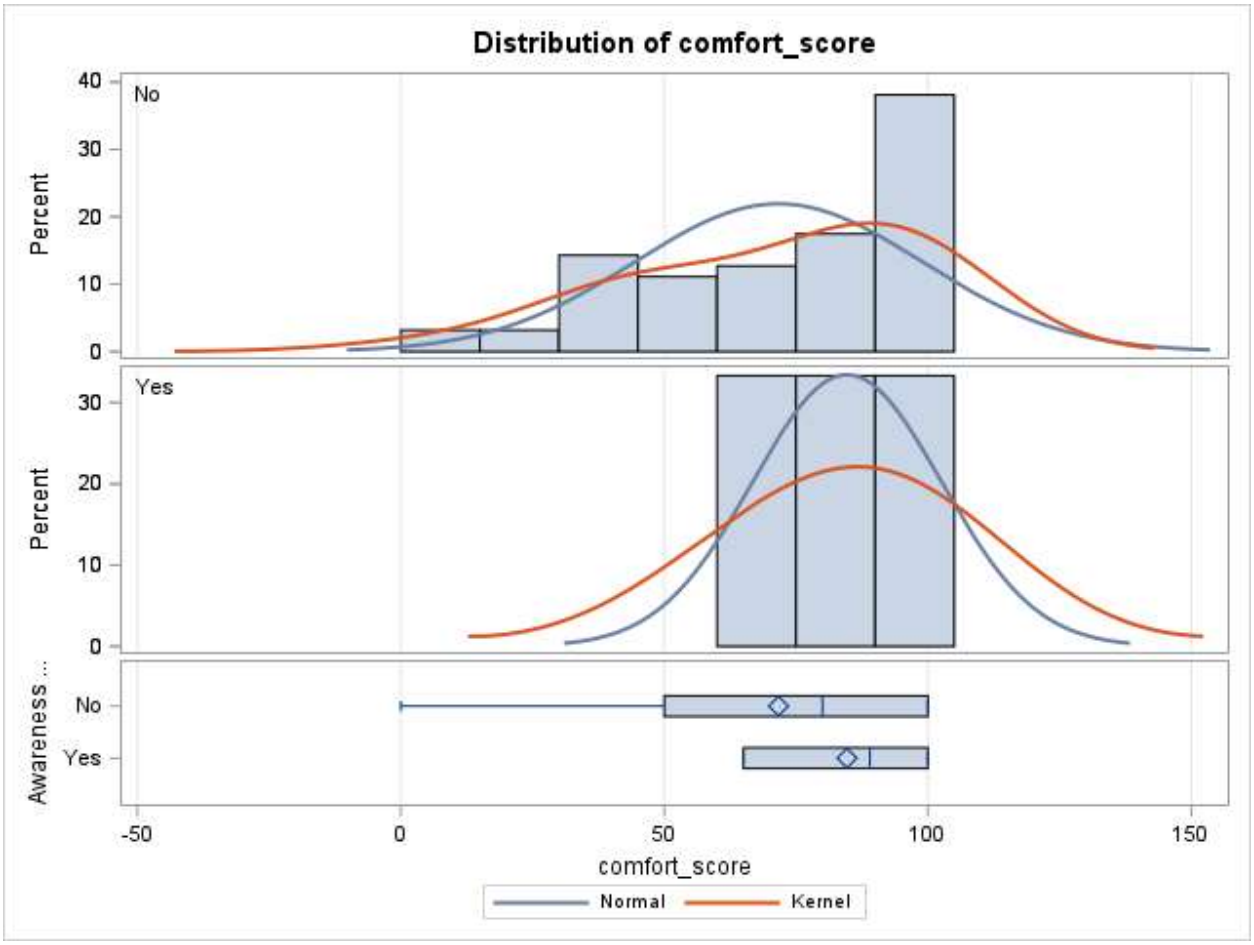
Variable: comfort_score

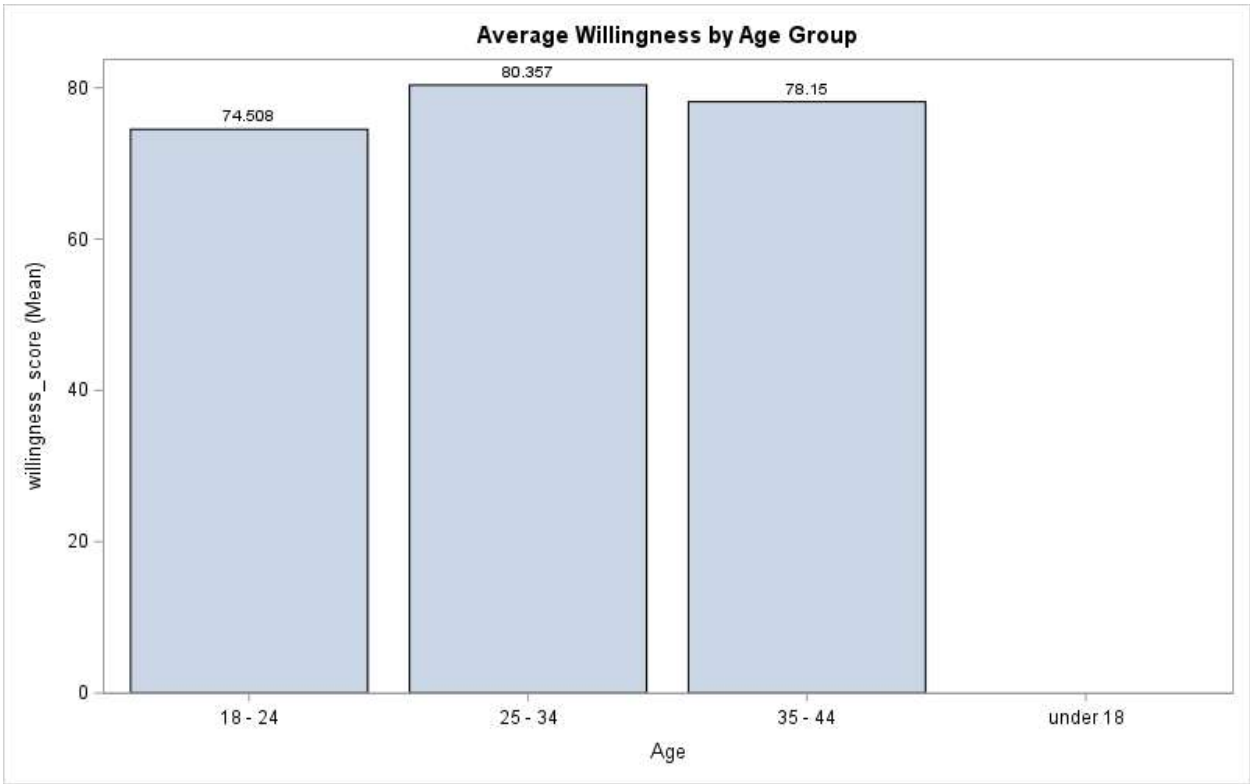
Awareness of Wearable Breast Ult	Method	N	Mean	Std Dev	Std Err	Minimum	Maximum
No		63	71.6667	27.2965	3.4390	0	100.0
Yes		3	84.6667	17.8979	10.3333	65.0000	100.0
Diff (1-2)	Pooled		-13.0000	27.0522	15.9862		
Diff (1-2)	Satterthwaite		-13.0000		10.8906		

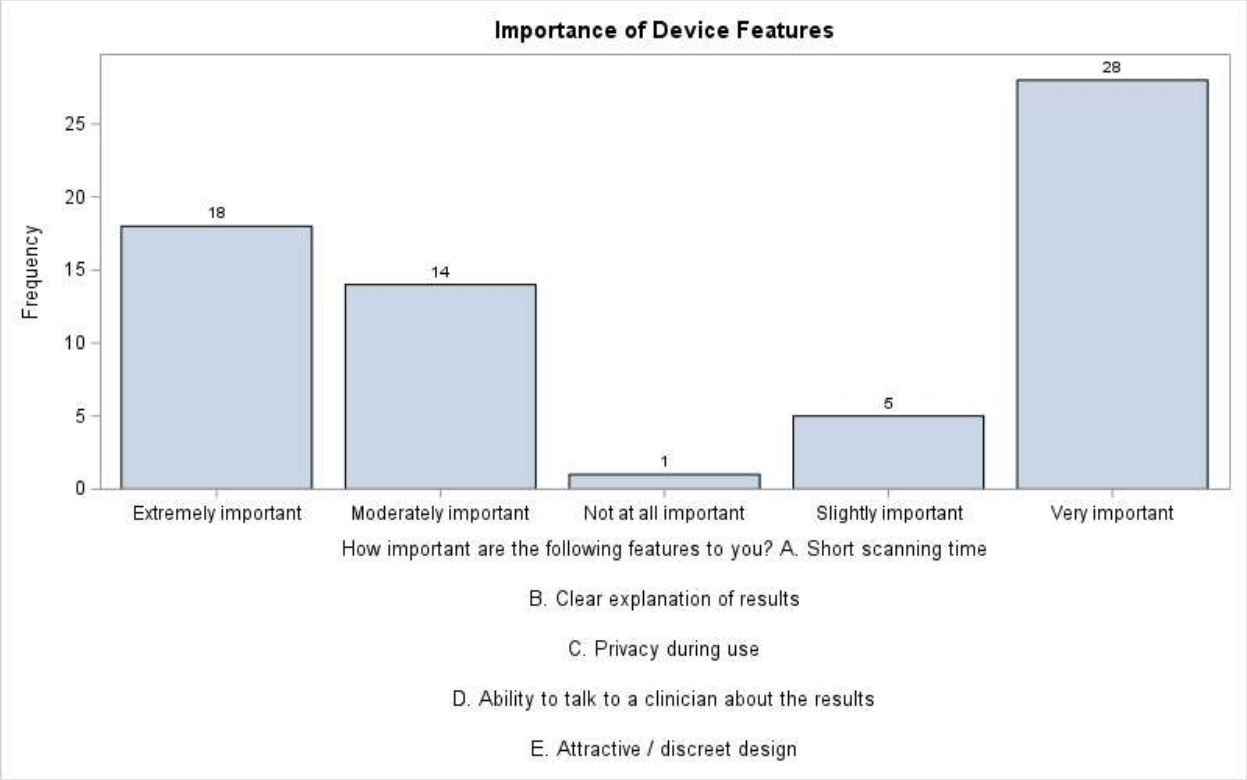
Awareness of Wearable Breast Ult	Method	Mean	95% CL Mean		Std Dev	95% CL Std Dev	
No		71.6667	64.7921	78.5412	27.2965	23.2236	33.1152
Yes		84.6667	40.2059	129.1	17.8979	9.3187	112.5
Diff (1-2)	Pooled	-13.0000	-44.9360	18.9360	27.0522	23.0697	32.7096
Diff (1-2)	Satterthwaite	-13.0000	-52.3097	26.3097			

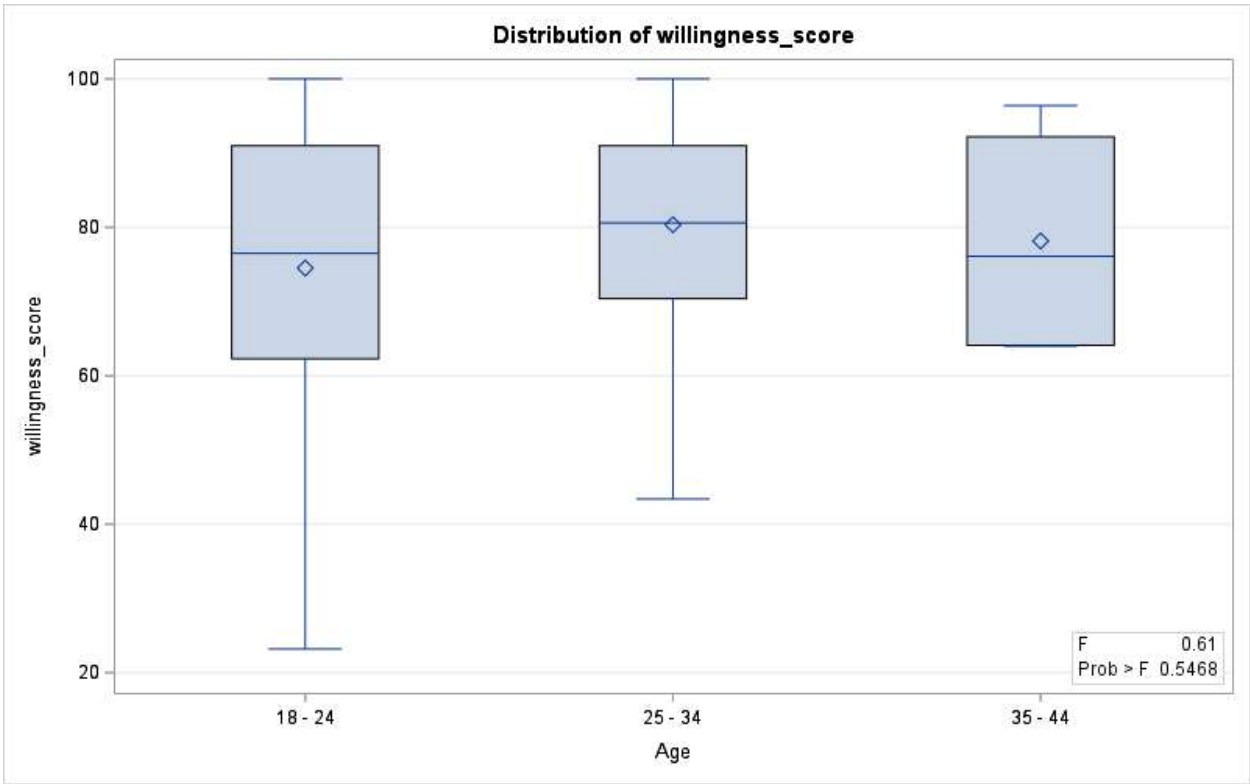
Method	Variances	DF	t Value	Pr > |t|
Pooled	Equal	64	-0.81	0.4191
Satterthwaite	Unequal	2.4666	-1.19	0.3347

Equality of Variances				
Method	Num DF	Den DF	F Value	Pr > F
Folded F	62	2	2.33	0.6950


Distribution of comfort_score
No
Yes
Percent
Awareness ...
No
Yes
40
30
20
10
0
-50
0
50
100
150
comfort_score
Normal
Kernel


Average Willingness by Age Group
willingness_score (Mean)
80
60
40
20
0
74.508
80.357
78.15
18 - 24
25 - 34
35 - 44
under 18
Age


Importance of Device Features
Frequency
25
20
15
10
5
0
18
14
1
5
28
Extremely important
Moderately important
Not at all important
Slightly important
Very important
How important are the following features to you? A. Short scanning time
B. Clear explanation of results
C. Privacy during use
D. Ability to talk to a clinician about the results
E. Attractive / discreet design


Distribution of willingness_score
willingness_score
100
80
60
40
20
18 - 24
25 - 34
35 - 44
Age
F 0.61
Prob > F 0.5468