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Telemedicine as a tool for bridging geographical inequity: insights in geospatial interactions from a study on chronic heart failure patients

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Abstract

Introduction Chronic heart failure patients experience large disparities in quality of and access to treatment, with rural populations receiving lower levels of care. Telemonitoring of patients is increasingly being used as an important tool for improving patient management and care and might reduce geographical inequities in healthcare.

Methods We investigate the presence and magnitude of a geospatial interaction effect on the health benefit of a supplementary telemedicine intervention, by analyzing the relationship between distance to regular place of treatment and the benefit of telemedicine in a secondary analysis of data from a previously conducted RCT. We use change in EQ5D health status, SF-36 Physical component score and SF-36 Mental component score as the outcomes. In the unadjusted analysis, intervention group and distance group and the interaction term are included as the independent variables, in the adjusted analysis, multiple socioeconomic and health related variables are included to account for potential confounders.

Results We find evidence of a significant interaction between the effects of telemedicine and long distance to treatment for change in EQ5D health status (unadjusted: $p = 0.016$, adjusted $p = 0.009$) and unadjusted but not adjusted mental component score (unadjusted: $p = 0.013$, adjusted $p = 0.0728$), for the change in physical component score the interaction term was not significant (unadjusted: $p = 0.118$, adjusted $p = 0.092$).

Conclusion In our study we find that supplementary telemedicine is likely to reduce the health access inequities associated with geographical distance for chronic heart failure patients. However, our sample size was modest and further research is needed to confirm these findings.

Keywords Health inequality, Geographical distance, Telehealth

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Background

Geographical inequity in access to and benefit of health care services has always been a challenge for modern health care systems. The cause of inequity is multifactorial, with complex socioeconomic and cultural factors contributing to disparities in health care. Part of this relationship is the practical barrier caused by distance to the treatment center, and routine care visits might require a significant investment of time and money for a rural resident [1]. This is well documented in an American context [1, 2], but geographically linked inequity in health is observed even in geographically small countries with universal healthcare, such as Denmark [3].

Chronic heart failure is a disease with significant inequities in both incidence and prognosis [4–6]. This includes geographical inequities. A study found evidence of geographical clusters of acute myocardial infarctions [3], a common precursor to chronic heart failure [7]. Another study found a strong correlation between proximity to the treatment center and the odds of receiving proper cardiac revascularization treatment [8].

With the advance of telemedicine as a potent tool in combating the rising costs of healthcare services for chronic diseases, such as chronic heart failure [9, 10]. Telemedicine has been suggested as a geographical equalizer, with the potential to decrease the geographical inequities of traditional healthcare services [1, 11]. This makes intuitive sense, as telemedicine can be delivered independently of the distance between carer and patient. However, many health services are still reliant on physical proximity, such as physical exams and surgery, and there is some doubt regarding whether patients can accurately be assessed in a telemedicine setting [12]. Inadvertently, telemedicine might even exacerbate existing inequities [13], and socioeconomic factors such as age, area-level income and race appear to be barriers to access to telemedicine interventions for patients with cardiovascular disease [14].

In a randomized controlled trial, an add-on telemedicine intervention (Telecare Nord Heart Failure) has proven successful in reducing health care costs [15] and improving mental health [16]. However, it is unclear whether supplementary telemedicine interventions, such as Telecare Nord Heart Failure, have an impact on the health disparity between urban and rural residents. Few studies have investigated telemedicine outside of the urban setting [17], and it is necessary to investigate whether telemedicine is successful in reducing the health inequity of rural populations.

The objective of this study is to investigate whether supplementary telemedicine is associated with a decrease in geographical health inequity for chronic heart failure patients.

Methods

Study design

Our aim is to investigate the presence and magnitude of a geospatial interaction effect on the health benefit of a supplementary telemedicine intervention by analyzing the relationship between distance to a regular place of treatment and the benefit of telemedicine in a secondary analysis of data from a previously conducted RCT. This study attempts to address the question of whether telemedicine is feasible as an approach to combat geographical inequity in healthcare.We used data from the Telenord Heart Failure study, where an RCT was conducted with chronic heart failure patients randomized to either usual care or a supplementary telemedicine intervention in addition to normal care. The TeleCare North Heart Failure trial aimed to evaluate the health effects and the economic impact of a supplementary telemedicine solution for chronic heart failure patients with 12 months of follow-up. The telemedicine intervention featured at-home measurements of biometric data, such as pulse, weight and blood pressure. These measurements were evaluated on a weekly basis by health care practitioners, with the hope that continuous measurements would allow a timelier response to any ongoing health deterioration. The original trial included 299 patients, 145 patients allocated to the supplementary intervention and 154 controls from the Region of Northern Denmark.

There is reason to believe that geographical inequity to healthcare access is a concern in the Region of Northern Denmark, as the Region has difficulties recruiting medical staff, including general practioners to most remote areas of the Region [18].

Patients were presented with a survey at enrollment and at the 1-year follow-up, including items related to socioeconomic status, general health questionnaires and disease-specific items. Patients were referred to the trial by the health care practitioner responsible for management of their chronic heart failure, either a collaborating hospital department specializing in heart failure (Aalborg, Hjørring or Thisted Hospital) or their general practitioner.

The full details of the RCT and the health and health economic effects of the intervention have been reported elsewhere [15, 16, 19].

Participants and setting

In this study, we included survey data from 168 patients (84 intervention and 84 controls), who had full follow-up on all of our primary endpoints. The per protocol follow-up time was 1 year, with patient enrollment starting in August 2016.

We include data from related general health questionnaires (EQ5D5L, SF-36) [20, 21]and several items pertaining to socioeconomic and health status described in the variables section. In addition the home address of the patient and the address of the managing health care practitioner, were used to calculate the geographical distance to treatment.

Patient characteristics are reported in the results section.

Variables

Dependent variable

A total of three different self-reported measures of health are used as the outcomes in this study.

Change in EQ5D health state utility, measured as the difference in momentaneous health utility between EQ5D-5 L survey administered at baseline and at the 1-year follow-up. The Danish EQ5D5L scoring was used to calculate the utility score at both points [22]. Scoring of the EQ5D5L questionnaire results in a health utility score between 0 and 1, with 1 indicating perfect health and 0 indicating death. In rare cases, scores less than 0 are seen, indicating a health state worse than death.

Change in Physical Component Score, measured as the difference in physical component summary score between baseline and 1-year follow-up, derived from the SF-36 health questionnaire, using the quality metrics proprietary scoring algorithm with Danish population weights [21]. Scoring of the physical component score results in a score between 0 and 100, with 100 indicating perfect physical health.

Change in Mental Component Score, measured as the difference in mental component summary score between baseline and 1-year follow-up, derived from the SF-36 health questionnaire, using the quality metrics proprietary scoring algorithm with Danish population weights [21]. Scoring of the mental component score results in a score between 0 and 100, with 100 indicating perfect mental health.

Each outcome was tested independently throughout the analysis.

Independent variables

Distance from center of treatment The main interest of this study is investigating the interaction between having a long distance to a regular place of treatment and the benefit of telemedicine. Distance was measured as the distance by car between the patient's home and the treatment provider responsible for the referral to the telemedicine provider and was subsequently grouped into 2 groups, regular and long distance, with long distance defined as the 4th quartile of distance (>40.2 km). The distance by car was collected through a google maps api using the ggmap package [23].

Intervention group As the data are derived from an RCT, patients are assigned to either supplementary telemedicine or control (treatment as usual). For the purposes of this study, the analysis was conducted as a complete case analysis, with patients being labeled in accordance with the initial randomization.

Baseline health utility. In the adjusted analysis, the health utility score at baseline is included for the corresponding change in value, i.e. EQ5D5L health utility at baseline is included for the model investigating change in EQ5D5DL health utility.

Age In the adjusted analysis, patient age is included. Age is defined as the age of the patient at enrollment in the study, calculated from the birth date and date of completion of the baseline survey. For a single patient, an error resulted in the loss of the original completion date. For this patient, age was defined as the mean of the population.

NYHA class In the adjusted analysis, patient NYHA class was included. The NYHA class is defined as the NYHA class of the patient at enrollment in the study, based upon self-reported status in the baseline survey.

Comorbidity In the adjusted analysis, the presence of comorbidity is included. Comorbidity is defined as a binary variable indicating the presence of one or more self-reported comorbidities at enrollment in the study. Self-reported comorbidities included various cancers, diabetes, arthritis and other non-communicable diseases.

Gender Gender was included in the adjusted analysis. Gender was defined by the civil national registry number of the patient.

Marital status Self-reported marital status was included in the adjusted analysis, and the available response categories were married/registered partnership, cohabiting, partner without cohabitation, single, divorced, and widowed. The responses were recoded into "In a relationship" and "Single" for the first and last three responses, respectively, before inclusion in the analysis.

Employment status Self-reported employment status was included in the adjusted analysis, and the available response categories were full-time employment, part-time employment, leave of absence, student, sick leave, retired, and unemployed but looking for employment. Responses were recategorized into "employed" for responses 1 and

2, "unemployed" for responses 3, 4, 5 and 7, and "retired" for response 6.

Social Ladder Self-reported social/societal status was included in the adjusted analysis. Patients were asked to assess their social status on a scale of 1–10, with 10 indicating the societal top and 1 indicating the lowest position in society.

Table 1 Patient characteristics stratified by treatment group

Table of Patient Characteristics			
Variable	**Intervention**	**Control**	**p value**
n	**84**	**84**	
Dependent Variables			
Change in EQ5D health utility score (mean (SD))	0.03 (0.19)	-0.01 (0.22)	0.257
Change in SF-36 PCS (mean (SD))	-0.01 (7.75)	1.41 (6.47)	0.200
Change in SF-36 MCS (mean (SD))	2.65 (9.28)	-0.99 (10.25)	0.017
Primary Independent variable			
Distance = Long (> 40.2 km) (%)	20 (23.8)	19 (22.6)	1.000
Distance in km (mean (SD))	25.41 (20.56)	30.42 (25.80)	0.166
Health utility baseline			
EQ5D5L	0.80 (0.21)	0.79 (0.22)	0.643
SF-36 Physical component score	41.03 (8.99)	40.49 (9.65)	0.706
SF-36 Mental component score	48.36 (9.88)	49.44 (11.42)	0.514
Sociodemographic variables			
Gender = Male (%)	69 (82.1)	67 (79.8)	0.844
Age (mean (SD))	68.99 (9.34)	67.76 (10.32)	0.421
NYHA class (%)			0.912
1	7 (8.3)	6 (7.1)	
2	44 (52.4)	44 (52.4)	
3	24 (28.6)	28 (33.3)	
4	6 (7.1)	4 (4.8)	
Missing	3 (3.6)	2 (2.4)	
Present Comorbidity (%)	46 (54.8)	46 (54.8)	1.000
Weight at baseline (mean (SD))	85.39 (17.15)	86.55 (19.32)	0.681
Marital status (%)			0.059
In a Relationship	65 (77.4)	53 (63.1)	
Single	18 (21.4)	31 (36.9)	
Missing	1 (1.2)	0 (0.0)	
Social ladder score (mean (SD))	5.93 (1.48)	5.99 (1.76)	0.811
Employment status (%)			0.204
Employed	9 (10.7)	16 (19.0)	
Unemployed	9 (10.7)	6 (7.1)	
Retired	64 (76.2)	62 (73.8)	
Missing	2 (2.4)	0 (0.0)	

Weight Self-reported weight at baseline was included in the adjusted analysis.

Handling of numerical and categorical variables

Numerical (continuous) variables were included in the analysis without further modification.

All categorical variables were dummy coded with 1 indicating the presence of the category for use in the analysis.

Baseline characteristics

Table 1 compares the baseline characteristics between the treatment group and the control group. For categorical variables a chi-square test with continuity correction was used to assess significance and for numerical variables a t-test was used.

Main analysis

To evaluate the presence and strength of an interaction effect between the benefit of telemedicine and distance to the usual treatment center, we used a linear regression framework with an interaction term. For the unadjusted models, the intervention group, distance quartile and intervention*distance group interaction term were included as independent variables. For the adjusted analysis, age, NYHA class, comorbidity, marital status, employment status, social ladder and baseline weight were included as potential confounders. The unadjusted and adjusted coefficient estimates, confidence intervals and p values are reported in Tables 2 and 3, respectively.

Model assumptions

To ensure that the assumptions of linear regression were not violated, diagnostic plots of the residual errors of the models were generated with the ggfortify package [24] and inspected. Residual vs. fitted plots were evaluated to assess linearity, Q–Q plots were evaluated to assess the distribution of errors, and scale-location plots were evaluated for homoscedasticity. As the unadjusted models contained only categorical predictors, the Levene test of homogeneity of variance was used to evaluate homoscedasticity for these models. The results of the visual inspection of the diagnostic plots are reported in the results section, and the full plots and results of the Levene test are shown in appendix 1.

Interaction effect interpretation

Coefficients and p values for individual interaction terms are presented in Tables 2 and 3 for the adjusted and unadjusted analyses, respectively. However, p values for individual terms are inappropriate for assessing evidence of interaction when the interaction has more than one term [25]. To assess whether the models show evidence of interaction, a likelihood ratio test is performed

Table 2 Coefficients from a linear regression model with a distance-intervention term included. Unadjusted

id	Term	estimate	std.error	*p*.value
EQ5D				
	(Intercept)	0.030	0.025	0.221
	Patient group = Intervention	-0.004	0.035	0.904
	Distance group = Long	-0.176	0.052	0.001
	Interaction between Distance = Long and Patient group = intervention	0.178	0.073	0.016
PCS				
	(Intercept)	1.92	0.885	0.031
	Patient group = Intervention	-2.37	1.256	0.061
	Distance group = Long	-2.27	1.860	0.224
	Interaction between Distance = Long and Patient group = intervention	4.09	2.607	0.118
MCS				
	(Intercept)	0.486	1.19	0.684
	Patient group = Intervention	1.601	1.69	0.346
	Distance group = Long	-6.509	2.51	0.010
	Interaction between Distance = Long and Patient group = intervention	8.868	3.51	0.013

between models with an interaction term and their respective nested model without, and a p value of < 0.05 indicates a significant interaction.

Missing data

We included only patients with complete follow-up on each of the three outcomes: EQ5D, PCS and MCS health scores for this analysis. Patients with follow-up data for only one or two of the health scores were excluded from this study, to maintain a consistent cohort in all analysis. A small number of patients ($n = 7$) had missing values in one or more of the categorical variables used in the adjusted analysis. The missing values were mode imputed for the analysis and reported as NA in Table 1.

In appendix 1, table comparing baseline characteristics between included and missing patients by patient group is available. Of note, age differs significantly between those included and those missing, with the missing group having a slightly lower age on average. Additionally, baseline MCS and EQ5D scores differ at baseline, with excluded patients having a slightly lower score in both categories. Baseline health scores and age are included as potential confounders in the adjusted models.

Statistical software

All analyses and data management were conducted in R (R version 4.2.1 [26]), using RStudio IDE (RStudio 2023.06.0 + 421 "Mountain Hydrangea" [27], .

Table 3 Coefficients from a linear regression model with a distance-intervention term included. Adjusted for age, gender, NYHA class, Comorbidity, Weight, Relationship status, Social status, and employment status

id	Term	estimate	std.error	*p*.value
EQ5D – Adjusted				
	(Intercept)	0.460	0.170	0.008
	Patient group = Intervention	0.010	0.034	0.773
	Distance group = Long	-0.188	0.050	< 0.001
	Interaction between Distance = Long and Patient group = intervention	0.184	0.069	0.009
PCS – Adjusted				
	(Intercept)	14.63	6.96	0.037
	Patient group = Intervention	-2.04	1.24	0.101
	Distance group = Long	-2.63	1.82	0.151
	Interaction between Distance = Long and Patient group = intervention	4.32	2.54	0.092
MCS – Adjusted				
	(Intercept)	24.15	7.58	0.002
	Patient group = Intervention	1.69	1.57	0.284
	Distance group = Long	-5.92	2.33	0.012
	Interaction between Distance = Long and Patient group = intervention	5.95	3.28	0.072

The "Tidyverse" package compilation (version 1.3.2 [28]), was used for data management and related tasks. The "Tidymodels" package was used to specify and implement the regression models (version 1.00 [29]), . Additional packages were used for various tasks related to visualization of the data and models [24, 30, 31].

Ethical disclosure and reporting guidelines

The Telecare Nord Heart Failure project has been assessed by The North Denmark Region Committee on Health Research Ethics (http://www.rn.dk/sundhed/til-sundhedsfaglige- og-samarbejdspartnere/forskning/den-videnskabsetiske- komite-for-region-nordjylland), which concluded that the project did not require ethical approval.

This study is reported in accordance with STROBE guidelines on the reporting of observational studies [32].

Results

Our analysis includes data from 168 patients that participated in the Telecare Nord Heart Failure randomized controlled trial [16, 19]. Of the original 299 patients that participated in the trial, 131 were excluded in this analysis due to missing follow-up on one or more of the primary endpoints. No significant differences in baseline characteristics were observed between the patient group randomized to supplementary telemedicine and the patient group randomized to treatment as usual. For two of the primary endpoints, EQ5D health utility score and the physical component summary score of the SF-36, no significant difference in change in health status was observed. However, the change in the mental component summary score of the SF-36 differed significantly between the two groups, with the intervention groups showing a slight increase of 2.65 points, while a slight decline of -0.99 points was observed in the control group.

All regression models reported in the following section were evaluated for accordance with the assumptions of a linear regression. No departures from these assumptions were observed in residual vs. fitted and QQ plots. The plots are available in appendix 1.

Table 2 shows the results of the unadjusted regression analysis. When examining the effect of long distance on EQ5D, we see that the main effect of long distance is associated with a significant decline in the health utility score of -0.176 ($p=0.001$), and we also see that the coefficient of the interaction term is significant with an increase of 0.178 ($p=0.016$). Similar results are seen when examining the change in MCS, where the long distance main effects are associated with a significant −6.509 ($p=0.010$) decrease in MCS and the interaction term is associated with a significant 8.804 ($p=0.013$) increase in MCS. The pattern is similar when examining PCS, with a main effects estimate of -2.27 ($p=0.224$) and an interaction term estimate of 4.09 ($p=0.118$); however, the terms do not reach significance.

Table 3 shows the results of the adjusted regression analysis. We see the same trends as in the unadjusted analysis, with main effect coefficient estimates of -0.188 ($p<0.001$), -2.63 ($p=0.151$) and −5.92 ($p=0.012$) for changes in EQ5D, PCS and MCS scores, respectively. The adjusted interaction terms are 0.184 ($p=0.009$), 4.32 ($p=0.092$) and 5.95 ($p=0.072$) for EQ5D, PCS and MCS, respectively. Similar to the unadjusted analysis, the PCS coefficient estimates fail to reach significance. In addition, the interaction term in the adjusted model for change in MCS falls just short of significance. The presence of potential interaction effects are visualized in Fig. 1, which shows a box plot of the observed changes in health utility score, stratified by patient and distance group.

Table 4 shows the results of the log-likelihood ratio test. When examining the change in EQ5D health utility, both the unadjusted and adjusted models show significant improvement ($p=0.014$ and $p=0.006$, respectively) with the addition of an interaction term between intervention and long distance. This is also true for the unadjusted MCS model, with a p value of 0.011, however the adjusted p value of 0.072 is not statistically significant. The significant improvement in log-likelihood for the EQ5D models suggests the presence of long distance effect modification for the general health and mental health effects of the telemedicine intervention. For the adjusted MCS model and both PCS models, the models with interaction terms were not significantly better than the main effects only models, suggesting no evidence of long distance effect modification physical health and the telemedicine intervention.

Discussion

Our aim was to investigate the relationship between distance to the treatment center and the benefit of telemedicine, measured as changes in the EQ5D-5 L health utility score, SF-36 physical component score and SF-36 mental component score. Our results indicate that distance to the treatment center has a significant interaction with the telemedicine intervention when assessing the change in EQ5D, with an estimated effect size of the interaction term of 0.184. This could indicate that receiving the telemedicine intervention in large parts negates the negative effects of having a long distance to your care provider, which is estimated to -0.188 in our adjusted model. No evidence of interaction was found when examining changes in PCS, while the findings for MCS depended on the model. The adjusted MCS model fails to reach significance, which might indicate no interaction or an insufficient sample size. Despite no being significant, the effect size of the interaction term is estimated to 5.95 points, with the negative effect of long distance estimated to -5.92 points, which similarly to the EQ5D analysis, shows that telemedicine might mitigate the negative health effects of the long distance group.

Our results support that supplementary telemedicine might be a potent tool in combating geographical inequities related to distance for chronic heart failure patients. As the intervention examined was supplementary to usual care, our results do not elucidate whether this holds true for telemedicine as a standalone treatment.

While our results show that telemedicine is effective in diminishing an observed negative correlation between long distance to treatment and health scores for chronic heart failure, it is not necessarily clear why this effect occurs. Telemedicine reduces distance as a barrier for seeking treatment [11, 12], but other studies have shown that telemedicine might reduce hospitalizations

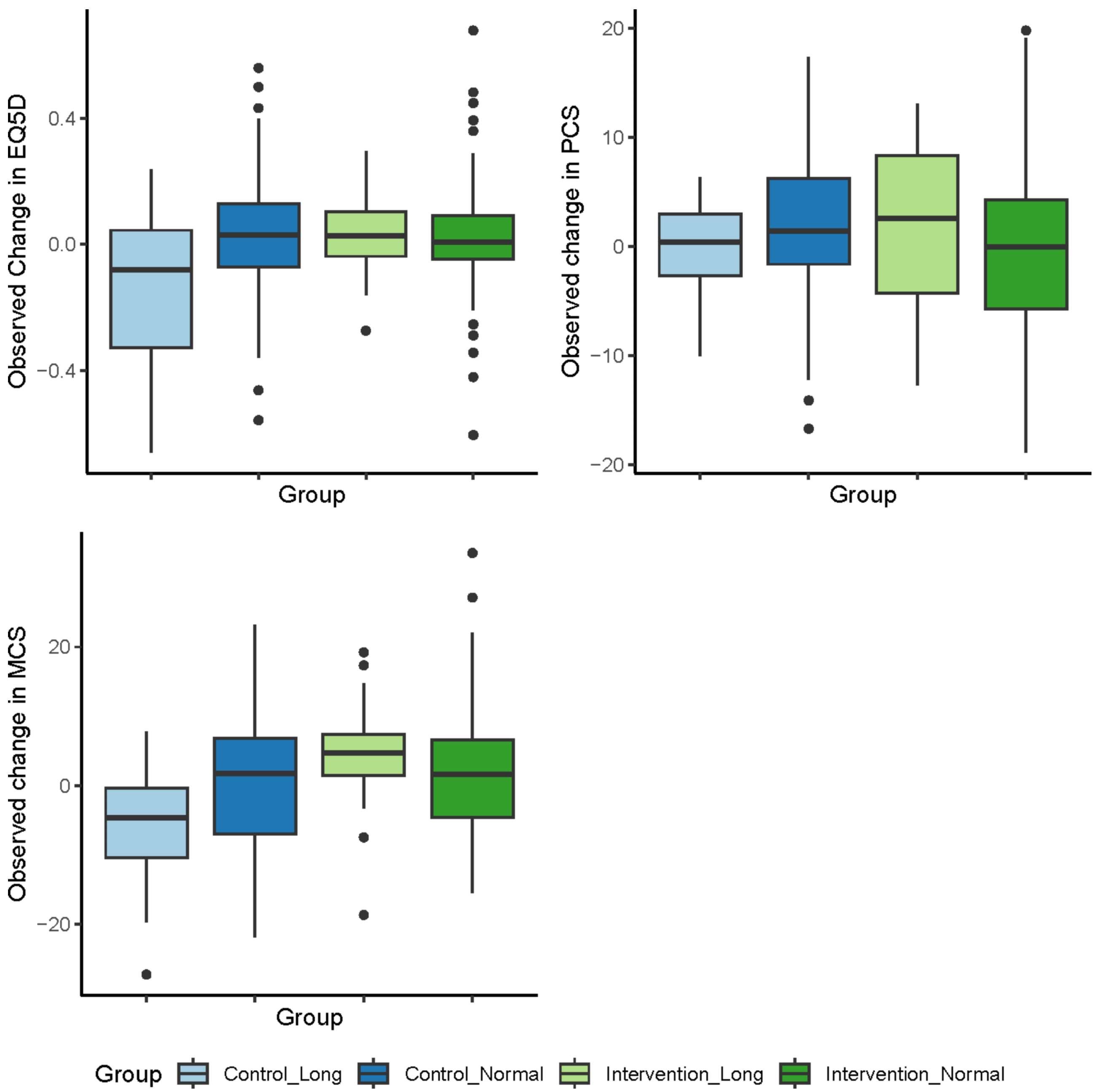

Fig. 1 Boxplot of observed change in the health utility score between baseline and one-year follow-up, stratified by patient and distance group

Table 4 Results of the log-likelihood ratio test

Term	LogLikelihood with interaction	Loglikelihood without interaction	*p*.value
EQ5D			
Unadjusted Model	34.6	31.6	0.014
Adjusted Model	53.6	49.8	0.006
PCS			
Unadjusted Model	-566	-568	0.113
Adjusted Model	-545	-546	0.076
MCS			
Unadjusted Model	-617	-620	0.011
Adjusted Model	-584	-586	0.058

among chronic heart failure patients [15], suggesting that telemedicine might help prevent deterioration of heart disease.

Comparison with prior work

To our knowledge, this is the first study investigating the interaction effects between distance to a treatment center and receiving a telemedicine intervention. However, previous research has investigated the relationship between digital treatment technologies and socioeconomic factors.

A review by Turnbull et al., 2020 found evidence of socioeconomic factors modifying the effects of web-based self-care interventions for 4 types of chronic illness [33], while our study investigated telemedicine as opposed to a web-based intervention. Some of the potential mechanisms for the propagation of inequities, such as health literacy, technological affinity and barriers to accessing conventional treatment, might be similar. Turnbull et al. conclude that proper implementation of web-based interventions can prove advantageous in the treatment of traditionally underserved populations.

The recent COVID-19 pandemic has accelerated adaptation and research into telemedicine interventions. One study investigating the differences in the characteristics of patients using telemedicine versus conventional care during the lockdown period found that sociodemographic characteristics differed significantly between groups [34]. They found that being younger, married, woman, Hispanic and more factors were all associated with increased odds of receiving telemedicine, which is evidence that the adaptation of telemedicine among vulnerable groups can be low.

Our study provides some evidence that telemedicine can mitigate the effects of geographical barriers to treatment, but care must be taken in the development and evaluation of interventions to ensure their accessibility and adaptation among disadvantaged populations.

Strengths and limitations

Our analysis is consistent across unadjusted and adjusted models, where we have tried to include the most prominent socioeconomic markers, indicating that the observed evidence of significant interaction is unlikely to be an artifact due to residual socioeconomic confounding.

This study is a secondary analysis of data gathered during a previously published RCT [16] with a modest sample size. However, despite the sample size being small, our results are consistent and, in the case of change in EQ5D, significant across unadjusted and adjusted models, indicating that lack of statistical strength is unlikely to be an issue in our analysis.

The origin of the data means that our analysis risks being impacted by any significant bias in the original RCT. Initial treatment allocation was through randomization, which should minimize any differences in confounders between the patient groups at baseline [25]. However, there is a risk of differential dropout between the two treatment arms, with patients experiencing little, no, or even adverse effects from the telemedicine intervention choosing to leave the study. In our complete case analysis, similar dropout rates were observed in the two treatment arms, indicating no difference in dropout. While equal dropout rates in both groups do not preclude nonrandom mechanisms of dropout from causing bias [35], the complete case intervention and complete case control groups were similar at baseline, which indicates that the dropout mechanisms were similar between the groups. In addition, when comparing the dropout population with the complete case group (appendix 1), only the age and baseline MCS and EQ5D5L of the two groups differed significantly at baseline. No evidence of differential dropout due to distance is apparent in the data. While we cannot preclude any residual bias, we believe that our finding of significant interaction is valid, but care should be taken when assessing the strength of the effect, as complete case analysis might bias the effect size if the data do not satisfy the missing completely random conditions [35].

In this study, we used changes in EQ5D5L and SF-36 health utility scores to measure the effect of the treatment. While no consensus exists on what constitutes the minimal clinically important differences (MCID) for the health utility scores, the MCID of SF-36 has been suggested to be 5-points [36] and the MCID of EQ5D5L to be 0.19 [37]. Our results indicate that the inequity in health outcomes due to geographical distance exceeds this threshold, however caution is advised when interpreting the estimated effects sizes, due to the small sample size of our study.

For our analysis we chose to dichotomize the distance variable, we chose this approach based on an expectation of a non-linear relationship between geographical distance and health effect. However, it is possible that an analysis using continuous distance measurements, might provide additional insights into the relationship between geographical distance and telemedicine.

While our analysis is conducted on RCT data and could be representative of experimental conditions, rather than a real-world setting, it is important to note that the intervention arm of the RCT was developed to mirror the subsequent real-world implementation of telemedicine for chronic heart failure patients in the Region of Northern Denmark. This makes it unlikely that our findings are confined to the experimental setting.

In this study, we chose to evaluate three different measures of self-reported health, leading to three main results. We find that the interaction effect of distance to the treatment center is confined to mental and general health and not physical health, and our analysis does not indicate why this is the case. One contributing factor could be specific mental health benefits of telemedicine; a qualitative investigation found that monitoring patient disease through telemedicine can increase the feeling of safety and trust of the patients [38]. Chronic heart failure is associated with significantly lower mental health, and while the causality is likely to be multifactorial [39], stressful experiences as a chronic disease patient might play an important role in the relationship, which might be mitigated in part by telemedicine intervention. Future studies should investigate patients' perceived experience of receiving telemedicine, as the increased feelings of safety and comfort associated with telemedicine might be important in preserving the mental health of remote patients.

Implications

Although distances in a single Region of Denmark are comparatively small, we see a significant interaction between distance and treatment effect. Further research should be conducted on whether the same or perhaps an even stronger association is observed in more rural populations.

Our findings indicate that monitoring patients within a telemedicine framework can be an appropriate tool in delivering high-quality care to remote patients with chronic heart failure. This patient group is a traditionally underserved and vulnerable population, where telemedicine might contribute to reducing health inequities imposed by geographical barriers, particularly barriers related to the distance to treatment.

Conclusion

We found evidence of a statistically significant interaction between the effects of supplementary telemedicine and the patient's travel distance to regular treatment. In our study, belonging to the 4th quartile in distance to treatment center group was associated with decreased general health utility and mental health component scores for the regular treatment group; however, this association was mitigated in the supplementary telemedicine group, indicating that telemedicine counteracts the negative effects of long distance.

Limitations

However, the generalizability of our findings are potentially limited by the small sample size and geographical setting of our sample. Further research should be conducted on the suggested benefits of telemedicine in regard to geographical inequity, with an emphasis on the impact of different geographical settings.

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12889-024-20438-4.

Supplementary Material 1

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Author contributions

AAPX conceptualized the study, conducted the analysis and wrote the first draft of the manuscript. SLC provided the data and contributed to data management. OH, SLC and FWU contributed to the design of the study, helped interpret the results of the analysis and provided literature and perspectives to the background and discussion sections. All authors read and approved the final manuscript.

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Data availability

The data that support the findings of this study are not publicly available, as they contain sensitive patient information and access requires approval from the North Denmark Region. Researchers interested in the data may contact the corresponding author for guidance.

Declarations

Ethics approval and consent to participate

According to national law in Denmark, all healthcare research involving patient data much be assessed by the regional ethics committee. This study is conducted as a secondary analysis of data collected in the Telecare Nord Heart Failure Randomized Controlled Trial (ClinicalTrials.gov, (NCT02860013, registered August 4th, 2016)), the trial protocol was assessed by The North Denmark Region Committee on Health Research Ethics (http://www.rn.dk/sundhed/til-sundhedsfaglige- og-samarbejdspartnere/forskning/den-videnskabsetiske- komite-for-region-nordjylland), and the project was assessed as not requiring further ethical approval according to Danish law [40].

Consent for publication

Not applicable.

Informed consent

Informed consent was obtained for all subjects participating in the study.

Competing Interests

The authors declare no competing interests.

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