Clinical Investigation

What Are Effective Program Characteristics of Self-Management Interventions in Patients With Heart Failure? An Individual Patient Data Meta-analysis

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ABSTRACT

Background: To identify those characteristics of self-management interventions in patients with heart failure (HF) that are effective in influencing health-related quality of life, mortality, and hospitalizations.

Methods and Results: Randomized trials on self-management interventions conducted between January 1985 and June 2013 were identified and individual patient data were requested for meta-analysis. Generalized mixed effects models and Cox proportional hazard models including frailty terms were used to assess the relation between characteristics of interventions and health-related outcomes. Twenty randomized trials (5624 patients) were included. Longer intervention duration reduced mortality risk (hazard ratio 0.99, 95%

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confidence interval [CI] 0.97–0.999 per month increase in duration), risk of HF-related hospitalization (hazard ratio 0.98, 95% CI 0.96–0.99), and HF-related hospitalization at 6 months (risk ratio 0.96, 95% CI 0.92–0.995). Although results were not consistent across outcomes, interventions comprising standardized training of interventionists, peer contact, log keeping, or goal-setting skills appeared less effective than interventions without these characteristics.

Conclusion: No specific program characteristics were consistently associated with better effects of self-management interventions, but longer duration seemed to improve the effect of self-management interventions on several outcomes. Future research using factorial trial designs and process evaluations is needed to understand the working mechanism of specific program characteristics of self-management interventions in HF patients. (*J Cardiac Fail 2016;22:861–871*)

Key Words: Heart failure, individual patient data meta-analysis, self-management.

Heart failure (HF) is a major health concern. Its prevalence is steadily increasing and presently more than 10% of the people aged 85 years and older have been diagnosed with HF.[1] Patients suffering from HF are faced with lifestyle adjustment to prevent deterioration, daily medication intake, and monitoring symptom changes.[2] Interventions to support patients' self-management behavior generally aim to equip patients with skills to actively participate in the management of their chronic condition, through stimulating symptom monitoring and enhancing problem-solving and decision-making skills for medical treatment management and healthy lifestyle.[3] Self-management interventions have received increasing attention as they have been shown to affect a range of outcomes, including all-cause hospitalization and HF-related hospitalization.[4,5] Despite favorable pooled effects, several recent large randomized trials have shown inconclusive results,[6–8] raising new questions regarding the effectiveness of those interventions.

A possible explanation for the ambiguous findings across trials can be sought in the diversity of interventions being evaluated. Self-management interventions vary widely in terms of intensity, duration, content, and delivery.[9] Analysis of multiple studies in a meta-analysis or meta-regression may provide insight into the program characteristics that are associated with better outcomes. This knowledge may contribute to the optimal design of effective self-management interventions.

Previous meta-analyses have tried to identify essential program characteristics by focusing on delivery of the intervention to patients. Interventions using face-to-face communication[10] and a multidisciplinary team of interventionists[10,11] were found to be more effective than interventions without these strategies. However, only a small selection of program characteristics was analyzed, isolated from other characteristics, thereby ignoring the possible impact of other characteristics on the outcome.[12]

Although aggregated data of studies allow for estimating global effects of program characteristics, using individual patient data (IPD) enables a uniform imputation of missing values and computation of treatment effects across studies.[13] Analytic assumptions, such as uncertainties regarding program characteristics, can be checked with principal investigators, leading to a more reliable analysis.[13] Our IPD meta-analysis aims to identify program characteristics of self-management interventions in patients with HF that affect HF-related quality of life (HF-QoL), mortality, all-cause, and HF-related hospitalization.

Material and Methods

Search Strategy and Study Selection

This IPD meta-analysis only included studies of self-management interventions. All individual studies had received approval from their local ethics committees, and this IPD meta-analysis was exempted from the Medical Research Involving Human Subjects Act of the Netherlands by the Medical Ethics Research Committee of the University Medical Center Utrecht. To identify randomized trials on self-management interventions in patients with HF, the electronic databases of PubMed, EMBASE, Cochrane Central Register of Controlled Trials, PsycINFO, and CINAHL were searched from January 1985 through June 2013 (for search syntax in PubMed see Supplementary Data Table S1) as well as reference lists from systematic reviews.

Studies were selected by 2 independent researchers (NHJ and HW). Discrepancies were resolved through consensus with a third researcher (JCAT). Self-management interventions were defined as interventions providing HF-related information to patients and including at least 2 of the following characteristics: (1) stimulation of sign/symptom monitoring, (2) education on problem solving skills (ie, self-treatment, stress/symptom management), and improvement of (3) medical treatment adherence, (4) physical activity, (5) dietary adherence, or (6) smoking cessation. Studies were included in the IPD meta-analysis if they (1) fulfilled the requirements of the definition of self-management intervention, (2) had a randomized trial design, (3) included patients with a confirmed diagnosis of HF, (4) compared the self-management intervention with usual care or another self-management intervention, (5) reported data on 1 or more of the selected outcomes, (6) reported outcome assessment for at least 6 months' follow-up, and (7) were reported in English, Dutch, French, German, Italian, Portuguese, or Spanish.

Data Collection

The principal investigators of selected studies were invited to participate in this IPD meta-analysis and share their

deidentified trial data. The complete list of all requested variables and details on collaboration with principal investigators are reported in the published study protocol.[14] Data from each trial were checked on range, extreme values, internal consistency, missing values, and consistency with published reports.

Outcomes

To identify characteristics of effective self-management interventions across different health outcomes, this study focused on several main outcomes: HF-QoL at 6- and 12-month follow-up (as measured with Heart Failure Symptom Scale,[15] Kansas City Cardiomyopathy Questionnaire,[16] MacNew Heart Disease Health-Related Quality of Life Instrument,[17] or Minnesota Living With Heart Failure Questionnaire[18]), mortality (time to event, at 6 months, at 12 months), all-cause hospitalization (time to first event, at 6 months, at 12 months), and HF-related hospitalization (time to first event, at 6 months, at 12 months).

Program Characteristics

A selection of program characteristics was identified as potential determinants of effective self-management interventions based on literature on self-management and behavior change and their presence across included studies:

1. Intensity: number of planned contacts between person who delivered the intervention and patient, including planned telephone contacts[19]
2. Duration: number of months that the intervention was planned to be delivered to the patient[19]
3. Standardized training: type of training given to person(s)who delivered the intervention to the patient (standardized protocoled training/heterogeneous nonprotocoled training)[20]
4. Multidisciplinary team: type of interventionist(s) delivering the intervention to the patient (multidisciplinary team/single interventionist)[10]
5. Peer contact: contact with peer patients during the intervention, including remote contact such as telephone contact (yes/no)[21,22]
6. Keeping logs: stimulating patient to keep logs for monitoring symptoms (yes/no)[23]
7. Goal-setting skills: teaching patient goal-setting skills for management of the condition or behavior change (yes/no)[21,22]
8. Problem-solving skills: teaching patient problem-solving skills for management of the condition (yes/no)[21,22]
9. Seeking support: teaching patient skills for seeking support in social network, from caregivers, or from health care professionals (yes/no).[21]

Information on program characteristics was extracted for the intervention and control arms of all included studies, and confirmed by the principal investigators.

Statistical Analysis

Original data from individual studies were merged to create 1 database. Missing values for baseline variables and outcomes were imputed within studies only using multiple imputation by chained equations (25 imputations)[24]; for an overview of missing values per study, see Supplementary Data (Table S2). The imputed datasets were used for the primary analysis and results of imputed datasets were pooled using Rubin's rules.[25]

All analyses were performed according to the intention-to-treat principle. Studies were analyzed using a 1-stage approach (ie, simultaneously analyzing all observations while accounting for clustering of observations and preserving randomization within studies).[26] The continuous outcomes (HF-QoL at 6 and 12 months) were rescaled to ensure all scales were in similar direction. Effects were quantified by standardized mean differences between intervention and control arms and analyzed using linear mixed effects models. Binary outcome data (mortality, all-cause, and HF-related hospitalization at 6- and 12-month follow-up) were analyzed with log-binomial mixed effects models, which estimated risk ratios (RRs). All mixed effects models included a random intercept and random slope for the treatment effect to take clustering within studies into account. For time-to-event endpoints, effects of self-management were quantified by estimating hazard ratios (HRs) using Cox proportional-hazard models, which included a frailty term for each study to account for clustering within studies. This frailty term was assumed to follow a normal distribution. The Cox proportional hazard models were fitted using the frailty command from the R package survival.

As an intermediary step in the analysis, we estimated the main effects of the self-management interventions in general (ie, without focusing on specific program characteristics). Main effects have been reported elsewhere,[27] but are presented to enable a comparison of the effects of specific program characteristics with the overall effects.

The primary analysis comprised the identification of program characteristics of effective self-management interventions. Characteristics were evaluated 1-by-1 in separate analyses. One trial had 2 intervention arms[5]; these were included as separate interventions in the analysis. To identify the effect of intensity and duration of interventions, the aforementioned models were repeated with the covariate for treatment (and random slope) being replaced by either intensity or duration of the intervention. Hence, the effects of intensity and duration were estimated irrespective of intervention arm. A different approach was applied for analyzing the binary program-specific characteristics. The studies were grouped according to the presence or absence of a binary program characteristic. Two regression models were then applied in parallel to estimate the treatment effect of self-management within both sets of studies. Differences between the 2 estimated effects from the 2 sets of studies were tested using a Q-test for heterogeneity.[28] Modification of the effects of program characteristics on clinical outcomes was

considered statistically significant if this test yielded $P < .05$. Only statistically significant findings from the primary analysis are presented to enable a direct comparison across the different endpoints.

Several sensitivity analyses were performed to assess robustness of findings from the primary univariable analysis (see Supplementary Data for details). All analyses were performed in R for Windows, version 3.1.1 (R Development Core Team. Released 2013. Vienna, Austria: R Foundation for Statistical Computing).

Results

Principal investigators of the 32 eligible studies were approached to participate in this IPD meta-analysis. Principal investigators of 20 studies responded positively and shared their deidentified trial data, representing 5624 patients in total.[6,7,29–47] The investigators of 5 studies could not be contacted,[8,48–51] 4 principal investigators were not willing to participate,[52–55] and trial data of 2 studies were no longer available.[56–58]

Baseline characteristics of HF patients are presented in Table 1. Variables were well-balanced over the intervention and control groups. The majority of patients were male (57%) and the average age was 69.7 years (standard deviation 12.4). The mean left-ventricular ejection fraction was 39.2% (standard deviation 18.2%) at baseline and most patients were in New York Heart Association class II (39%) or III (37%). Median time since diagnosis of HF was 1.6 years (interquartile range 0.1–5.4).

Included Interventions

Included studies have been presented previously[27] and are described in Table 2. Studies were carried out between 1990 and 2007 in the United States,[7,34,40–43] Netherlands,[6,33,35,44] Sweden,[29,37,46] Spain,[30,31] Canada,[47] Germany,[39] Japan,[38] Switzerland,[36] and United Kingdom.[32] Sample size ranged from 42[36] to 1023 patients.[6] Included interventions had an average intensity of 11.5 planned contacts (range 1.6–32) and duration of 8.7 months (range 0.5–18). Table 3 presents program characteristics per intervention. The majority of interventions (15/21) used a standardized protocol to train interventionists. Eight interventions (38%) involved a multidisciplinary team, 2 (10%) included contacts with peers, and 9 (43%) used logs for symptom monitoring. Patients were taught goal-setting skills in 5 interventions (24%), problem-solving skills in 6 (29%), and seeking support in 12 interventions (57%).

Primary Analysis of Program Characteristics

None of the program characteristics in self-management interventions was effective for all endpoints considered. However, several program characteristics showed an effect on 1 or more endpoints (Table 4). Figure 1 presents a forest plot for the effect on time to first all-cause hospitalization across different program characteristics. The duration of the interventions reduced risk on time to death, with a declining risk for each additional month of the intervention (hazard ratio [HR] 0.99, 95% confidence interval [CI] 0.97–0.999). A similar effect was observed for time to first HF-related

Table 1. Baseline Characteristics of Heart Failure Patients in Control and Self-Management Intervention Arm Included in the Individual Patient Data Meta-Analysis

Characteristic	Control (n = 2674)	Intervention (n = 2950)	Total (n = 5624)
Sex			
Male	1505 (56.2)	1711 (58.0)	3126 (57.2)
Female	1169 (43.7)	1239 (42.0)	2408 (42.8)
Age—mean (SD)	69.9 (12.3)	69.6 (12.4)	69.7 (12.4)
Percentage LVEF—mean (SD)	39.7 (18.4)	38.7 (18.1)	39.2 (18.2)
NYHA class			
I	190 (7.5)	168 (6.0)	358 (6.7)
II	951 (37.7)	1149 (41.0)	2100 (39.4)
III	899 (35.6)	1065 (38.0)	1964 (36.9)
IV	484 (19.2)	422 (15)	906 (17.0)
Years since diagnosis—median (IQR)	2.0 (0.1–6.0)	1.3 (0.1–5.2)	1.6 (0.1–5.4)
Level of education			
Primary education or below	807 (42.3)	910 (39.4)	1717 (40.7)
Secondary education	711 (37.3)	939 (40.6)	1650 (39.1)
Higher education	388 (20.4)	461 (20.0)	849 (20.1)
Living status			
Living with others	1064 (75.2)	1076 (73.2)	2140 (74.2)
Living alone	350 (24.8)	393 (26.8)	743 (25.8)
Clusters of comorbid conditions			
Cardiovascular	1354 (59.7)	1310 (52.3)	2664 (55.8)
Endocrine	870 (36.2)	932 (34.6)	1802 (35.4)
Neurological/psychiatric	343 (17.8)	389 (17.5)	732 (17.6)
Respiratory	506 (27.0)	558 (25.7)	1664 (26.3)
Renal/hepatic/gastrointestinal	303 (24.7)	377 (24.7)	680 (24.7)
Musculoskeletal	76 (11.7)	147 (14.1)	223 (13.2)

IQR, interquartile range; LVEF, left ventricular ejection fraction; NYHA, New York Heart Association; SD, standard deviation.
Values are n (%), mean (SD), or median (interquartile range).

Table 2. Description of Trials on Self-Management in Heart Failure Patients Included in the Individual Patient Data Meta-Analysis

Study	Country	Sample Size	Start Recruitment	Setting	Control Group	Intervention Group	Duration (Mo)*
Agren 2012[29]	Sweden	155	2005	Clinic/hospital or home	Usual care (standard care in hospital and outpatient education and support)	3 individual sessions for patient and partner by nurse	3
Aldamiz 2007[30]	Spain	279	2001	Clinic/hospital and home	Usual care (follow-up in primary health care)	4 home visits by nurse/physician	0.5
Atienza 2004[31]	Spain	338	1999	Clinic/hospital	Usual care (discharge planning according to protocol)	1 individual session prior to discharge by nurse, 1 visit to physician, 3-monthly follow-up visits and tele-monitoring	12
Blue 2001[32]	United Kingdom	165	1997	Clinic/hospital and home	Usual care (follow-up by admitting physician and in primary health care)	Home visits by nurse, follow-up telephone calls with intensity based on patient's need	12
Bruggink 2007[33]	Netherlands	240	2000	Clinic/hospital	Usual care (including optimal application of medical therapy)	2 individual sessions by nurse/physician, 1 telephone call, follow-up 6 visits	12
DeWalt 2012[7]	United States	605	2007	Clinic/hospital	Enhanced usual care (1 initial session on self-management and educational manual)	1 individual session by trained health educator, follow-up multiple telephone calls	12
Heisler 2013[34]	United States	266	2007	Clinic/hospital and home	Enhanced usual care (1 group session on self-management and educational materials)	1 group session by lay peer tutor, weekly telephone contact with matched peer, follow-up 3 optional group sessions	6
Jaarsma 1999[35]	Netherlands	179	1994	Clinic/hospital and home	Usual care (possibly including written/oral information about medication and lifestyle)	1 home visit and 1 telephone call after discharge by nurse	0.5
Jaarsma 2008[6]	Netherlands	1023	2002	Clinic/hospital	Usual care (standard management by cardiologist)	(A) 2 individual session by cardiologist, 9 visits to nurse, possibility to contact nurse (B) 2 individual sessions by cardiologist, 18 visits to nurse, 2 home visits, 2 multidisciplinary sessions, follow-up telephone contact by nurse	18
Leventhal 2011[36]	Switzerland	42	2003	Clinic/hospital and Home	Enhanced usual care (lifestyle recommendations and educational booklet)	1 home visit by nurse, educational booklet, 17 follow-up telephone calls	12
Martensson 2005[37]	Sweden	153	1999	Home (recruited general practice)	Usual care (follow-up in multidisciplinary primary health care)	1 individual session by nurse, follow-up educational CD-ROM and telephone contact	12
Otsu 2011[38]	Japan	102	2007	Clinic/hospital	Usual care (follow-up at a medical facility)	6 individual sessions by nurse	6
Peters-Klimm 2010[39]	Germany	197	2006	Home (recruited general practice)	Usual care (follow-up in primary health care)	1 individual session by nurse/physician, 3 follow-up home visits and telephone calls	12
Rich 1995[40]	United States	282	1990	Clinic/hospital and home	Usual care (follow-up by primary physician)	Daily visits by multidisciplinary professionals during hospitalization, follow-up home visits and telephone calls by nurse at decreasing intensity	3
Riegel 2002[41]	United States	358	1998	Telephonic case management	Usual care (not standardized, possibly including education on heart failure management)	Telephone calls by nurse at decreasing intensity	6
Riegel 2006[42]	United States	135	2002	Telephonic case management	Usual care (not standardized, possibly including education on heart failure management)	Telephone calls by nurse at decreasing intensity	6
Sisk 2006[43]	United States	406	1999	Clinic/hospital	Usual care (including federal guidelines on heart failure)	1 individual session by nurse, follow-up telephone calls	12
Smeulders 2009[44,45]	Netherlands	317	2004	Clinic/hospital	Usual care (including regular check-ups with cardiologist and/or nurse specialist in outpatient clinic)	6 group sessions by lay peer tutor and nurse, booklet, follow-up telephone contact with coparticipants	1.5
Stromberg 2003[46]	Sweden	106	1997	Clinic/hospital	Usual care (follow-up in primary health care)	1 clinic visit shortly after discharge by nurse, individualized follow-up (face-to-face and/or telephone)	12
Tsuyuki 2004[47]	Canada	276	1999	Clinic/hospital	Usual care (including general brochure on heart disease)	1 individual session by pharmacist, 7 follow-up telephone calls by nurse	6

*Duration of the self-management intervention evaluated in the study.

Table 3. Program Characteristics of the Different Self-Management Interventions in Patients With Heart Failure Included in the Individual Patient Data Meta-Analysis

Study	Year of Recruitment	Standardized Training	Multidisciplinary Team	Peer Contact	Keeping Logs	Goal-Setting Skills	Problem-Solving Skills	Seeking Support
Rich 1995[40]	1990		X		X			X
Jaarsma 1999[35]	1994						X	
Blue 2001[32]	1997	X						X
Stromberg 2003[46]	1997	X						X
Riegel 2002[41]	1998	X						X
Sisk 2006[43]	1999	X						
Atienza 2004[31]	1999		X					
Tsuyuki 2004[47]	1999	X			X			
Martensson 2005[37]	1999	X						
Bruggink 2007[33]	2000		X		X			
Aldamiz 2007[30]	2001		X					
Jaarsma 2008a[6,*]	2002	X			X			X
Jaarsma 2008b[6,*]	2002	X	X		X			X
Riegel 2006[42]	2002	X					X	X
Leventhal 2011[36]	2003	X			X	X	X	X
Smeulders 2009[44,45]	2004	X	X	X		X	X	X
Agren 2012[29]	2005					X	X	X
Peters-Klimm 2010[39]	2006	X	X		X	X	X	
DeWalt 2012[7]	2007	X			X	X		
Heisler 2013[34]	2007	X	X	X				X
Otsu 2011[38]	2007	X			X			X

*Study comprised 2 different intervention arms.

hospitalization (HR 0.98, 95% CI 0.96–0.99) and HF-related hospitalization at 6-month follow-up (RR 0.96, 95% CI 0.92–0.995).

Interventions with standardized training of interventionists showed no treatment effects in contrast to favorable effects for interventions with heterogeneous training on time to first all-cause hospitalization (interaction $P = .001$), all-cause hospitalization at 6 months (interaction $P = .009$), at 12 months (interaction $P = .014$), and time to first HF-related hospitalization (interaction $P = .022$). Interventions with a multidisciplinary team showed no treatment effect on time to first HF-related hospitalization, whereas the interventions delivered by 1 person reduced the risk (interaction $P = .045$). The 1 intervention comprising peer contact in the analysis of mortality[34] showed an increased risk on time to death (HR 2.01, 95% CI 1.15–3.53) and mortality at 6 months (RR 1.88, 95% CI 0.89–3.96), whereas the interventions without peer contact reduced risk on time to death (HR 0.86, 95% CI 0.75–0.99, interaction $P = .004$) and mortality at 6 months (RR 0.79, 95% CI 0.63–0.97, interaction $P = .028$). Interventions including log keeping showed no effects, whereas interventions without logs showed favorable effects on time to first all-cause hospitalization (interaction $P \leq .001$), all-cause hospitalization at 12 months (interaction $P = .035$), and time to first HF-related hospitalization (interaction $P = .001$). Interventions including goal-setting skills showed a trend toward increased risk compared with risk reductions for interventions without goal-setting skills on time to first all-cause hospitalization (interaction $P = .023$), all-cause hospitalization at 12 months (interaction $P = .006$), and HF-related hospitalization at 12 months (interaction $P = .029$).

Sensitivity Analysis

Observational analysis of the data in a multivariable model confirmed the direction of effects, except for the effects of standardized training (HR 0.55, 95% CI 0.29–1.08) and multidisciplinary teams (HR 0.91, 95% CI 0.64–1.29) on time to HF-related hospitalization, now both appearing advantageous (see Supplementary Data Table S3). The sensitivity analyses, consisting of a complete-case analysis, repeating the analyses by excluding the largest trial,[6] and pooling the published main effects of studies without individual patient data available (see Supplementary Data Table S4) yielded similar findings compared to the primary analysis.

Two post hoc sensitivity analyses were performed to check for possible confounding by a time effect (ie, a possible decrease of treatment effects over time because of improvements in usual care). One post hoc analysis included only older studies (recruitment through 2000, N = 10), whereas the second analysis included only recent studies (recruitment after 2000, N = 10). Although effect sizes were more pronounced in the subset of older studies, the direction of the effects of program characteristics remained similar to the primary analysis (see Supplementary Data Table S5).

Discussion

This IPD meta-analysis contributes to the discussion on the optimal design of self-management interventions for patients with HF. Even analyzing 20 trials representing 5624 patients, we could not identify program characteristics that showed a consistent pattern in modifying the effects of self-management interventions across all outcomes considered.

Table 4. Effects of Self-Management Interventions and Characteristics in Patients With HF Included in the Individual Patient Data Meta-Analysis

Outcome	N Studies	N Patients	Analysis	Effect Measure	Effect (95% CI)	*P* Value for Heterogeneity
HF-related quality of life						
6 mo follow-up	10	3419	**Intervention effect**	SMD	**0.13 (0.00–0.26)**	NA*
			No significant characteristic			
12 mo follow-up	11	3356	**Intervention effect**	SMD	**0.15 (0.00–0.30)**	NA
			No significant characteristic			
Mortality						
Time to event	14	4312	**Intervention effect**	HR	**0.91 (0.79–1.04)**	NA
	14	4312	Duration (per mo)		0.99 (0.97–0.999)	.045
	1	266	Peer contact		2.01 (1.15–3.53)	.004
	13	4046	No peer contact		0.86 (0.75–0.99)	
6 mo follow-up	17	4985	**Intervention effect**	RR	**0.83 (0.66–1.05)**	NA
	17	4985	Intensity (per contact)		0.97 (0.94–0.99)	.007
	1	266	Peer contact		1.88 (0.89–3.96)	.028
	16	4719	No peer contact		0.79 (0.63–0.97)	
12 mo follow-up	14	4204	**Intervention effect**	RR	**0.86 (0.72–1.03)**	NA
			No significant characteristic			
All-cause hospitalization						
Time to first event	12	3833	**Intervention effect**	HR	**0.93 (0.85–1.03)**	NA
	9	2976	Standardized training		1.01 (0.91–1.13)	.001
	3	857	Heterogeneous training		0.70 (0.57–0.85)	
	5	2186	Keeping logs		1.11 (0.97–1.26)	<.001
	7	1647	No logs		0.78 (0.68–0.90)	
	2	644	Goal-setting skills		1.26 (0.96–1.66)	.023
	10	3186	No goal-setting skills		0.90 (0.81–0.99)	
6 mo follow-up	14	4329	**Intervention effect**	RR	**0.92 (0.83–1.01)**	NA
	10	3293	Standardized training		0.98 (0.89–1.08)	.009
	4	1036	Heterogeneous training		0.72 (0.58–0.89)	
12 mo follow-up	13	4266	**Intervention effect**	RR	**0.95 (0.87–1.04)**	NA
	9	3124	Standardized training		1.01 (0.92–1.12)	.014
	4	1139	Heterogeneous training		0.80 (0.69–0.94)	
	6	2389	Keeping logs		1.06 (0.93–1.20)	.035
	7	1874	No logs		0.87 (0.78–0.99)	
	4	1161	Goal-setting skills		1.17 (0.98–1.39)	.006
	9	3102	No goal-setting skills		0.89 (0.81–0.97)	
HF-related hospitalization						
Time to first event	10	3461	**Intervention effect**	HR	**0.80 (0.69–0.92)**	NA
	10	3461	Duration (per mo)		0.98 (0.96–0.99)	.002
	7	2604	Standardized training		0.88 (0.75–1.04)	.022
	3	857	Heterogeneous training		0.61 (0.46–0.80)	
	3	1202	Multidisciplinary team		1.01 (0.80–1.28)	.045
	8	2598	Single interventionist		0.75 (0.64–0.88)	
	5	2186	Keeping logs		0.99 (0.82–1.20)	.001
	5	1275	No logs		0.61 (0.49–0.76)	
6 mo follow-up	12	3741	**Intervention effect**	RR	**0.81 (0.66–0.99)**	NA
	12	3741	Duration (per mo)		0.96 (0.92–0.995)	.046
12 mo follow-up	11	3503	**Intervention effect**	RR	**0.82 (0.64–1.05)**	NA
	3	844	Goal-setting skills		1.16 (0.84–1.61)	.029
	8	2659	No goal-setting skills		0.72 (0.55–0.95)	

CI, confidence interval; HR, hazard ratio; NA, not available; RR, risk ratio; SMD, standardized mean difference.

Results are only presented if program characteristic showed an effect with $P < .05$ in the primary analysis. Boldface effect values are main effects of the self-management interventions.

*Not applicable for main effects because reported *P* values indicate test for heterogeneity for specific program characteristic.

However, longer duration of self-management interventions reduced the risk on mortality and HF-related hospitalization with 1–4% for each increasing month of the intervention. Unfavorable associations were observed for standardized training of interventionists, log keeping, goal-setting, and peer contact, but only on specific outcomes.

Meta-analyses of similar interventions have shown that the use of multidisciplinary teams[10,11] and face-to-face contact[10] improved outcomes in patients with HF. Our primary analysis suggested only that a longer duration of self-management interventions was more effective. It is likely that sustained contact over time with a health care professional who helps identify signs and symptoms of decompensation may support the patient's self-management. A similar finding was reported by a meta-analysis of HF disease management programs, which found an association between longer follow-up of programs and reduced risk of mortality.[59]

In contrast to the previous meta-analyses,[10,11] we found a less favorable effect of multidisciplinary teams compared with a single interventionist on time to first HF-related hospitalization. This effect disappeared after adjustment for other program characteristics, suggesting a correlation with the

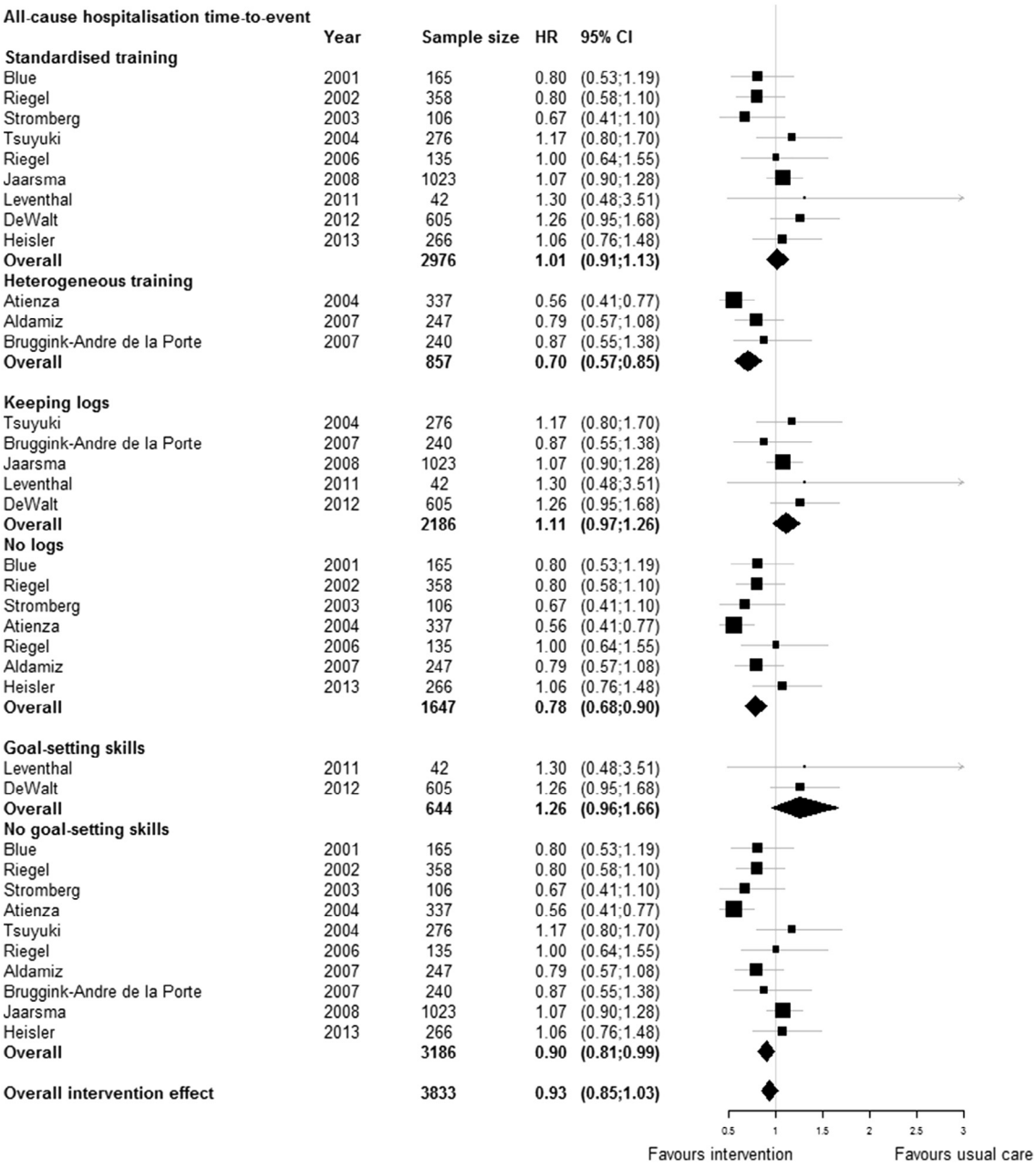

Fig. 1. Forest plot of effects of self-management interventions on time to first all-cause hospitalization with subgroup effects for program characteristics. CI, confidence interval; HR, hazard ratio.

presence of other characteristics. Because this effect disappears, we do not believe our study contradicts the favorable association reported by previous meta-analyses. The other beneficial characteristic revealed by the prior meta-analysis, face-to-face contact,[10] could not be analyzed in our study because it was known a priori that nearly all eligible interventions used face-to-face contact. Overall, the self-management interventions elicited favorable main effects on HF-QoL and HF-related hospitalization. These effects could not be attributed to any of the binary characteristics considered in our study. The face-to-face contact present in nearly all intervention arms might be a critical characteristic in explaining the favorable effects of self-management interventions; this possibility deserves attention in future research.

From earlier work on social cognitive theory[21,22] and meta-regressions on effective behavior change techniques,[20,23] we assumed that standardized training of interventionists, keeping logs for symptom-monitoring, goal-setting, and contact with peers would positively influence the effect of self-management interventions. However, our findings were counterintuitive and showed that self-management interventions comprising those characteristics resulted in less favorable outcomes than interventions without those characteristics. It may be that studies had commonalities on methodological aspects or on other

characteristics that confounded our results[60] (ie, additional [medical] care provided along with the self-management intervention). Inspection of other study characteristics and aggregate baseline variables in tables[61] revealed that there was a tendency for the self-management program characteristics to be particularly present in more recently conducted studies. We hypothesized that treatment effects may have decreased over time, because usual care has evolved because of insights from research (ie, new treatments, more comprehensive care protocols). Although the post hoc sensitivity analyses did not confirm this hypothesis, differences in usual care given to control patients or additional care given in the intervention arms might still be confounding factors for the observed effects. The information on usual care was limited and we could not appropriately adjust for the wide diversity in usual care in our analysis.

Without a clear explanation for the unfavorable effects, it would be unjustified to recommend that self-management interventions should not comprise specific program characteristics. The large number of program characteristics analyzed increases the chance of false-positive findings and any observed effect therefore should be considered explorative rather than confirmative.[61] Considering the complex nature of self-management interventions, we might even question the extent that researchers should look at isolated program characteristics of complex self-management interventions in a meta-regression analysis, because the interventions were designed as a cohesive compilation instead of separate characteristics.[12] Our findings support the notion that effectiveness of self-management interventions may not be attributable to specific program characteristics, but rather that certain types of interventions show a pattern of effects that is dependent on the context in which the intervention is delivered.[62]

From this perspective, this IPD meta-analysis should be considered the first large effort toward identifying characteristics of effective self-management interventions in patients with HF. It applied a careful data collection and analysis, and the causal nature of effect modifiers was addressed by checking the primary findings on confounding factors. Nevertheless, several limitations are worth discussing. First, despite the inclusion of 20 studies and data on 5624 patients, the number of studies was too restricted for multivariable analysis using mixed effects models, limiting causal interpretation of our findings. Second, the use of meta-regression techniques required a categorization of program-specific features. This may have left room for interpretation of categories and may have created large, still heterogeneous sets of studies being grouped together (ie, goal-setting in 1 study may have differed from that in another study). Underreporting of intervention details prevented us from creating detailed categories following existing taxonomies like the behavior change technique taxonomy,[63] which deserves attention by future trials. Finally, fidelity to study protocols and adherence to interventions by patients was unknown in a majority of included studies. Process evaluations of behavioral interventions such as self-management interventions have shown that fidelity to study protocols is often compromised[64,65]; consequently, patients in the intervention groups might have actually received different program characteristics than assumed. The unavailability of these data prevented assessment of the impact of treatment compliance on the outcomes.[66] This IPD meta-analysis highlights the need for incorporating the complexity of this type of intervention in the study design (eg, through carefully defining intervention components, planning feasibility studies, and process evaluations of intervention delivery alongside trials). This may contribute to a thorough understanding of *how* the intervention exerts its effects.

Conclusions

Despite the large numbers of patients included in this IPD meta-analysis, no specific program characteristics could be identified that were clearly associated with better outcomes of self-management interventions. There were indications that a longer duration positively modified the effects of self-management interventions on several outcomes, supporting sustained contact over time between health care professionals and patients with HF. Advances in usual care for patients with HF over time may have confounded the effects observed. Future research using factorial trial designs and process evaluations is needed to assess adherence to self-management interventions and understand the mechanism whereby self-management interventions enhance clinical outcomes in patients with HF.

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Supplementary Data

Supplementary data related to this article can be found at doi:10.1016/j.cardfail.2016.06.422.

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