




# The Health Diary Telemonitoring and Hospital-Based Home Care Improve Quality of Life Among Elderly Multimorbid COPD and Chronic Heart Failure Subjects

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**Background:** Elderly, multimorbid patients with advanced chronic obstructive pulmonary disease (COPD) and/or chronic heart failure (CHF) exhibit poor health-related quality of life (HRQoL). Telemonitoring, based on digital pen technology, supported by hospital-based home care (HBHC) significantly reduces the number of hospitalizations. We hypothesized that the same intervention would prevent the deterioration of HRQoL that follows upon disease progression.

**Methods:** Elderly computer-illiterate subjects with  $\geq 2$  hospitalizations the previous year were included. HRQoL was assessed at inclusion (baseline) and at 1, 6 and 12 months employing EuroQol-5 Dimensions (EQ-5D) and RAND-36 for general HRQoL, and Minnesota Living with Heart Failure Questionnaire (MLHFQ) and St. Georges Respiratory Questionnaire (SGRQ) for disease-specific HRQoL. Healthcare contacts, hospitalizations, as-needed medications, prescription changes and healthcare costs were registered.

**Results:** Ninety-four patients were enrolled of which 53 subjects completed the 12-month study period. Compared to baseline, most domains of RAND-36 were improved significantly at 1 time-point or more. Only among COPD subjects, the disease-specific HRQoL was worsened at the 12 month evaluation. Measures of healthcare dependency were associated with poor HRQoL.

**Conclusion:** The Health Diary system and HBHC together improve general HRQoL, and measures of healthcare dependency are associated with HRQoL variables.

**Keywords:** digital pen, exacerbation, home care services, hospital-based, hospitalization, multimorbidity, telemedicine, QoL

## Introduction

Both chronic obstructive pulmonary disease (COPD) and chronic heart failure (CHF) are progressive diseases characterized by organ failure and frequent hospitalizations at end-stage diseases.<sup>1,2</sup> As both diseases are associated with significant co-morbidity,<sup>3</sup> they also commonly co-exist.<sup>4</sup> Symptom distress due to COPD or CHF is associated with poor health-related quality of life (HRQoL).<sup>5,6</sup> Deterioration of HRQoL occurs over time as the diseases progress.<sup>7,8</sup> At end-stage diseases, subjects with COPD and CHF typically experience impaired functioning and impaired HRQoL.<sup>9,10</sup> Janssen et al compared subjects with advanced COPD or CHF in a 12-month longitudinal study.<sup>11</sup> Impaired HRQoL correlated with physical

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and psychological symptoms, care dependency and number of drugs, while age, gender, disease severity and comorbidities did not.<sup>11</sup>

The effects of telemonitoring on HRQoL have been evaluated among subjects with COPD and CHF with varying success.<sup>12,13</sup> One meta-analysis reports inconsistent findings on the positive impact of telehealthcare on HRQoL measures among CHF subjects.<sup>13</sup> Indeed, a recent study by Cichosz et al demonstrated that only the short form (SF)-36 questionnaire Mental Component Summary score was significantly higher among CHF subjects in the telehealthcare group compared to the control group during the 12-month follow-up.<sup>14</sup> In that study, the Kansas City Cardiomyopathy Questionnaire (KCCQ) was used to assess the disease-specific HRQoL, which did not differ between the two groups of CHF subjects.<sup>14</sup> As for subjects with COPD, Lilholt et al recently reported no statistically significant differences in general HRQoL, assessed by Short Form 36-Item Health Survey, between telehealthcare and usual practice.<sup>15</sup> The review and meta-analysis by McLean et al indicated a possible impact of telehealthcare on the HRQoL of COPD subjects.<sup>16</sup> Moreover, a review by Cruz et al indicated inconsistency in HRQoL findings, but most of the studies reported no significant changes in HRQoL.<sup>17</sup> Possibly, the inconsistent results reported were due to the different HRQoL instruments employed.<sup>16,17</sup>

We have recently reported on the eHealth Diary study, which is a 12-month longitudinal telemonitoring study.<sup>18,19</sup> Elderly, multimorbid subjects, the majority computer illiterate with advanced stages of CHF and COPD, were included.<sup>18,19</sup> Clinical features, such as disease severity, as well as number of hospitalizations, healthcare contacts and ensuing healthcare costs were registered during an intervention of telemonitoring, employing digital pen technology, combined with healthcare provided by a hospital-based home-care (HBHC) unit.<sup>18,19</sup> Subjects were very ill and death was the major cause for not finalizing the study; the death rate was 36% and 28% among COPD and CHF subjects, respectively.<sup>18</sup> Compared to the 12-month prior inclusion, the intervention significantly reduced number of hospitalization.<sup>18</sup> Accordingly, costs associated with hospitalizations were significantly reduced for both CHF and COPD subjects.<sup>19</sup>

The present study is an intervention non-randomized single-center clinical study compared with expected outcomes. We hypothesized that an intervention, consisting of the Health Diary telemonitoring system supported by

HBHC, would at least maintain HRQoL among the elderly, multimorbid subjects included. Thus, we thought the intervention would to some extent compensate for the expected loss of HRQoL when advanced stage of disease progress into end-stage disease and ultimately death. Moreover, we also hypothesized that measures of healthcare dependency would be of great importance for the HRQoL displayed by these subjects. The primary aim was to assess HRQoL, general and disease-specific, during a 12-month intervention in the study population. Secondary aims were to evaluate the influence of measures of healthcare dependency on HRQoL or vice versa. Measures of healthcare dependency were the registered use of as-needed (pro re nata; P.R.N.) medications, the number of changes of prescribed medications, alarms and all healthcare contacts and related costs during the study period. For hospitalizations, we also included the number of those during the 1-yr prior inclusion.

## Materials and Methods

### Study Setting and Design

This study is part of the longitudinal study the eHealth Diary study that was performed at the HBHC unit, Linköping University Hospital. Thus, study settings and design are described in more detail elsewhere.<sup>18,19</sup>

Briefly, following written informed consent to participate in the study patients aged  $\geq 65$  years with  $\geq 2$  hospitalizations due to exacerbation for either COPD or CHF during the last 12 months were included in the study. The study lasted a 4-yr period (November 2013–December 2017) due to an inclusion period of 3 yrs and a planned study period of 12 months for each patient. Subjects participating in the eHealth Diary study received a multi-disciplinary healthcare of COPD and/or CHF provided by HBHC, but study subjects had to consult primary care or other care providers for health conditions not related to CHF or COPD or end-of-life care. Subjects reported their daily health status using a digital pen and a Health Diary paper form (green, yellow, blue), thereby providing the professional caregivers at HBHC, nurses and/or physicians supervising the system, with data signaling early signs of patients' deterioration. CHF subjects reported their health using the green and blue Health Diary forms, and the COPD subjects used the yellow and blue forms.<sup>18</sup> The Health Diary forms let the subjects report various symptoms, measurement values and intake of P.R.N. medication. Moreover, the subjects could write

free text messages on each form if desirable. Responsible physicians decided on individual ranges for all symptoms and measurements to be reported by the subjects and adjusted these whenever needed. If the reported values were below/above the limits, the system generated alarms. Besides showing these alarms as icons in the Health Diary system, more serious alarms, generated due to low oxygen saturation or an increased breathlessness, were additionally shown as Short Message Service (SMS; cellular phone text messaging) text messages in a mobile nurse phone. SMS alarms were also generated if a patient failed to send in a report or if the care providers forgot to check and sign the patient report in time (for more details, see Reference [18]).

Co-morbidities were documented at baseline and scored accordingly using the Charlson Co-morbidity index (CCI).

## Assessment of General and Disease-Specific Health-Related Quality of Life

All study subjects were asked to complete validated questionnaires reflecting general and disease-specific HRQoL at the time of inclusion (hereafter called “baseline”) and at 1, 6 and 12 months of the study period. The minimal clinically important difference (MCID) is defined as the cut-off for clinically meaningful changes.

For assessment of general HRQoL, two questionnaires were employed; EuroQol-5 Dimensions (EQ-5D)<sup>20</sup> and the RAND-36, the latter developed by the RAND company.<sup>21</sup> EQ-5D consists of five questions assessing mobility (EQ-5D1), self-care (EQ-5D2), usual activity (EQ-5D3), pain/discomfort (EQ-5D4) and anxiety/depression (EQ-5D5). For every question, the subject can choose either “no problems”, “some problems” or “extreme problems”. An index score is created; -0.59 is the worst and 1.0 is the best. Subjects are also requested to score their current health using a visual analogue scale (VAS), which ranges from 0 to 100 (0 = worst possible health; 100 = best possible health). The RAND-36 questionnaire is validated in previous studies.<sup>22</sup> It consists of 36 items, which are divided into eight domains assessing physical functioning (PF), role-physical (RP), bodily pain (BP), general health (GH), vitality (VT), social functioning (SF), role-emotional (RE) and mental health (MH). For each domain, scores range from 0, which is the worst, to 100 points, which is the best.

For assessment of disease-specific HRQoL among COPD and CHF subjects, the St. Georges Respiratory Questionnaire (SGRQ)<sup>23</sup> and the Minnesota Living with

Heart Failure Questionnaire (MLHFQ)<sup>24</sup> were employed, respectively. SGRQ consists of three domains (symptoms, activities, and impact), which together give a total score, ranging from 0 points, which is the best, to 100 points, which is the worst. MLHFQ consists of two domains [physical, which ranges from 0 points (the best) to 40 points (the worst), and emotional, which ranges from 0 points (the best) to 25 points (the worst)], which together give a total score, which ranges from 0 points, which is the best, to 105 points, which is the worst.

## Collection of Data on Healthcare Dependency

Every use of P.R.N. medication and every change of prescription were registered. Common P.R.N. medication, often used by COPD and/or CHF patients, was listed on the Health Diary forms for the subject to put a mark on, if taken. The listed P.R.N. medications were: “Extra inhalation”, “Cortisone”, “Antibiotics”, “Extra anxiolytics”, “Diuretics”, “Nitroglycerines” and “Other as needed medication”. For example, if a COPD subject was prescribed extra inhalation and anxiolytics for shortness of breath, he/she could decide to take these P.R.N. medications and report this via the Health Diary. For every study subject, data on healthcare contacts (hospitalization and outpatient) and direct healthcare costs were collected for one yr or to date of death or earlier exclusion. For hospitalizations, the number during the 1-yr period prior the study inclusion was also recorded. All uses of healthcare resources and costs were registered since COPD and CHF are systemic disorders, which may cause hospitalization for various reasons. By employing the unique 10-digit Swedish personal identity number, patient data were then linked to the Care Data Warehouse in Östergötland (CDW) and the Cost Per Patient database (CPP). The CDW registers all healthcare contacts (hospitalization, outpatient, and primary care) including both private care and public care, while CPP records costs for all contacts within the public care only. Types of healthcare contacts were hospitalization, physician visit, district nurse visit, registered nurse visit, and visit to nurse assistant. Less than 1% of contacts with missing costs were related to inpatient care. The contacts with health services were then divided into hospitalization, emergency care, primary care, other outpatient care, and care provided by the multi-disciplinary team of the HBHC unit.<sup>19</sup>

## Ethics

The study was approved by the Regional Ethical Review Board in Linköping, Sweden (no. 213/309-31) and was

registered at ISRCTN (ISRCTN34252610). The study was conducted in accordance with the Declaration of Helsinki, the guidelines of the International Conference on Harmonization of Good Clinical Practice (ICH-GCP), and the applicable Swedish laws. It was required that study subjects gave informed written consent before participation.

### Statistical Analysis

Subject's baseline characteristics and HRQoL are presented as means  $\pm$  1 S.D. (range) for continuous variables and percentage for categorical variables. The Student's *t*-test was used on continuous variables and the Chi-square test was used on categorical variables when comparing CHF and COPD subjects. Fisher's exact test was used on EQ-5D dimensions because of few numbers in each category. Because of repeated measures per subject (baseline, +1, +6 and +12 months), the Generalized Estimating Equations (GEE) method was used to assess HRQoL over time with baseline as reference. In all models, a normal distribution with an identity link was used and correlations were handled by an unstructured correlation matrix. Estimated marginal means for all time points were extracted from the GEE method and values for +1, +6 and +12 months were compared to baseline. Correlations between healthcare dependency variables and mean HRQoL values were calculated with Pearson's correlation coefficient (*r*). Healthcare dependency variables as well as baseline characteristics were further investigated against HRQoL using a backward elimination linear regression. The level of significance was 0.05 and all *p*-values were two-tailed. All analyses except for the Fisher's exact test were undertaken using SPSS version 25.0 (IBM Corp., Armonk, NY). Fisher's exact test was undertaken using R version 3.5.2 (R Core Team, Vienna, Austria).

## Results

### Health-Related QoL at Baseline

Compared to elderly multimorbid subjects with CHF as a major cause of hospitalizations, subjects with COPD as a major cause of hospitalizations were significantly younger and thinner and had significantly more pack-*yr*s tobacco and co-morbidities (Table 1). Subjects with COPD also exhibited significantly reduced lung function, reflected by lower FEV<sub>1</sub> as % of predicted and lower blood oxygenation (Table 1). Some COPD subjects even depended on LTOT (Table 1). Both diseases presented

with advanced stages, reflected by NYHA stage 3–4 and GOLD stage C-D (Table 1).

The major reason to stop study participation was death; 28% in the CHF group and 36% in the COPD group. Other reasons for not finalizing the study period were physical or cognitive deterioration or change of residency, mostly by moving to a nursing home.

Despite the described differences of clinical features, CHF and COPD subjects exhibited great similarity regarding their general HRQoL at baseline. Results are summarized in Table 2. Indeed, only the domain GH of the RAND-36 differed significantly (Table 2). Consequently, for further analysis of general HRQoL changes over time the two groups were analyzed as a single group.

### General and Disease-Specific Health-Related QoL Over Time

Compared to baseline, general HRQoL assessed for all subjects at +1, +6 and +12 months using EQ-5D and RAND-36 demonstrated a significant improvement of almost all variables at  $\geq 1$  time point (Table 3). Exceptions were the EQ-5D index and the RAND-36 domain PF, which did not deviate from baseline significantly at any time-point (Table 3). Although significant, the improvement of EQ-5D VAS did not reach the specified MCID, which is set to 8 points.<sup>25</sup> In contrast, all significant improvements of the RAND-36 domains were above the 3–5 points specified as the MCID of RAND-36.<sup>26</sup>

Disease-specific HRQoL among CHF subjects, assessed as the change of the MLHFQ score and emotional domain from baseline, was significantly improved at +1 month, and disease-specific HRQoL among COPD subjects, assessed as the change of the symptom domain of SGRQ from baseline, was also significantly improved at +1 month (Table 3). However, by time disease-specific HRQoL became worsened among the COPD subjects as reflected by significant deviations from baseline of the SGRQ domain activity and impact, which appeared at +12 months (Table 3). Although significant, the improvement of the MLHFQ score at +1 month did not reach the specified MCID, considered as 8.20<sup>27</sup> and neither did the significant improvement of the SGRQ symptom domain noted at +1 month (Table 3). In contrast, the worsening of the SGRQ domain activity and impact noted at +12 months did exceed the MCID limit set at 4 points (Table 3).<sup>28</sup>

**Table 1** Subject Characteristics

	All (n = 94)	CHF (n = 58)	COPD (n = 36)	P-value CHF vs COPD
Age	80 ± 8 (65–100)	83 ± 7 (65–100)	75 ± 6 (65–86)	<0.001
Women, n (%)	51 (54)	29 (50)	22 (61)	n.s.
Current smokers, n (%)	12 (13)	2 (3)	10 (29)	<0.001
Ex-smokers, n (%)	56 (60)	31 (54)	25 (71)	
Never smokers, n (%)	25 (27)	25 (43)	0 (0)	
Pack-year	19 ± 21 (0–100)	8 ± 13 (0–59)	38 ± 19 (1–100)	<0.001
BMI	26 ± 6 (12–43)	27 ± 5 (16–43)	24 ± 6 (12–41)	<0.01
SAT (%)	93 ± 5 (70–99)	95 ± 3 (82–99)	90 ± 6 (70–98)	<0.001
Subjects on LTOT, n (%)	7 (7)	0 (0)	7 (19)	
CCI, mean (SD)	4.3 (2.3)	4.9 (2.3)	3.4 (2.0)	<0.001
CCI, n (%)				
0–1	9 (10)	4 (7)	5 (14)	<0.001
2	13 (14)	4 (7)	9 (25)	
3	19 (20)	7 (12)	12 (33)	
≥4	53 (56)	43 (74)	10 (28)	
Subjects with COPD, n (%)	53 (56)	17 (29)	36 (100)	
FEV <sub>1</sub> (% predicted), COPD subjects only	46 ± 19 (13–96)	58 ± 18 (23–96)	39 ± 15 (13–79)	<0.001
GOLD stage, n (%)				
I-II	16 (30)	13 (76)	3 (8)	<0.001
III	10 (19)	3 (18)	7 (20)	
IV	27 (51)	1 (6)	26 (72)	
GOLD grade, n (%)				
A-B	7 (13)	6 (35)	1 (3)	<0.001
C	0 (0)	0 (0)	0 (0)	
D	46 (87)	11 (65)	35 (97)	
Subjects with CHF, n (%)	80 (85)	58 (100)	22 (61)	
NYHA-class, n (%)				
3	66 (82)	46 (79)	20 (91)	n.s.
4	14 (18)	12 (21)	2 (9)	

**Notes:** Results are presented as means ± 1 S.D. (range) for continuous variables and percentage for categorical variables. P-values are from Chi-square test and Student's t-test (unpaired).

**Abbreviations:** BMI, body mass index; CCI, Charlson Comorbidity Index; CHF, chronic heart failure; COPD, chronic obstructive pulmonary disease; FEV<sub>1</sub>, forced expiratory volume in one second; GOLD, Global Initiative for Chronic Obstructive Lung Disease; LTOT, long-term oxygen therapy; NYHA, New York Heart Association Functional Class; SAT, blood oxygen saturation; yrs, years; N.s., not significant (p-value ≥ 0.05).

## Healthcare Dependency

Advanced stage of the disease, and in many cases even end-stage disease resulting in death during the study period, was described in measures of healthcare dependency. Measures used to assess healthcare dependency and the results of these are presented for all subjects and the sub-groups CHF and COPD subjects in Table 4. Compared to CHF subjects, COPD subjects had significantly more prescription changes, home visits by a physician and total home care contacts executed by HBHC and more contacts with primary care (Table 4). During the 4 yr eHealth Diary study, the subjects

together reported a total of 74,923 assessed symptoms and measured physiological parameters. The number of reported symptoms and measurements that generated the more serious SMS alarms, due to certain values outside predetermined limits, was significantly higher among COPD subjects, as were all SMS alarms, including SMS alarms due to subjects missing their daily reports and care providers missing to sign incoming reports (Table 4). Moreover, COPD subjects demonstrated significantly greater costs regarding HBHC, primary care, other outpatient care and subsequently total costs as well (Table 4).

**Table 2** General HRQoL Assessed with EQ-5D and RAND-36 at Inclusion (Baseline)

	All (n = 89–92)	CHF (n = 56–58)	COPD (n = 33–34)	P-value CHF vs COPD
EQ-5D index	0.53 ± 0.30 (–0.24–1.00)	0.54 ± 0.30 (–0.18–1.00)	0.52 ± 0.31 (–0.24–1.00)	n.s.
EQ-5D VAS	50.3 ± 16.4 (0–90)	50.9 ± 16.5 (0–90)	49.4 ± 16.5 (10–80)	n.s.
EQ-5D1, mobility, n (%)				
• No problems	25 (27.2)	16 (27.6)	9 (26.5)	n.s.
• Some problems	67 (72.8)	42 (72.4)	25 (73.5)	n.s.
• Extreme problems	0 (0)	0 (0)	0 (0)	n.s.
EQ-5D2, self-care, n (%)				
• No problems	55 (59.8)	36 (62.1)	19 (55.9)	n.s.
• Some problems	34 (37.0)	20 (34.5)	14 (41.2)	n.s.
• Extreme problems	3 (3.3)	2 (3.4)	1 (2.9)	n.s.
EQ-5D3, usual activity, n (%)				
• No problems	34 (37.0)	24 (41.4)	10 (29.4)	n.s.
• Some problems	43 (46.7)	24 (41.4)	19 (55.9)	n.s.
• Extreme problems	15 (16.3)	10 (17.2)	5 (14.7)	n.s.
EQ-5D4, pain/discomfort, n (%)				
• No problems	19 (20.7)	12 (20.7)	7 (20.6)	n.s.
• Some problems	61 (66.3)	38 (65.5)	23 (67.6)	n.s.
• Extreme problems	12 (13.0)	8 (13.8)	4 (11.8)	n.s.
EQ-5D5, anxiety/depression, n (%)				
• No problems	37 (40.2)	27 (46.6)	10 (29.4)	n.s.
• Some problems	50 (54.3)	29 (50.0)	21 (61.8)	n.s.
• Extreme problems	5 (5.4)	2 (3.4)	3 (8.8)	n.s.
RAND-36				
• PF	20.7 ± 18.4 (0–95)	22.0 ± 19.5 (0–95)	18.4 ± 16.4 (0–50)	n.s.
• RP	10.8 ± 24.3 (0–100)	13.6 ± 27.2 (0–100)	6.1 ± 17.7 (0–75)	n.s.
• BP	55.4 ± 28.5 (10–100)	55.0 ± 29.9 (10–100)	56.1 ± 26.5 (10–100)	n.s.
• GH	38.2 ± 21.2 (0–85)	46.4 ± 19.3 (10–85)	24.2 ± 16.6 (0–65)	<0.001
• VT	41.4 ± 18.1 (0–90)	42.5 ± 18.8 (0–90)	39.4 ± 16.9 (0–70)	n.s.
• SF	51.6 ± 28.3 (0–100)	54.1 ± 28.5 (0–100)	47.4 ± 27.8 (0–100)	n.s.
• RE	40.4 ± 41.6 (0–100)	43.5 ± 43.1 (0–100)	35.4 ± 39.0 (0–100)	n.s.
• MH	60.4 ± 18.9 (20–96)	62.6 ± 18.0 (20–96)	56.8 ± 20.0 (20–96)	n.s.

**Notes:** Results are presented as means ± 1 S.D. (range) for continuous variables and percentage for categorical variables. P-values are from Fisher's exact test and Student's t-test (unpaired).

**Abbreviations:** BP, bodily pain; CHF, chronic heart failure; COPD, chronic obstructive pulmonary disease; GH, general health; HRQoL, health-related quality of life; MH, mental health; PF, physical functioning; RE, role-emotional; RP, role-physical; SF, social functioning; VT, vitality; N.s. = not significant (p-value ≥ 0.05).

## Extensive Healthcare Dependency Is Associated with Poor HRQoL

Next, we assessed correlations between measures of healthcare dependency and HRQoL variables (Table 5). Among all subjects, number of P.R.N medications per subject negatively correlated with the EQ-5D index. Likewise, number of HBHC home visits by physician and number of HBHC phone calls by curator per subject negatively correlated with the RAND-36 domains VT and MH, respectively. Among CHF subjects, number of

HBHC phone calls by nurse and number of HBHC phone calls by physician correlated positively with MLHFQ score and the emotional domain of MLHFQ, respectively. Among COPD subjects, number of HBHC home visits by physiotherapist correlated positively with SGRQ total score. All these correlations were significant when tested in a multivariable regression analysis (for details see below). Regarding all SMS alarms, Pearson's correlation coefficients were significant for the GH and RE domains of RAND-36, but these correlations were not

**Table 3** General and Disease-Specific HRQoL – Changes Over Time

	All					CHF					COPD				
	Baseline	+1 month	+6 months	+12 months		Baseline	+1 month	+6 months	+12 months		Baseline	+1 month	+6 months	+12 months	
EQ-5D index	0.53	0.57	0.53	0.46											
EQ-5D VAS	50.4	54.1*	50.7	53.0											
RAND-36															
• PF	20.7	20.8	20.4	18.6											
• RP	10.8	20.0*	22.4***	18.7											
• BP	55.4	62.2*	55.8	56.0											
• GH	38.2	42.6*	43.5*	42.0											
• VT	41.4	43.2	46.6*	42.6											
• SF	51.6	61.0***	60.3***	62.0***											
• RE	40.5	55.8*	57.4***	55.5*											
• MH	60.4	67.5***	69.4***	66.5*											
MLHFQ Score															
MLHFQ Physical					42.6	36.2*	39.3	40.3							
MLHFQ Emotional					20.4	19.4	21.9	21.2							
					9.0	7.5*	8.2	8.7							
SGRQ Symptom										57.2	50.9*	52.9	57.5		
SGRQ Activity										78.4	80.8	82.5	84.8***		
SGRQ Impact										46.6	49.2	47.4	50.9*		
SGRQ Total										59.4	58.9	58.9	62.7		

**Notes:** Results are presented as means. P-values are from GEE regression analysis. P-value vs baseline is indicated; \*p < 0.05; \*\*\*p < 0.001.

**Abbreviations:** BP, bodily pain; CHF, chronic heart failure; COPD, chronic obstructive pulmonary disease; GEE, Generalized Estimating Equations; GH, general health; HRQoL, health-related quality of life; MLHFQ, Minnesota Living with Heart Failure Questionnaire; MH, mental health; PF, physical functioning; RE, role-emotional; RP, role-physical; SF, social functioning; SGRQ, St. Georges Respiratory Questionnaire; VT, vitality.

**Table 4** Measures of Healthcare Dependency

	All Subjects (n = 94)	CHF (n = 58)	COPD (n = 36)	P-value CHF vs COPD
Hospitalizations (all causes) during the yr prior inclusion per subject (n)	3.2 ± 1.7 (2–10)	3.1 ± 1.5 (2–10)	3.4 ± 1.8 (2–9)	n.s.
Hospitalizations (all causes) during the study period per subject (n)	0.9 ± 1.4 (0–7)	0.8 ± 1.3 (0–7)	1.2 ± 1.5 (0–6)	n.s.
HBHC; use of P.R.N. medication per subject (n)	128.4 ± 235.3 (0–1329)	97.2 ± 178.6 (0–910)	178.6 ± 301.5 (0–1329)	n.s.
HBHC; changed prescriptions per subject (n)	8.5 ± 7.0 (0–39)	6.9 ± 4.3 (0–17)	10.9 ± 9.6 (0–39)	<0.01
HBHC; home care visits per subject (n)				
By physician per subject	9.2 ± 6.2 (1–32)	8.0 ± 4.5 (1–18)	11.2 ± 7.9 (1–32)	<0.01
By nurse per subject	33.7 ± 34.7 (2–251)	28.8 ± 18.8 (2–87)	41.6 ± 49.4 (2–251)	n.s.
By physiotherapist per subject	2.5 ± 2.6 (0–12)	2.3 ± 2.2 (0–9)	2.7 ± 3.2 (0–12)	n.s.
By dietician per subject	0.3 ± 0.7 (0–4)	0.2 ± 0.7 (0–4)	0.5 ± 0.8 (0–3)	n.s.
By curator per subject	0.4 ± 1.4 (0–9)	0.0 ± 0.1 (0–1)	0.9 ± 2.1 (0–9)	n.s.
HBHC; total home care contacts (home visits & phone calls) per subject (n)	77.7 ± 61.9 (3–334)	67.4 ± 38.0 (5–187)	94.4 ± 84.4 (3–334)	<0.05
Other healthcare contacts per subject (n)				
Emergency care	0.9 ± 1.4 (0–7)	0.8 ± 0.9 (0–4)	1.2 ± 1.9 (0–7)	n.s.
Primary care	10.4 ± 14.6 (0–85)	13.0 ± 15.6 (0–85)	6.4 ± 11.9 (0–46)	<0.05
Other outpatient care	4.7 ± 5.2 (0–22)	4.1 ± 4.6 (0–21)	5.6 ± 6.0 (0–22)	n.s.
HBHC; number of serious SMS alarms per subject (n)				
Alarms; patient-reported values were outside predetermined limits	18.0 ± 29.1 (0–198)	10.7 ± 16.1 (0–80)	29.8 ± 40.0 (0–198)	<0.01
Alarms; all SMS	35.4 ± 38.2 (0–242)	27.7 ± 25.1 (0–98)	47.7 ± 50.9 (0–242)	<0.05
Healthcare costs per subject (€)				
HBHC	15,534 ± 13,200 (246–76,994)	13,122 ± 8034 (993–36,774)	19,420 ± 18,240 (246–76,994)	<0.05
Hospitalizations	7003 ± 14,217 (0–76,376)	4823 ± 9802 (0–41,068)	10,516 ± 18,974 (0–76,376)	n.s.
Emergency care	488 ± 753 (0–3944)	410 ± 495 (0–1949)	615 ± 1039 (0–3944)	n.s.
Primary care	1315 ± 1892 (0–9971)	1707 ± 2188 (0–9971)	683 ± 1024 (0–4636)	<0.05
Other outpatient care	1903 ± 2494 (0–12,181)	1453 ± 1977 (0–8914)	2627 ± 3049 (0–12,181)	<0.05
Total costs	26,244 ± 22,459 (246–123,482)	21,515 ± 14,753 (1848–58,566)	33,862 ± 29,818 (246–123,482)	<0.01

**Notes:** Results are presented as means ± 1 S.D. (range) and p-values are from Student's *t*-test.

**Abbreviations:** CHF, chronic heart failure; COPD, chronic obstructive pulmonary disease, HBHC, specialized hospital-based home care; P.R.N., as-needed; N.s., not significant (p-value ≥ 0.05).

significant when tested in the multivariable regression model.

Using a multivariable linear regression analysis (backward elimination method) the correlations stated in Table 5 were all significant. Results are summarized in Table 6. Additional significant correlations were: use of P.R. N. medications was positively associated with the symptom domain of SGRQ among COPD subjects; the number of HBHC phone calls by nurse was negatively associated with GH, RE and MH domains of RAND-36 among all subjects and positively associated with the physical domain of

MLHFQ among CHF subjects; the number of HBHC phone calls by physician was positively associated with the impact domain of SGRQ among COPD subjects; the number of HBHC home visits by physiotherapist was negatively associated with the RP and BP domains of RAND-36 among all subjects; the number of HBHC total home visits was negatively associated with the EQ-5D index and the PF and SF domains of RAND-36 among all subjects; healthcare costs for hospitalizations during the study period were positively associated with the impact domain of SGRQ among COPD subjects; healthcare costs for HBHC were negatively



**Table 5** Significant Correlations of Measures of Healthcare Dependency and HRQoL Variables

	EQ-5D			RAND-36										MLHFQ					SGRQ				Total
	Index	VAS	PF	RP	BP	GH	VT	SF	RE	MH	Score	Phys.	Emot.	Symp.	Act.	Imp.							
Exacerbations	-0.12	-0.17	-0.10	-0.03	-0.05	-0.35**	-0.06	-0.12	-0.06	-0.08	-0.03	-0.01	-0.10	0.31	0.12	0.22	0.25						
Alarms; patient-reported values were outside predetermined limits	-0.15	-0.21*	-0.18	-0.22*	-0.17	-0.31**	-0.10	-0.23*	-0.22*	-0.16	-0.10	0.25	0.17	0.16	0.13	0.25	0.23						
Alarms; all SMS	-0.12	-0.15	-0.14	-0.18	-0.18	-0.27**	-0.11	-0.19	-0.22*	-0.17	-0.19	0.20	0.12	0.17	0.04	0.18	0.16						
Hospitalizations (previous year)	-0.10	0.03	-0.20	0.07	-0.07	-0.01	-0.09	0.03	-0.14	-0.11	0.15	0.07	0.01	-0.09	-0.12	0.04	0.01						
Hospitalizations (study year)	-0.19	-0.05	-0.17	-0.17	-0.16	-0.03	-0.10	-0.08	0.02	0.01	0.01	0.04	-0.04	0.01	0.17	0.27	0.26						
Emergency care	-0.13	0.01	-0.13	-0.14	-0.05	-0.04	-0.12	-0.06	-0.07	0.04	-0.15	-0.18	-0.21	0.05	0.14	0.28	0.26						
Primary care	0.10	-0.07	0.15	0.05	-0.07	0.05	0.03	0.05	0.05	0.11	0.11	0.07	-0.01	-0.35*	-0.30	-0.27	-0.33						
Other outpatient care	0.03	-0.08	-0.08	-0.13	-0.13	-0.13	0.01	-0.06	-0.21*	0.02	0.07	0.03	-0.07	-0.25	-0.09	0.04	-0.06						
Healthcare by HBHC;																							
PR.N. medications	-0.24*	-0.17	-0.16	-0.15	-0.23*	-0.21*	-0.09	-0.21*	-0.14	-0.03	0.26	0.26*	0.18	0.28	0.18	0.27	0.29						
Changed prescriptions	-0.13	-0.18	-0.10	-0.11	-0.10	-0.29**	-0.15	-0.12	-0.07	-0.10	0.28*	0.34**	0.09	0.32	0.04	0.24	0.23						
HBHC phone calls by nurse	-0.25*	-0.17	-0.21*	-0.27**	-0.26*	-0.29**	-0.24*	-0.25*	-0.27*	-0.25*	0.38**	0.39**	0.26*	0.24	0.08	0.27	0.25						
HBHC phone calls by physician	-0.10	-0.22*	-0.05	-0.17	-0.22*	-0.32**	-0.16	-0.22*	-0.24*	-0.16	0.34*	0.29*	0.27*	0.16	0.07	0.22	0.19						
HBHC phone calls by physiotherapist	-0.01	0.04	0.02	-0.08	0.08	-0.05	-0.08	-0.05	-0.13	-0.08	0.12	0.09	0.11	0.13	0.08	0.25	0.22						
HBHC phone calls by dietician	-0.25*	-0.29**	-0.12	-0.13	-0.19	-0.29**	-0.13	-0.16	-0.07	-0.07	0.12	0.11	0.05	0.22	0.29	0.27	0.30						
HBHC phone calls by curator	-0.15	-0.22*	-0.07	-0.03	-0.19	-0.23*	-0.10	-0.23*	-0.27**	-0.28**	0.21	0.18	0.12	-0.02	-0.03	0.14	0.08						
Total HBHC phone calls	-0.27*	-0.21*	-0.19	-0.23*	-0.25*	-0.27*	-0.22*	-0.25*	-0.27*	-0.22*	0.40**	0.40**	0.33*	0.31	0.10	0.36*	0.32						
HBHC home visit by nurse	-0.16	-0.13	-0.13	-0.13	-0.10	-0.21*	-0.10	-0.10	-0.05	-0.05	0.26	0.32*	0.11	0.16	0.08	0.06	0.09						
HBHC home visit by physician	-0.28**	-0.27**	-0.23*	-0.18	-0.20	-0.36**	-0.20	-0.20	-0.17	-0.18	0.35**	0.38**	0.15	0.33	0.12	0.37*	0.34						
HBHC home visit by physiotherapist	-0.21*	-0.19	-0.17	-0.31**	-0.21*	-0.26*	-0.27**	-0.22*	-0.20	-0.14	0.28*	0.30*	0.21	0.25	0.15	0.37*	0.35*						
HBHC home visit by curator	-0.24*	-0.23*	-0.15	-0.09	-0.22*	-0.28**	-0.15	-0.28**	-0.28**	-0.33**	0.20	0.16	0.10	0.03	0.17	0.26	0.22						
HBHC home visit by dietician	-0.01	-0.01	-0.09	-0.04	-0.11	-0.21*	-0.19	-0.08	0.05	-0.01	0.11	0.12	0.11	-0.03	-0.01	0.13	0.08						
Total HBHC home visits	-0.19	-0.17	-0.16	-0.16	-0.14	-0.26*	-0.15	-0.13	-0.09	-0.09	0.30*	0.36**	0.14	0.20	0.10	0.13	0.15						
Healthcare costs;																							
Hospitalizations (study year)	-0.09	-0.01	-0.13	-0.18	-0.13	-0.05	-0.13	-0.05	0.02	0.02	0.05	0.06	-0.03	-0.12	0.08	-0.02	0.03						
Emergency care	-0.18	-0.04	-0.15	-0.15	-0.08	-0.07	-0.17	-0.04	-0.06	-0.01	-0.08	-0.13	-0.19	0.08	0.08	0.27	0.25						
Primary care	0.02	-0.04	0.02	-0.01	0.01	0.11	0.04	0.06	-0.04	0.09	0.04	0.01	-0.03	-0.35*	-0.32	-0.26	-0.32						
Other outpatient care	0.13	-0.01	-0.01	-0.10	-0.07	-0.14	0.07	-0.04	-0.08	0.15	0.07	0.02	-0.07	-0.40*	0.01	-0.10	-0.15						
HBHC	-0.21*	-0.22*	-0.19	-0.17	-0.15	-0.30**	-0.18	-0.16	-0.11	-0.11	0.34*	0.39**	0.15	0.21	0.13	0.19	0.20						
Total cost	-0.17	-0.14	-0.20	-0.23*	-0.18	-0.21*	-0.18	-0.13	-0.07	-0.02	0.23	0.25	0.05	-0.01	0.12	0.09	0.12						

**Notes:** Pearson's correlation coefficient (r) was calculated for normally distributed continuous variables. \*p < 0.05; \*\*p < 0.01.

**Abbreviations:** BP, bodily pain; CHF, chronic heart failure; COPD, chronic obstructive pulmonary disease; GH, general health; HBHC, specialized hospital-based home care; HRQoL, health-related quality of life; MLHFQ, Minnesota Living with Heart Failure Questionnaire; MH, mental health; PF, physical functioning; PR.N., as-needed; RP, role-physical; SF, social functioning; SGRQ, St. Georges Respiratory Questionnaire; VT, vitality.

**Table 6** Results of a Multivariable Linear Regression Analysis (Backward Elimination)

	EQ-5D		RAND-36						MLHFQ				SGRQ				
	Index	VAS	PF	RP	BP	GH	VT	SF	RE	MH	Score	Phys.	Emot.	Symp.	Act.	Imp.	Total
Intercept	0.59***	53***	75***	23***	66***	-2.8	49***	62***	130***	-19	27***	14***	6.7***	24*	80***	42***	58***
Group (ref=CHF)	-	-	-	-	-	-12**	-	-	-25**	-	-	-	-	-	-	-	-
Age	-	-	-0.47*	-	-	0.56*	-	-	-	0.82***	-	-	-	-	-	-	-
Sex (ref=men)	-	-	-7.5*	-	-	0.8*	-	-	-	0.76*	-	-	-	-	-	-	-
BMI	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CCI points	-	-	-	-	-	-	-	-	-5.4**	-	14*	6.1*	-	3.5*	-	-	-
NYHA (Ref=3)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
GOLD stage (Ref=I-III)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Exacerbations	-	-	-3.0*	-	-	-	-	-	-4.9*	2.0*	-	-	-	-	-	-	-
Hospitalizations (previous year)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Hospitalizations (study year)	-	-	-	-	-	-	-	-	6.4*	-	-	-	-	-	-	9.2*	-
Other outpatient care	-	-	-	-	-	-	-	-	-	0.79*	-	-	-	-	-	-	-
Healthcare by HBHC;																	
PR.N. medications	-0.00031*	-	-	-	-	-	-	-	-	-	-	-	-	0.02*	-	-	-
Changed prescriptions	0.02**	-	-	-	-	-	-	-	1.5*	-	-	-	-	-	-	-	-
HBHC phone calls by nurse	-	-	-	-	-0.61*	-0.41*	-0.41*	-	-1.9***	-0.71***	0.80**	0.41**	0.31*	0.78**	-	1.1*	-
HBHC phone calls by physician	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
HBHC phone calls by dietician	-	-3.1**	-	-	-	-	-	-	-	4.0*	-	-	-	-	-	-	-
HBHC phone calls by curator	-	-	-	-	-	-	-	-	-	-	-	-	-	-3.7*	-	-	-
HBHC home visit by nurse	-	-	0.77**	-	-	-	-	0.88*	-	-	-	-	-	-	-	-	-
HBHC home visit by physician	-0.02*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
HBHC home visit by physiotherapist	-	-	-	-2.8**	-	-	-	-	-	-3.9**	-	-	-	-	-	-	1.9*
HBHC home visit by curator	-	-	-0.66**	-	-	-	-	-0.78*	-	-	-	-	-	-	-	-	-
Total HBHC home visits	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Healthcare costs;																	
Primary care	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-0.0057*
Other outpatient care	0.000028*	-	-	-	-	-	-	-	-	-	-	-	-	-0.0032***	-	-	-
Total cost	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
R <sup>2</sup>	0.22	0.09	0.21	0.10	0.07	0.35	0.06	0.08	0.28	0.32	0.22	0.22	0.07	0.56	-	0.24	0.27
Adjusted R <sup>2</sup>	0.17	0.08	0.16	0.09	0.06	0.32	0.05	0.06	0.23	0.26	0.19	0.19	0.06	0.46	-	0.16	0.22

Notes: \*p < 0.05; \*\*p < 0.01; \*\*\*p < 0.001.

Abbreviations: BMI, body mass index; BP, bodily pain; CCI, Charlson Comorbidity Index; CHF, chronic heart failure; COPD, chronic obstructive pulmonary disease; GH, general health; GOLD, Global Initiative for Chronic Obstructive Lung Disease; HBHC, hospital-based homecare; HRQoL, health-related quality of life; MLHFQ, Minnesota Living with Heart Failure Questionnaire; MH, mental health; NYHA, New York Heart Association Functional Class; PF, physical functioning; RE, role-emotional; RP, role-physical; SF, social functioning; SGRQ, St. Georges Respiratory Questionnaire; VT, vitality.

associated with index and VAS of EQ-5D and the PF and SF domains of RAND-36. Collectively, these correlations indicate that the dependence of healthcare is to a great extent associated with poor HRQoL. Indeed, healthcare dependence before study participation, here represented by frequent hospitalizations the yr prior study inclusion, correlated significantly to poor general HRQoL as demonstrated by the PF domain of the RAND-36 (Table 6).

In addition, advanced stages of CHF and COPD, reflected by the NYHA and the GOLD state, were significantly associated with poor disease-specific HRQoL, reflected by MLHFQ and SGRQ (Table 6).

## Discussion

To the best of our knowledge, the present study is the first study to show that HRQoL is possible to maintain, and, indeed, even to improve by very simple telemonitoring technology; as in the present study, executed daily by subjects using a digital pen and Health Diary forms. In Sweden 2018, approximately 500,000 individuals, corresponding to approximately 5% of the total population, the majority being  $\geq 75$  yrs, never use the internet.<sup>29</sup> Barriers to telecommunication technologies may be impaired functioning of sensory and motor organs due to high age in many cases,<sup>30,31</sup> but the most common reasons given are “no interest” and “complicated technology”.<sup>29,32</sup> Considering this, it becomes crucial to use telemonitoring technologies suitable to this group of elderly, multimorbid patients.

Present knowledge, summarized in a review by Gregersen et al from 2016, suggests that the positive effect of telehealth interventions on HRQoL in COPD subjects is limited.<sup>33</sup> This is in contrast to an earlier review by Kamei et al, which concluded that telehealth intervention improved HRQoL in severe and very severe COPD patients receiving the intervention for more than 6 months.<sup>34</sup> Very recently a study by Talboom-Kamp et al analyzed the impact of usage of a COPD self-management Web-based platform on disease-specific HRQoL of COPD subjects.<sup>35</sup> The authors concluded that subscales of the clinical COPD questionnaire (CCQ), reflecting the mental state and the symptoms, improved significantly before and after the introduction of the program.<sup>35</sup> In contrast, a large Danish 12-month study published 2017 found no statistical HRQoL differences among COPD subjects randomized to the telemonitoring group, compared to the control group offered conventional healthcare.<sup>15</sup> In this study, the SF-36-Item Health Survey, Version 2, was used to assess general HRQoL.<sup>15</sup> Moreover, an RCT by Rixon et al found no

reductions in COPD patients' HRQoL in the longer term by a telehealth intervention, observed through disease-specific measures.<sup>36</sup> In a recent paper by Tupper et al, a 6-month telehealth intervention significantly improved HRQoL, assessed by a health-related QoL questionnaire (15D©) and the COPD Assessment Test (CAT), compared to the control group.<sup>37</sup> Notably, subjects included presented with advanced COPD; indeed, 86% of the subjects were stage 3 or 4 and the subjects were considered at high risk of exacerbations.<sup>37</sup>

Likewise, the possible positive impact of telehealthcare on HRQoL measures of CHF subjects should be cautiously interpreted as well, due to inconsistent findings as shown by two systematic reviews.<sup>38,39</sup> However, due to a larger amount of studies, there is much more evidence on the effect on HRQoL of telehealthcare to patients with CHF than for COPD. In a recently published Danish RCT, the mental component of SF-36, used to evaluate general HRQoL, was significantly improved in the telehealth intervention group compared to the control group.<sup>14</sup> The telehealth intervention focused on self-empowerment achieved by engaging the patients in their own illness through self-monitoring.<sup>14</sup> Notably, patients were excluded if they lacked a landline phone, a mobile phone or GSM (Global System for Mobile communications) coverage.<sup>14</sup> The disease-specific questionnaire employed, the KCCQ12 score, did not demonstrate any significant change due to intervention nor did the physical component of SF-36.<sup>14</sup> The CHF subjects addressed in this study displayed median NYHA score 2.<sup>14</sup> Thus, these CHF subjects were much less ill compared to the CHF subjects included in the present study. Notably, a recent paper by Nouryan et al report significant beneficial effects on CHF subjects, NYHA 1–2, by a telehealth intervention (weekly video-televisits with daily vital sign monitoring) on all-cause emergency department utilization, length of stay and HRQoL, assessed by MLHFQ, compared to comprehensive outpatient management (weekly contacts by telephone).<sup>40</sup>

Few previous studies have made a longitudinal telemonitoring comparison of general and disease-specific HRQoL among both CHF and COPD subjects as in the present study. In a recent paper by Bernocchi et al the authors evaluated the effects of a combination of medical/nursing telesurveillance and telerehabilitation on disease-specific HRQoL.<sup>41</sup> Disease-specific HRQoL were assessed among CHF subjects by MLHFQ and among COPD subjects by the CAT.<sup>41</sup> Following a 4-month intervention, not only physical parameters but also the

disease-specific HRQoL were improved in the telehealth intervention group compared to the control group.<sup>41</sup> Unlike the present study, the study by Bernocchi et al was an RCT and the telemonitoring applied was used for surveillance as well as home training purpose.<sup>41</sup> Study subjects were elderly and multimorbid, but stages of CHF and COPD were less advanced; thus, compared to the present study, subjects were better suited for physical training at home.<sup>41</sup> Clearly, as demonstrated in the present study, improvement of general HRQoL among much sicker subjects than those in the study by Bernocchi et al is possible to achieve by telesurveillance only. This is because of the possibility offered by telesurveillance, to start treatment of exacerbations early, as previously reported by us.<sup>18</sup> In contrast to the present study, a telehealth intervention (the Whole Systems Demonstrator telehealth trial), executed by the general practice, did not improve HRQoL, assessed by SF-12 and EQ-5D, for patients with COPD, diabetes, or CHF compared to usual healthcare over 12 months.<sup>42</sup>

Whether a telehealth intervention turns out beneficial on the HRQoL of the included subjects or not very much depends on the study settings applied and the subjects chosen to study. It might be that CHF subjects benefit more by telehealth interventions than COPD subjects do, and, it might be that subjects presenting with more advanced stages of these diseases exhibit greater benefit than subjects with less advanced diseases do. In this context, the telemonitoring study by Gellis et al is particularly interesting.<sup>43</sup> The inclusion criteria and the outcomes of intervention were very much like the present study.<sup>43</sup> Similar to the present study, homebound medically ill older adults diagnosed with CHF or COPD were randomized to either a multifaceted telehealth intervention for 12 months, but a parallel group offered usual care was also studied.<sup>43</sup> CHF subjects dominated over COPD subjects with an inclusion ratio of 3–4:1;<sup>43</sup> the corresponding ratio for the present study was 1.6:1. At follow-up, employing the questionnaire SF-36, the telehealth intervention group reported significantly greater improvement on GH and SF; findings in line with the present study.<sup>43</sup> Gellis et al used the Honeywell “HomMed” Health Monitoring System, which consisted of a small, tabletop in-home monitor and a Central Station located at the home healthcare agency.<sup>43</sup> Notably, among excluded patients were those who were unable to learn how to use the “HomMed” telehealth device.<sup>43</sup> Importantly, in the present study, we did not

have to exclude any patients due to difficulties in handling the digital pen and Health Diary forms.

To the best of our knowledge, there is no previous study that evaluates, in a telehealth context, the association between healthcare dependence and HRQoL as extensively as the present study does. In a non-telehealth context, Janssen et al have presented data on subjects with advanced CHF and COPD.<sup>3</sup> In that study, the results of baseline measures of general HRQoL were very similar to the data presented in the present study (Table 2).<sup>3</sup> Indeed, as in the present study, only the GH domain of the RAND-36 demonstrated significant difference when CHF and COPD subjects were compared.<sup>3</sup> To assess healthcare dependence, Janssen et al used the instrument The Care Dependency Scale (CDS), a questionnaire consisting of 15 items regarding basic and instrumental activities of daily living, such as personal care, household activities, social and recreational activities.<sup>3</sup> Multiple regression analyses in that study showed that CDS and the number of drugs were correlated with impaired HRQoL in advanced COPD or CHF, while disease severity was not correlated.<sup>3</sup> In contrast, due to a thorough analysis of healthcare consumption and costs, the present study is for the first time, in a telehealth context, able to show that poor HRQoL – general as well as disease-specific – in addition to disease severity, is associated with a variety of important healthcare dependence measures presented in Tables 5 and 6. It should be pointed though that many of the correlations of measures of healthcare dependency and HRQoL variables were rather weak.

We have previously reported on the beneficial effects of the eHealth Diary study on hospitalization frequency.<sup>18</sup> Indeed, for both CHF and COPD subjects, numbers of hospitalizations and associated costs were significantly reduced compared to the yr prior study participation.<sup>18,19</sup> In addition, the present study also reports significant improvement in general HRQoL. Among previous studies with the aim to reduce the number of hospitalizations as well as to improve HRQoL, the study by Ong et al deserves special attention.<sup>44</sup> In that study, approximately 1400 CHF subjects were randomized to usual care or a telemonitoring intervention. Unlike the eHealth Diary study,<sup>18</sup> no significant difference was observed regarding number of hospitalizations during a follow-up of 180 days, while, similar to our study, significant improvement of HRQoL was reported.<sup>44</sup> Furthermore, we have previously reported differences between CHF and COPD subjects observed in the eHealth Diary study.<sup>18,19</sup> In addition to much more frequent exacerbations among COPD subjects

and healthcare costs, we here report significantly more serious alarms created by this group of subjects.

The present study has limitations. Major limitations are a small sample size, due to a considerable loss of enrolled patients, and a lack of a control group. Although significant, the effects of intervention found on measures of healthcare dependency and HRQoL variables were rather weak. Moreover, we did not conduct a further post-study analysis of HRQoL to determine whether the improvements were maintained after the telemonitoring period ceased.

## Conclusion

The Health Diary system and HBHC together improve general HRQoL of elderly multimorbid subjects with CHF and/or COPD, and measures of healthcare dependency are associated with HRQoL variables. The simplicity of the technology applied makes this telemonitoring system very suitable for computer-illiterate subjects. As the subjects in the present study were very ill, it is very favorable that the healthcare providers responsible for monitoring and, if needed, medical actions undertaken at home, have characteristics like the HBHC unit in the present study. In future studies, we will adopt the same telemonitoring system using the primary healthcare as a responsible healthcare giver.

## Abbreviations

BMI, body mass index; BP, bodily pain; CAT, COPD Assessment Test; CCI, Charlson Comorbidity Index; CCQ, clinical COPD questionnaire; CDS, Care Dependency Scale; CDW, Care Data Warehouse in Östergötland; CHF, chronic heart failure; COPD, chronic obstructive pulmonary disease; CCP, Cost Per Patient database; EQ-5D, EuroQol-5 Dimensions; FEV<sub>1</sub>(% of predicted), forced expiratory volume in one second expressed as % of predicted; GEE, Generalized Estimating Equations (GEE); GH, general health; GOLD, global initiative for chronic obstructive lung disease; GSM, Global System for Mobile communications; HBHC, specialized hospital-based home care; HRQoL, health-related quality of life; ICH-GCP, International Conference on Harmonization of Good Clinical Practice; KCCQ, Kansas City Cardiomyopathy Questionnaire; LTOT, long-term oxygen therapy; MH, mental health; MCID, minimal clinically important difference; MLHFQ, Minnesota Living with Heart Failure Questionnaire; NYHA, New York Heart Association; PF, physical functioning; P.R.N., pro re nata (as needed); RCT, randomized control study; RE, role-emotional; RP, role-physical; SAT, blood oxygen saturation; SF, social functioning; SF-36,

Short Form-36; SMS, Short Message Service; SGRQ, St. Georges Respiratory Questionnaire; VAS, Visual Analogue Scale; VT, vitality; yrs, years.

## Data Sharing Statement

The data upon which this analysis was based are available from the corresponding author in anonymized form, upon receipt of a reasonable request.

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## Author Contributions

H.L.P. and L.L. designed and led the study, collected and analyzed data, and wrote the manuscript. J.L. collected and analyzed data and wrote the manuscript. All authors contributed to data analysis, drafting or revising the article, gave final approval of the version to be published, and agree to be accountable for all aspects of the work.

## Disclosure

The authors have no financial or non-financial conflicts to disclose in relation to the present study.

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