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ORIGINAL RESEARCH

Patient motivation and adherence to an on-demand app-based heart rate and rhythm monitoring for atrial fibrillation management: data from the TeleCheck-AF project

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Aims The aim of this TeleCheck-AF sub-analysis was to evaluate motivation and adherence to on-demand heart rate/rhythm monitoring app in patients with atrial fibrillation (AF).

Methods and results Patients were instructed to perform 60 s app-based heart rate/rhythm recordings 3 times daily and in case of symptoms for 7 consecutive days prior to teleconsultation. Motivation was defined as number of days in which the expected number of measurements (≥3/day) were performed per number of days over the entire prescription period. Adherence was defined as number of performed measurements per number of expected measurements over the entire prescription period.

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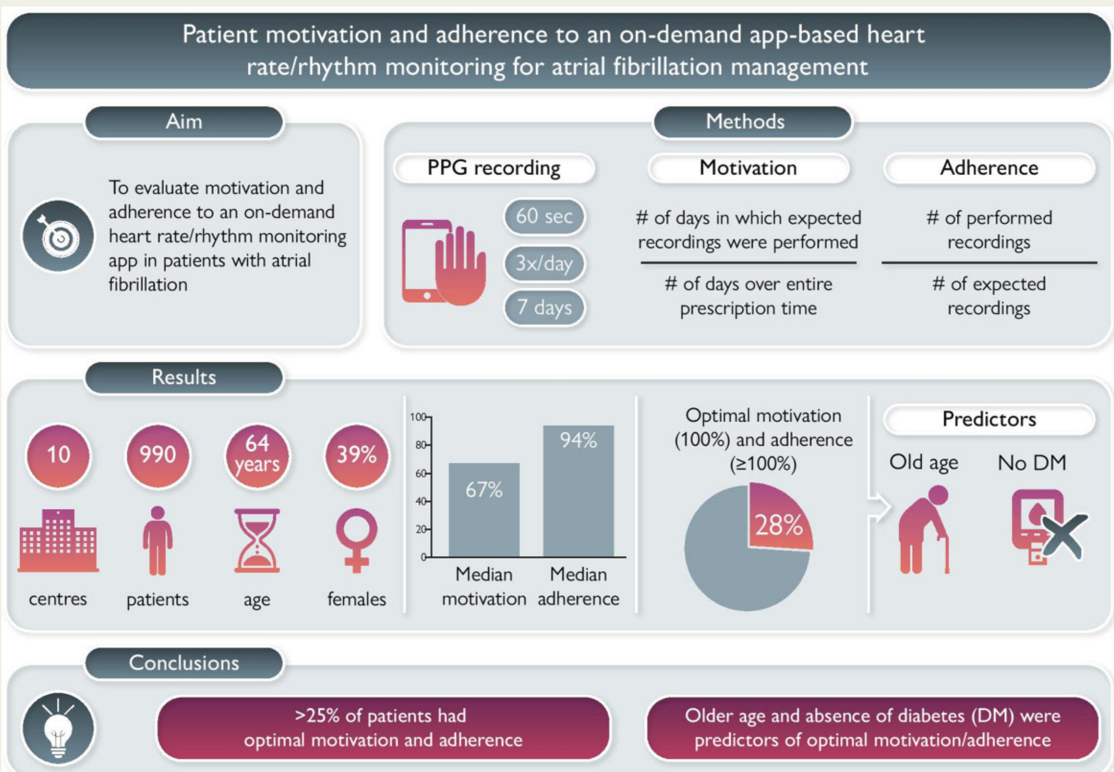
Data from 990 consecutive patients with diagnosed AF [median age 64 (57–71) years, 39% female] from 10 centres were analyzed. Patients with both optimal motivation (100%) and adherence (≥100%) constituted 28% of the study population and had a lower percentage of recordings in sinus rhythm [90 (53–100%) vs. 100 (64–100%), $P < 0.001$] compared with others. Older age and absence of diabetes were predictors of both optimal motivation and adherence [odds ratio (OR) 1.02, 95% coincidence interval (95% CI): 1.01–1.04, $P < 0.001$ and OR: 0.49, 95% CI: 0.28–0.86, $P = 0.013$, respectively]. Patients with 100% motivation also had ≥100% adherence. Independent predictors for optimal adherence alone were older age (OR: 1.02, 95% CI: 1.00–1.04, $P = 0.014$), female sex (OR: 1.70, 95% CI: 1.29–2.23, $P < 0.001$), previous AF ablation (OR: 1.35, 95% CI: 1.03–1.07, $P = 0.028$).

Conclusion In the TeleCheck-AF project, more than one-fourth of patients had optimal motivation and adherence to app-based heart rate/rhythm monitoring. Older age and absence of diabetes were predictors of optimal motivation/adherence.

Graphical Abstract



Keywords Atrial fibrillation • Mobile health • Photoplethysmography • Risk factors • Thromboembolic risk

Novelty

- TeleCheck-AF is a mobile health (mHealth) infrastructure which consists of structured teleconsultation ('Tele'), on-demand app-based heart rate, rhythm, and symptom monitoring ('Check') and its integration into comprehensive atrial fibrillation (AF) management ('AF').
- Herein, we present the first real-world data set on patient adherence and motivation to a standardized mHealth application integrated in remote AF management with a novel way to assess motivation and adherence.
- Older age is not an exclusion criterion for the use of mHealth; elderly patients are adherent and motivated in the use of mHealth.

Introduction

The number of mobile health (mHealth) applications dedicated to heart rate and rhythm monitoring in patients with atrial fibrillation (AF) is constantly increasing with growing numbers of devices and/or applications with Conformité Européenne (CE) and/or Food and Drug Administration approval.[1,2] Despite high accuracy to detect AF, the efficacy of these mHealth applications is critically determined by the ability and willingness of the patient to use them. The World Health Organization (WHO) has stated that increasing patient adherence to interventions may have a far greater impact on the health of the population than any improvement in specific medical treatments.[3] Therefore, the evaluation of patient motivation and adherence to mHealth applications in real-life scenarios and understanding their predictors is important to further improve their usability in contributing to the delivery of patient care.

During the coronavirus disease 2019 (COVID-19) pandemic, a novel mHealth approach consisting of the on-demand use of a photoplethysmography (PPG)-based mobile app for remote heart rate and rhythm monitoring supported a scheduled teleconsultation and the integration into comprehensive AF management was communicated and set up within the TeleCheck-AF project.[4] Multiple centres participated in the TeleCheck-AF project, and all centres provided standardized patient education and material to their patients, which was specifically developed to optimize patient involvement and engagement during the remote care delivery.[5] The educational material was designed based on the experience of the coordinating centre [Maastricht University Medical Centre+ (MUMC +)] during the implementation of this mHealth infrastructure in the healthcare system.[6,7] Systematically assessed patient experience and feedback collected within AF-dedicated outpatient clinics were continuously incorporated to further refine the TeleCheck-AF approach. Project members also frequently organized workshops that brought patients and healthcare providers in contact with scientists to exchange insights of the TeleCheck-AF infrastructure. A large number of patients were enrolled in the TeleCheck-AF project and recent surveys showed positive patient and centre experiences.[6] The majority (>80%) of patients reported ease of use and installation of the mHealth app and more than 80% of the centres reported no problems during the implementation of the TeleCheck-AF approach in the healthcare system.[6] However, patient motivation and adherence to this mHealth approach and their predictors has not been investigated previously.

The aim of this sub-analysis of the real-world mHealth project TeleCheck-AF was to evaluate patient motivation and adherence to an on-demand mobile app-based heart rate and rhythm monitoring application.

Methods

TeleCheck-AF

Details on the TeleCheck-AF project have been reported elsewhere.[4] Briefly, TeleCheck-AF is an mHealth infrastructure developed to provide ongoing management and comprehensive care to patients with AF during the COVID-19 pandemic lockdown within cardiology centres in Europe. The TeleCheck-AF infrastructure consists of a structured teleconsultation ('Tele'), on-demand app-based heart rate, rhythm, and symptom monitoring ('Check') and its integration into comprehensive AF management ('AF'). The retrospective data collection from the participating TeleCheck-AF centres was conducted in accordance with the Declaration of Helsinki[8] and was approved by the local ethics committees.

Patient population

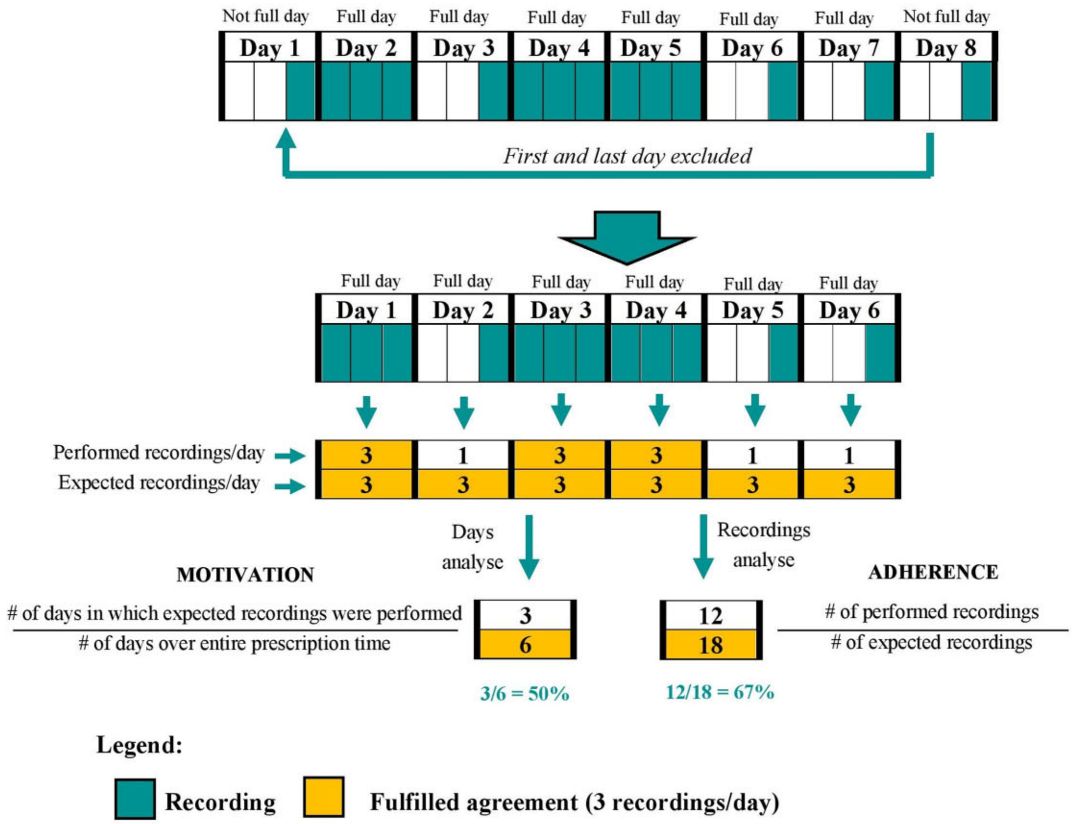
From April 2020 to July 2021, patients aged ≥ 18 years, scheduled for teleconsultation in participating European cardiology centres were offered to participate within the TeleCheck-AF project. Participating patients were eligible if they had a smartphone and were willing to use the on-demand heart rate and rhythm monitoring mobile application. Among all 41 centres, the 10 centres that included the highest number of patients (≥25) were invited to participate in the retrospective data collection: (i) MUMC+, Maastricht, the Netherlands; (ii) Radboud University Medical Center, Nijmegen, the Netherlands; (iii) Rijnstate Hospital, Arnhem, the Netherlands; (iv) Hannover Heart Rhythm Center, Hannover, Germany; (v) University Hospital Cologne, Cologne, Germany; (vi) Medical University of Graz, Graz, Austria; (vii) Ziekenhuis Oost-Limburg, Leuven, Belgium; (viii) Liverpool Heart and Chest Hospital, Liverpool, United Kingdom; (ix) Department of Cardiology, King George Hospital, Ilford, United Kingdom; (x) Medical University of Warsaw, Warsaw, Poland.

Definitions

In the healthcare sector, motivation can be defined as an 'individual's degree of willingness to exert and maintain an effort towards organizational goals'.[9] Medication adherence is defined by the WHO as 'the degree to which the person's behaviour corresponds with the agreed recommendations from a healthcare provider'.[3]

In the current analysis, the first and last day of the prescription were removed, as these were non-complete days (first day was the day of receiving the QR code and the last day was the day of the teleconsultation). Therefore, motivation and adherence were calculated for 6 consecutive full days. Motivation was defined as the number of days in which the expected number of measurements (at least 3 daily) were performed per number of days over the entire prescription period. Adherence was defined as the number of measurements per number of expected measurements (at least 3 daily) over the entire prescription period. In case of multiple prescriptions, the initial prescription was used in the analyses. The detail scheme of analysis is provided in *Figure 1* with examples of motivation and adherence calculations. Based on *Figure 1*, patients can have only motivation of 0% (without day of 3 or more recordings during 6 full monitoring days), 17% (1 day of 3 or more recordings during 6 full monitoring days), 33% (2 days), 50% (3 days), 67% (4 days), 83% (5 days), or 100% (6 days). The same was applicable to adherence, where patients could have 0%, 5.6%, 11%, and so on adherence, given performing 0, 1, 2, and so on recordings per 18 expected recordings.

The patients were divided into 2 groups according to motivation as low-to-moderate (<100%) and optimal (100%) groups, and adherence as low-to-moderate (<100%) and optimal (≥100%) groups. The low-to-moderate motivation group was further divided into 2 numerically similar halves of patients: a low (motivation of 0, 17, or 33%) and a moderate (motivation of 50, 67, or 83%) groups. The low-to-moderate adherence group was further divided in 2 into numerically similar halves of patients: a low (adherence of 0, 5.6, 11, 17, 22, 28, 33, 39, 44, 50, 56, 61, or 67%) and moderate (adherence of 72, 78, 83, 89, or 94%) groups. The PPG recordings were interpreted by the FibriCheck® algorithm (sensitivity: 96%; specificity: 97%[10]) as sinus rhythm, AF-rhythm and non-regular rhythm that could not be classified as AF (e.g. extrasystoles, bradycardia, or tachycardia).



Example: Three days with minimum 3 recordings gives a motivation of 3/6= 50%.

# of days in which expected recordings were performed	0	1	2	3	4	5	6
# of days over entire prescription time	18	18	18	18	18	18	18
Motivation, %	0	17	33	50	67	83	100

Example: Twelve recordings during the 6 days gives an adherence of 12/18= 67%.

# of performed recordings	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	⩾18
#of expected recordings	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18
Adherence, %	0	5.6	11	17	22	28	33	39	44	50	56	61	67	72	78	83	89	94	⩾100

Figure 1 Motivation and adherence analyses. Patients were prescribed the mobile app for 7 days to monitor their heart rate/rhythm. On the first day, patients received the QR code and on the last day, the teleconsultation was scheduled. Given that the first and last days were non-complete days, motivation and adherence were calculated for 6 full days. In the figure, each day was divided into 3 cells providing the expected 3 recordings per day. Green cells represent the performed recording. Days with performed 3 recordings fulfilled the study agreement and are marked in yellow. Motivation was defined as the number of days in which the expected number of measurements were performed per number of days over the entire prescription period (in this scenario, per 6 days). Adherence was defined as the number of measurements per number of expected measurements over the entire prescription period (in this scenario, per 18 recordings). The examples of motivation and adherence calculations are shown in the figure.

Patient guidance and instruction

At least 1 week prior to a scheduled teleconsultation appointment, patients were provided with a CE-marked PPG-based mobile phone heart rate and rhythm monitoring application (FibriCheck®, Qompium, Hasselt, Belgium). Patients were instructed to perform 60 s recordings 3 times daily and in case of symptoms for 7 consecutive days. To support patient motivation and adherence, several educational and reminding interventions were introduced. Once daily, patients received a notification through the app as a reminder to perform heart rate and rhythm recordings. In addition, patients were instructed by the app how to improve recording quality in case of measurements with insufficient quality and were provided with educational information about AF, its complications, and treatment. For more details, see our previous work.[4]

Data collection

Baseline patient characteristics (demographics and medical history) were retrieved from patients' electronic case report forms provided to all centres participating in the retrospective analysis.

Statistical analysis

All continuous variables were pre-tested for normal distribution using the Shapiro–Wilk test and were assessed as non-parametric. Continuous variables are therefore presented as median [interquartile range (IQR)]; however, in 'Recordings (per patient)' part of *Table 1* assessing the percentage of a particular rhythm, we additionally provided percentages as mean ± standard deviation, given low IQR. Categorical variables are presented as numbers (*n*) with percentages (%). Differences in continuous parameters were compared using the non-parametric Mann–Whitney *U* test or Kruskal–Wallis test as applicable. The Bonferroni correction was applied to address the multiple comparison issue. For the comparison of categorical data, the Pearson's χ^2 test was used. To assess predictors of optimal motivation and adherence, multiple logistic regression analysis was performed using a stepwise forward procedure. In this analysis, statistically significant (in univariate analysis) baseline characteristic variables were included. Age was included as continuous variable assessed every 10 units. A two-sided *P*-value of 0.05 was considered statistically significant. For database management and statistical analysis, we used SAS 14.1 (SAS Institute Inc., Cary, NC, USA).

Results

Available data from 990 patients with diagnosed AF were analyzed. Median age was 64 (57–71) years and 387 (39%) of patients were females (*Table 1*). Almost one-third (29%; 288/990) of all patients were aged ≥70 years, whereas 32 (3.2%) were aged ≥80 years, The overall median patient motivation and adherence was 67 and 94%, respectively, and its detailed distribution is shown in *Figure 2* (in detail in Supplementary material online, *Figure S1*). Patients were divided into 3 groups regarding their motivation: low ($n = 346$), moderate ($n = 362$), and optimal ($n = 282$), as well as their adherence: low ($n = 254$), moderate ($n = 291$), and optimal ($n = 445$). All patients ($n = 282$) with optimal motivation had also optimal adherence.

Motivation and adherence

Patients with both optimal motivation and adherence were older compared with the rest of the study population (median age 66 (58–72) vs. 63 (56–70) years, $P = 0.001$), less frequently had diabetes (5.7% vs. 10%, $P = 0.034$) and had a lower percentage of recordings in sinus rhythm [90 (53–100%) vs. 100 (64–100%), respectively, $P < 0.001$] in favour of a larger percentage of recordings in non-regular rhythm [0 (0–14%) vs. 0 (0–1.3%), respectively, $P < 0.001$]. Less patients with both optimal motivation and adherence had just sinus rhythm (39% vs. 51%, $P < 0.001$) in the recordings compared with the remaining cohort. Detailed comparison of patients with optimal motivation and adherence with the remaining study population is presented in *Table 1*.

Adherence alone

All patients with 100% motivation had in parallel at least 100% adherence. Patients with optimal adherence alone were older than patients with moderate and low adherence [median age 65 (58–71) vs. 64 (56–70) and 62 (55–70) years, respectively, $P = 0.009$], were more often females (46% vs. 33% and 34%, respectively, $P = 0.007$), had more often undergone AF ablations (52% vs. 49% and 41%, respectively, $P = 0.024$), and had higher thromboembolic risk based on CHA_2DS_2-VASc score [2 (1–3) vs. 2 (1–3) and 1 (1–3), $P = 0.023$]. Patients with optimal adherence had a higher percentage of recordings with AF [0 (0–18%) vs. 0 (0–0%) and 0 (0–0%), respectively, $P < 0.001$] and recordings with non-regular rhythm [0 (0–13%) vs. 0 (0–0%) and 0 (0–0%), respectively, $P < 0.001$) in favour of lower percentage of recordings with sinus rhythm [90 (57–100%) vs. 100 (80–100%) and 100 (54–100%), respectively, $P < 0.001$]. Interestingly, patients with low adherence more often had only symptomatic recordings or only sinus rhythm recordings (6.8% vs. 3.2%, $P = 0.035$ and 59% vs. 40%, $P < 0.001$, respectively) than patients with optimal adherence. Detailed comparison of patients with low, moderate and optimal adherence is presented in *Table 2*.

Predictors of optimal motivation and adherence

In logistic regression analysis, higher age and absence of diabetes were identified as independent predictors of both optimal motivation and adherence [odds ratio (OR): 1.02, 95% coincidence interval [95% CI]: 1.01–1.04, $P < 0.001$ and OR, 0.49, 95% CI: 0.28–0.86, $P = 0.013$, respectively). As the patients with 100% motivation also had ≥100% adherence, independent predictors for optimal adherence alone were age (OR: 1.02, 95% CI: 1.00–1.04, $P = 0.014$), female sex (OR: 1.70, 95% CI: 1.29–2.23, $P < 0.001$) and previous AF ablation (OR: 1.35, 95% CI: 1.03–1.70, $P = 0.028$). The results of the logistic regression are presented in *Figure 3*.

Age group analysis

As age was an independent predictor of optimal motivation and adherence to the mHealth application, we illustrated this association in *Figure 2*. First, we collated the motivation (x-axis) and adherence (y-axis) with circles (z-axis) whose size correlated with the number of the patient group in particular percentage of motivation and adherence (also mentioned as numbers). Low motivation or adherence were represented by orange bars, moderate motivation or adherence by blue bars, and optimal motivation or adherence by green bars. Then, we divided patients in tertiles regarding age for groups: aged <59 years ($n = 313$), 59–68 ($n = 348$) and >68 ($n = 329$). The dominance of patients aged <59 years, 59–68 years, and >68 years in a group of particular percentage of motivation and adherence was represented as yellow, blue, and red circles, respectively. The clear increasing in contribution of the oldest group of patients (red circles) and decreasing contribution of the youngest group (yellow circles) of patients along with the increasing motivation and adherence was observed.

Within each age tertile (<59, 59–68, and >68 years), patients were divided for those with and without optimal motivation/adherence as shown in Supplementary material online, *Table S1*. *Figure 4* shows that higher percentage of patients with 100% motivation

Table 1 Baseline characteristics of study population according to adherence and motivation

Variable	All ($n = 990$)	Both optimal motivation (100%) and adherence (≥100%)		*P*-value
		No ($n = 708$)	Yes ($n = 282$)	
Demographics				
Female sex	387/990 (39%)	273/708 (39%)	114/282 (40%)	0.614
Age (years)	64 (57–71)	63 (56–70)	66 (58–72)	0.001
BMI (kg/m2)	27 (25–30); $n = 926$	27 (25–30); $n = 655$	27 (24–30); $n = 271$	0.954
AF				
AF	873/979 (89%)	622/699 (89%)	251/280 (90%)	0.716
First detected AF	64/870 (7.4%)	46/619 (7.4%)	18/251 (7.2%)	1.000
Paroxysmal AF	546/869 (63%)	393/619 (64%)	153/250 (61%)	0.290
Persistent AF	297/869 (34%)	211/619 (34%)	86/250 (34%)	
Permanent AF	26/869 (3.0%)	15/619 (2.4%)	11/250 (4.4%)	
Previous CV	444/938 (47%)	310/669 (46%)	134/269 (50%)	0.289
Ablation therapy for AF	456/950 (48%)	315/679 (46%)	141/271 (52%)	0.131
Cardiovascular diseases				
Vascular disease	143/951 (15%)	99/673 (15%)	44/278 (16%)	0.690
Congestive heart failure	114/990 (12%)	81/708 (11%)	33/282 (12%)	0.912
Device therapy (PM/CRT/ICD)	41/986 (4.2%)	35/704 (5.0%)	6/282 (2.1%)	0.051
Stroke/TIA/pulmonary embolism	91/989 (9.2%)	59/707 (8.4%)	32/282 (11%)	0.145
Hemorrhagic events	8/989 (0.8%)	5/707 (0.7%)	3/282 (1.1%)	0.695
Hypertension	477/989 (48%)	342/707 (48%)	135/282 (48%)	0.888
Diabetes mellitus	87/990 (8.8%)	71/708 (10%)	16/282 (5.7%)	0.034
Smoking (current/former)	298/807 (37%)	219/574 (38%)	79/233 (34%)	0.261
Non-cardiovascular diseases				
Sleep apnoea	72/750 (9.6%)	50/530 (9.4%)	22/220 (10%)	0.787
Chronic obstructive pulmonary disease	48/989 (4.9%)	34/707 (4.8%)	14/282 (5.0%)	0.872
Chronic kidney disease	46/989 (4.7%)	37/707 (5.2%)	9/282 (3.2%)	0.185
Thromboembolic risk				
CHA_2DS_2-VASc	2 (1–3)	2 (1–3)	2 (1–3)	0.107
CHA_2DS_2-VASc score ≥ 2 (if male), ≥3 (if female)	440/943 (47%)	299/667 (45%)	141/276 (51%)	0.085
Medications				
Cardiovascular drugs ≥4	265/988 (27%)	194/706 (29%)	71/282 (25%)	0.475
Cardiovascular drugs ≥3	514/988 (52%)	373/706 (53%)	141/282 (50%)	0.438
Oral anticoagulants	756/986 (77%)	536/704 (76%)	220/282 (78%)	0.560
Antiplatelet drugs	39/986 (4.0%)	30/704 (4.3%)	9/282 (3.2%)	0.588
Beta-blockers	562/986 (57%)	396/704 (56%)	166/282 (59%)	0.477
Antiarrhythmic drugs	335/985 (34%)	247/703 (35%)	88/282 (31%)	0.265
Diuretics	187/986 (19%)	139/704 (20%)	48/282 (17%)	0.369
Dihydropyridine-CCB	105/881 (12%)	79/627 (13%)	26/254 (10%)	0.360
Non-dihydropyridine-CCB	56/881 (6.4%)	35/627 (5.6%)	21/254 (8.3%)	0.169
RAAS-acting agents	402/986 (41%)	287/704 (41%)	115/282 (41%)	0.931
Digoxin	63/986 (6.4%)	44/704 (6.3%)	19/282 (6.7%)	0.774
Median recordings (per patient)				
Total	17 (12–20)	15 (12–17)	22 (19–27)	<0.001
Symptomatic[a]	17 (3.8–41%) 26 ± 29%	15 (0–41%) 26 ± 29%	18 (5.3–43%) 27 ± 27%	0.077
AF[a]	0 (0–10%) 16 ± 34%	0 (0–0%) 15 ± 33%	0 (0–18%) 19 ± 35%	0.003
Sinus rhythm[a]	100 (64–100%) 75 ± 37%	100 (64–100%) 76 ± 37%	90 (53–100%) 72 ± 36%	<0.001
Non-regular rhythm[a]	0 (0–7.1%) 7.4 ± 16%	0 (0–1.3%) 6.7 ± 16%	0 (0–14%) 9.3 ± 16%	<0.001

Continued

Table 1 ***Continued***

Variable	All ($n = 990$)	Both optimal motivation (100%) and adherence (≥100%)		P-value
		No ($n = 708$)	Yes ($n = 282$)	
Number of patients with 100% recordings accompanied by:				
Symptoms	49/990 (5.0%)	34/708 (4.8%)	9/282 (3.2%)	0.303
AF	100/990 (10%)	79/708 (11%)	34/282 (12%)	0.660
Sinus rhythm	516/990 (52%)	394/708 (51%)	111/282 (39%)	<0.001

[a]percentage of quality recordings.
AF, atrial fibrillation; BMI, body mass index; CCB, calcium channel blocker; CRT, cardiac resynchronization therapy; ICD, implantable cardioverter-defibrillator; M. pacemaker; RAAS, renin–angiotensin–aldosterone system; TIA, transient ischaemic attack. Data provided after semicolon indicated available data per variable.

and at least 100% adherence was observed in the cohort older than 68 years compared with those aged 59–68 and <59 years (34% vs. 29% and 24%, respectively, $P = 0.007$). Patients with (vs. without) optimal motivation and adherence had higher percentage of recordings with AF [0 (0–18%) vs. 0 (0–0%), $P = 0.005$] in age group <59 years, and higher percentage of recordings with non-regular rhythm in age group of 59–68 and >68 years [0 (0–15%) vs. 0 (0–0%), $P < 0.001$ and 0 (0–15%) vs. 0 (0–5.6%), $P = 0.011$, respectively]. A higher, although non-statistically significant, number of patients with 100% recordings accompanied with symptoms were observed in group with (vs. without) optimal motivation and adherence in <59 and 59–68 age groups (4.2% vs. 3.7%, $P = 0.738$ and 6.0% vs. 4.4%, $P = 0.584$, respectively); however, inverse association was observed in oldest (>68 years) group (0% vs. 6.4%, $P = 0.003$) as shown in Supplementary material online, *Table S1*.

Discussion

This is the first study assessing patient motivation and adherence to on-demand heart rate and rhythm monitoring application for remote AF management supported by teleconsultation in a large real-world mHealth project.

Assessment and explanation of optimal motivation and adherence

The optimal or most appropriate way to assess motivation and adherence to mHealth application remains unclear, and consensus is lacking. In this analysis of the TeleCheck-AF project, we propose a novel way to assess motivation and adherence. Based on our definitions, median motivation and adherence were 67 and 94%, respectively. Twenty-eight percent of patients showed an optimal (100%) motivation and 45% showed an optimal (at least 100%) adherence. Higher adherence than motivation could be explained by the fact that patients performed more than the expected recording (≥3/day) for example to 'compensate' low number of days in which recordings were performed or due to higher percentage of AF (especially in age group >59 years) and non-regular heart rhythm recordings (mainly in those aged ≥59 years), which may have led to uncertainty and triggered additional measurements. Therefore, not just patient education on AF and on how and when to use the application but also on other causes of irregular heart rhythm recordings, such as respiratory sinus arrhythmia and premature contractions, should be discussed with patients in whom mHealth-based heart rate and rhythm monitoring is used.[11] Interestingly, in the group with low adherence, a larger proportion of PPG recordings was accompanied by symptoms, compared with the group with optimal adherence. This suggests that patients with low adherence may mainly perform measurements when they experience symptoms, whereas patients with optimal adherence stick to the recommendations to perform 3 recordings per day, which accumulates PPG recordings irrespective of symptoms over time.

Threshold of optimal motivation and adherence

According to a recent WHO report, adherence to long-term therapy for chronic illnesses in developed countries averages 50%.[3] However, the WHO report mainly focuses on a long treatment period. In contrast, TeleCheck-AF was designed as a 1-week mHealth intervention only, which may explain the relatively high observed adherence. In the literature, there is no clear agreement on how to stratify patients into 'good' and 'poor' adherence. Some classifications have been proposed to evaluate the adherence to hypertensive drug administration.[12] However, the arbitrarily selected thresholds to categorize patients to good and poor adherence (set at 80%) are usually not challenged by sensitivity testing, different interventions or links to outcome and should therefore not be generalized to different clinical scenarios. In the mobile Atrial Fibrillation App (mAFA)-II trial, good management adherence was assessed as monitoring time (at least 14 days) since initial monitoring of at least 70%.[13] Although, this cut-off resulted in a high proportion of patients that had good adherence to (70.8%) and persistence of use of (91.7%) the mAFA app, the validity of this cut-off point and detailed definition of 'adherence to treatment' in this study remain unknown. To overcome the limitation of the absence of clear thresholds for 'good' and 'poor' adherence, we mainly reported on patients with optimal adherence and/or motivation in this study.

Most of the available studies concern the impact of mHealth solutions on motivation and adherence to specific behaviour change strategies such as medication use by sending motivational messages/alerts, drug adherence statistics, or remote educational

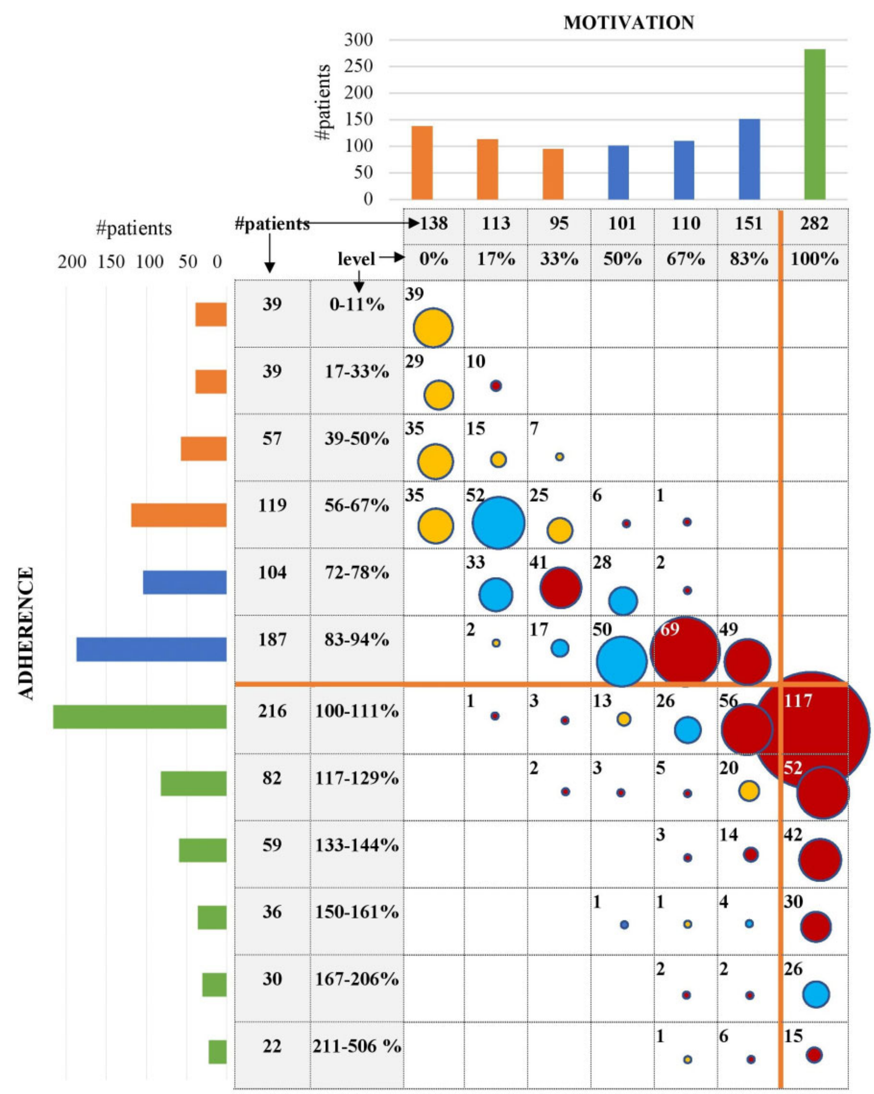


Figure 2 Distribution of patients according to motivation and adherence level. Orange bars represent low motivation or adherence, blue bars represent moderate motivation or adherence, and green represent mean optimal motivation or adherence. Patients were divided into tertiles based on age groups: aged <59 years, 59–68 years and >68 years. The circles reflect the dominance of patients aged <59 years (yellow), aged 59–68 years (blue), and aged >68 years (red) in each motivation/adherence group. Thick orange lines divide motivation and adherence for optimal and non-optimal values.

platforms. The actual motivation and adherence to mHealth devices/apps use is sparse, and more research is required in this field.

Predictors of optimal motivation and adherence

In TeleCheck-AF, higher age was identified as an independent predictor for better motivation and adherence. Both the large proportion of older patients enrolled in TeleCheck-AF, as well as the good motivation and adherence to the instructions suggest a good mHealth literacy and acceptance in older patients. Similarly, in a study by Desteghe *et al.*[14], motivation to use an mHealth app, aiming to improve adherence to performing a daily 'healthy' challenge during a 90-day period, was higher in elderly AF patients (mean age of 69 years) than in younger participants of the study. Therefore, increased age of patients should not discourage physicians, nurses, and allied health professionals to provide mHealth applications to their patients.

Another independent predictor for both optimal motivation and adherence was lack of diabetes. In a recent study by Larsen *et al.*[15], although median adherence to daily use of a heart rhythm/rate wrist monitor for 8–12 weeks to reinforce physical activity change strategies in pregnant women with diabetes was 90%, full days of wear (≥600 min) were much more infrequent and median adherence was 50%. Diabetic neuropathy or other diabetes-associated complications may affect the perception of symptoms and therefore reducing the number of symptom-triggered recordings.

In addition, female sex and previous history of AF ablation were identified as independent predictors of optimal adherence. Higher

Table 2 Baseline characteristics of study population according to motivation

Variable	Motivation			*P*-value	Adherence			*P*-value
	Low (0–33%) (*n* = 346)	Moderate (50–83%) (*n* = 362)	Optimal (100%) (*n* = 282)		Low (<72%) (*n* = 254)	Moderate (72 to <100%) (*n* = 291)	Optimal (≥ 100%) (*n* = 445)	
Demographics								
Female sex	122/346 (35%)	139/362 (42%)	114/282 (40%)	0.184	87/254 (34%)	96/291 (33%)	204/445 (46%)	0.007
Age (years)	62 (55–70)	64 (56–71)	66 (58–72)	0.002	62 (55–70)	64 (56–70)	65 (58–71)	0.009
BMI (kg/m2)	27 (25–30); *n* = 313	27 (24–30); *n* = 342	27 (24–30); *n* = 271	0.905	27 (25–30); *n* = 230	27 (25–29); *n* = 270	27 (24–30); *n* = 426	0.514
AF								
AF	303/343 (88%)	319/356 (90%)	251/280 (90%)	0.827	222/252 (88%)	259/285 (91%)	392/442 (89%)	0.530
First detected AF	25/303 (8.3%)	21/316 (6.7%)	18/251 (7.2%)	0.740	17/222 (7.7%)	18/256 (7.0%)	29/392 (7.4%)	0.966
Paroxysmal AF	189/301 (63%)	204/318 (64%)	153/250 (61%)	0.540	135/221 (61%)	176/258 (68%)	235/390 (60%)	0.287
Persistent AF	106/301 (35%)	105/318 (33%)	86/250 (34%)		80/221 (36%)	76/258 (29%)	141/390 (36%)	
Permanent AF	6/301 (2.0%)	9/318 (2.8%)	11/250 (4.4%)		6/221 (2.7%)	6/258 (2.3%)	14/390 (3.6%)	
Previous CV	152/328 (46%)	158/341 (46%)	134/269 (50%)	0.524	113/243 (47%)	127/278 (46%)	204/417 (49%)	0.849
Ablation therapy for AF	145/332 (44%)	170/347 (49%)	141/271 (52%)	0.112	101/247 (41%)	135/278 (49%)	220/425 (52%)	0.024
Cardiovascular diseases								
Vascular disease	54/320 (17%)	45/353 (13%)	44/278 (16%)	0.297	38/236 (16%)	44/279 (16%)	61/436 (14%)	0.705
Congestive heart failure	39/346 (11%)	42/362 (12%)	33/282 (12%)	0.984	31/254 (12%)	32/291 (11%)	51/445 (11%)	0.906
Device therapy (PM/CRT/ICD)	18/343 (5.3%)	17/361 (4.7%)	6/282 (2.1%)	0.122	16/252 (6.4%)	10/290 (3.5%)	15/444 (3.4%)	0.130
Stroke/TIA/pulmonary embolism	25/345 (7.3%)	34/362 (9.4%)	32/282 (11%)	0.207	15/253 (5.9%)	31/291 (11%)	45/445 (10%)	0.110
Hemorrhagic events	3/345 (0.9%)	2/362 (0.6%)	3/282 (1.1%)	0.763	2/253 (0.8%)	3/291 (1.0%)	3/445 (0.8%)	0.869
Hypertension	167/346 (48%)	175/361 (48%)	135/282 (48%)	0.988	119/254 (47%)	145/291 (50%)	213/444 (48%)	0.778
Diabetes mellitus	29/346 (8.4%)	42/362 (12%)	16/282 (5.7%)	0.029	20/254 (7.9%)	28/291 (9.6%)	39/445 (8.8%)	0.772
Smoking (current/former)	106/268 (40%)	113/306 (37%)	79/233 (34%)	0.426	75/193 (39%)	93/249 (37%)	130/365 (36%)	0.742
Non-cardiovascular diseases								
Obstructive sleep apnea syndrome	27/271 (10%)	23/259 (8.9%)	22/220 (10%)	0.889	19/195 (9.7%)	24/221 (11%)	29/334 (8.7%)	0.693
Chronic obstructive pulmonary disease	22/345 (6.4%)	12/362 (3.3%)	14/282 (5.0%)	0.166	15/253 (5.9%)	11/291 (3.8%)	22/445 (4.9%)	0.505
Chronic kidney disease	18/345 (5.2%)	19/362 (5.3%)	9/282 (3.2%)	0.388	12/253 (4.7%)	18/291 (6.2%)	16/445 (3.6%)	0.263
Thromboembolic risk								
CHA_2DS_2-VASc score	2 (1–3)	2 (1–3)	2 (1–3)	0.091	1 (1–3)	2 (1–3)	2 (1–3)	0.023
CHA_2DS_2-VASc score ≥ 2 (if male), ≥3 (if female)	135/317 (43%)	164/350 (47%)	141/276 (51%)	0.117	95/233 (41%)	130/277 (47%)	215/433 (50%)	0.090
Medications								
Cardiovascular drugs ≥4	103/344 (30%)	91/362 (25%)	71/282 (25%)	0.270	78/252 (31%)	73/291 (25%)	114/445 (26%)	0.227
Cardiovascular drugs ≥3	186/344 (54%)	187/362 (52%)	141/282 (50%)	0.589	137/252 (54%)	150/291 (52%)	227/445 (51%)	0.683
Oral anticoagulants	258/343 (75%)	278/361 (77%)	220/282 (78%)	0.701	185/252 (73%)	222/290 (77%)	349/444 (79%)	0.297

Continued

Table 2 ***Continued***

Variable	Motivation: Low (0–33%) ($n = 346$)	Motivation: Moderate (50–83%) ($n = 362$)	Motivation: Optimal (100%) ($n = 282$)	*P*-value	Adherence: Low (<72%) ($n = 254$)	Adherence: Moderate (72 to <100%) ($n = 291$)	Adherence: Optimal (≥ 100%) ($n = 445$)	*P*-value
Antiplatelet drugs	16/343 (4.7%)	14/361 (3.9%)	9/282 (3.2%)	0.640	10/252 (4.0%)	14/290 (4.8%)	15/444 (3.4%)	0.616
Beta-blockers	203/343 (59%)	193/361 (53%)	166/282 (59%)	0.233	155/252 (62%)	146/290 (50%)	261/444 (59%)	0.355
Antiarrhythmic drugs	119/342 (35%)	128/361 (35%)	88/282 (31%)	0.492	82/251 (34%)	100/290 (34%)	153/444 (34%)	0.874
Diuretics	66/343 (19%)	73/361 (20%)	48/282 (17%)	0.582	50/252 (20%)	53/290 (18%)	84/444 (19%)	0.898
Dihydropyridine-CCB	44/299 (15%)	35/328 (11%)	26/254 (10%)	0.183	31/221 (14%)	33/266 (12%)	41/394 (10%)	0.396
Non-dihydropyridine-CCB	17/299 (5.7%)	18/328 (5.5%)	21/254 (8.3%)	0.333	11/221 (5.0%)	19/266 (7.1%)	26/394 (6.6%)	0.600
RAAS-acting agents	144/342 (42%)	143/362 (40%)	115/282 (41%)	0.831	106/252 (42%)	116/290 (40%)	180/444 (41%)	0.958
Digoxin	19/343 (5.5%)	25/361 (6.9%)	19/282 (6.7%)	0.724	14/252 (5.6%)	19/290 (6.6%)	30/444 (6.8%)	0.816
Recordings (per patient)								
Total	11 (9–13)	17 (16–19)	22 (19–27)	<0.001	11 (8–12)	16 (15–17)	21 (19–25)	<0.001
Symptomatic[a]	14 (0–35%) 24 ± 29%	18 (5.6–46%) 28 ± 29%	18 (5.3–43%) 27 ± 27%	0.002	14 (0–39%) 25 ± 30%	13 (0–36%) 24 ± 27%	20 (5.3–45%) 29 ± 28%	<0.001
AF[a]	0 (0–0%) 16 ± 35%	0 (0–9.7%) 15 ± 31%	0 (0–18%) 19 ± 35%	0.005	0 (0–0%) 17 ± 36%	0 (0–0%) 13 ± 31%	0 (0–18%) 18 ± 33%	<0.001
Sinus rhythm[a]	100 (62–100%) 74 ± 40%	100 (67–100%) 78 ± 34%	90 (53–100%) 72 ± 36%	0.002	100 (54–100%) 73 ± 41%	100 (80–100%) 81 ± 34%	90 (57–100%) 73 ± 35%	<0.001
Non-regular rhythm[a]	0 (0–0%) 5.7 ± 16%	0 (0–6.7%) 7.5 ± 16%	0 (0–14%) 9.3 ± 16%	<0.001	0 (0–0%) 5.3 ± 16%	0 (0–0%) 6.0 ± 15%	0 (0–13%) 9.6 ± 17%	<0.001
Number of patients with 100% recordings accompanied by:								
Symptoms	20/346 (5.8%)	14/362 (3.9%)	9/282 (3.2%)	0.248	21/306 (6.8%)	8/239 (3.4%)	14/445 (3.2%)	0.035
AF	44/346 (13%)	35/362 (9.7%)	34/282 (12%)	0.415	42/306 (14%)	23/239 (9.6%)	48/445(11%)	0.289
Sinus rhythm	204/346 (59%)	190/362 (52%)	111/282 (39%)	<0.001	182/306 (59%)	145/239 (61%)	178/445 (40%)	<0.001

[a]percentage of quality recordings.

AF, atrial fibrillation; BMI, body mass index; CCB, calcium channel blocker; CRT, cardiac resynchronization therapy; ICD, implantable cardioverter-defibrillator; M. pacemaker; RAAS, renin-angiotensin-aldosterone system; TIA, transient ischaemic attack. Data provided after semicolon indicated available data per variable.

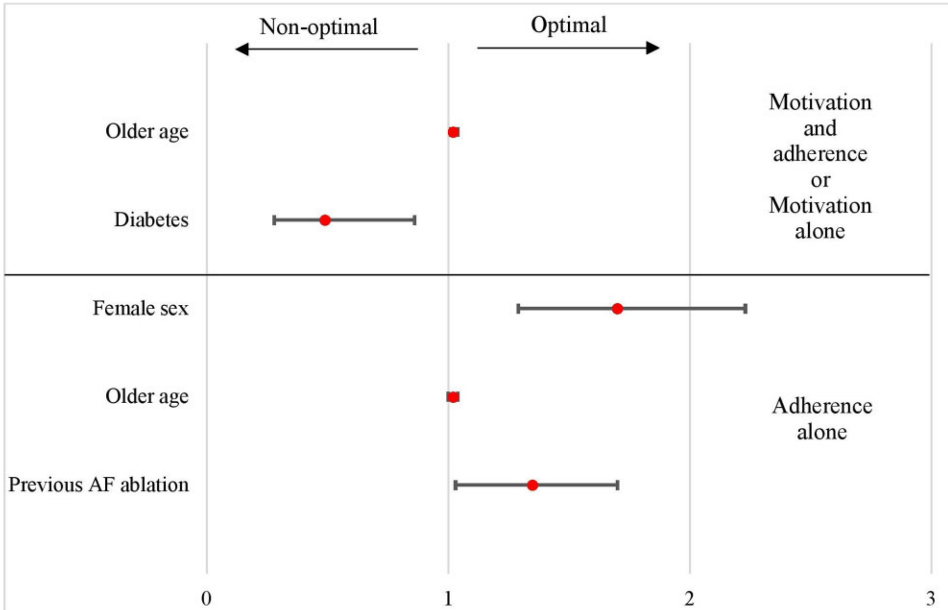


Figure 3 Predictors for both optimal motivation and adherence and optimal adherence alone shown as odd ratio (OR) and 95% coincidence intervals (CIs). Predictors for both optimal motivation and adherence, and optimal motivation alone are the same and are shown jointly, whereas predictors for optimal adherence alone are shown separately.

adherence to mHealth treatment in the group of patients who previously underwent AF ablation could be explained by patients' concerns about their own health and willingness to control their health as best and scrupulously as possible. According to previous studies,[16] women are more sensitive to threat-related stimuli and experience more negative effects than men. They are more likely to seek medical advice, preventive measures, and remedies. That well-described behavioural difference between men and women could explain higher adherence of female (vs. male) patients to mHealth treatment in our study population.

Assistance in obtaining optimal motivation and adherence

Patient education and information are important and established approaches to ensure and facilitate patient adherence and motivation.[17] According to a recent study, age and educational level are crucial domains for successful implementation of telemedicine.[18] Within TeleCheck-AF, we developed and published standardized instructions that were followed by all participating centres.[4–6,19] Information about strategies to educate and empower patients to self-manage the on-demand mHealth application and the required care co-ordination, including implementation of the approach into clinical practice, were provided to the participating centres.[7] However, as this mHealth-based approach was tailored to the individual patient and in centre-/country-specific conditions, it cannot be ruled out that some changes in patient management have been adopted. Moreover, education and involvement of patients and their carers in the care process is a crucial part of integrated care approaches.[20] Specialized AF clinics based on the concept of integrated care[21] are highly suitable to incorporate educational strategies to empower patients to be involved, use the technology, and thus take ownership of their self-management. The availability of such infrastructure and tailored patient educational strategies has likely contributed critically to the herein described adherence and motivation of enrolled patients. However, it is worth to emphasize that adherence and motivation to treatment should be a part of the long-term management of AF. Globally, AF guidelines advocate a self-management approach that encompasses a range of activities such as tracking symptoms, increasing physical activity, or supporting mental health in an effort to engage patients to take an active role in their own care, which has become even more evident during the COVID-19 lockdown periods.[22] Patient self-efficacy is a key enabler of self-management and should be promoted through education, guidance and empowerment.[23] Considering that the average AF patient is burdened with numerous conditions, education should be tailored to the individual patient, provided in a structured approach and by multidisciplinary teams with sufficient knowledge to ensure comprehensive care.[24,25]

Strengths and limitations

To our knowledge, this analysis of the TeleCheck-AF project provides the first real-world data set on patient adherence and motivation to a standardized mHealth application integrated in remote AF management. Importantly, TeleCheck-AF incorporated an on-demand mHealth application for 7 days only. Longer mHealth-based monitoring has been associated with longitudinally decreasing patient adherence and motivation over time. In addition, there may be selection bias, as it includes only patients who were willing to use the mobile app in this real-life setting, and there should be caution in generalizing these findings to all patients with AF.

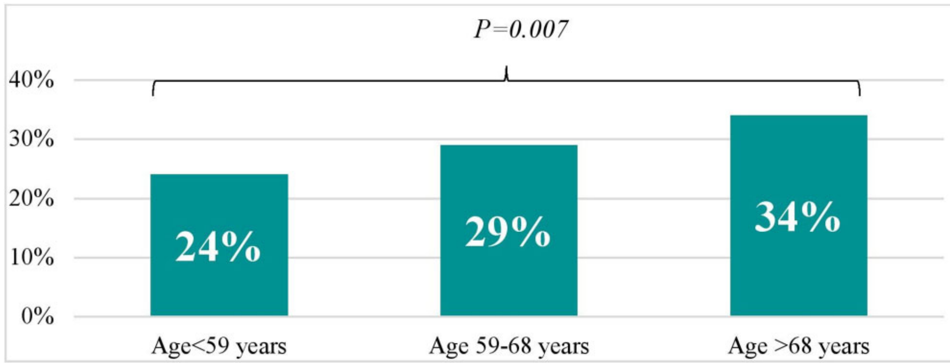


Figure 4 Percent age of patients with both optimal motivation and adherence in the different age groups. Patients were divided in tertiles based on age groups: aged <59 years, 59–68 years, and >68 years. Columns represent the percentage of both optimal motivation and adherence in each age group. *P*-value is provided for all group comparisons.

Further intervention studies comparing the effect of notifications reminding to perform recordings on motivation and adherence level are required. Finally, differences in providing education and information on this mHealth project in particular centre could have influenced the results.

Conclusions

Within the TeleCheck-AF project, the overall adherence to this mHealth application was high, with a mean adherence of 94% and a motivation of 67%. Higher age and absence of diabetes are independent predictors for patient motivation and adherence to instructions to use a PPG-based app on-demand for 7 days supported teleconsultation within the TeleCheck-AF project. Therefore physicians, nurses, and allied health specialists involved in the management and care for patients with AF should not be discouraged to provide a mHealth infrastructure to elderly patients. Other predictors of mHealth adherence in TeleCheck-AF were the female sex and previous AF ablation (adherence).

Supplementary material

Supplementary material is available at European Journal of Cardiovascular Nursing online.

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Data availability

The data underlying this article will be shared on reasonable request to the corresponding author.

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