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Self-Monitoring and Self-Efficacy in Patients with Chronic Kidney Disease During Low-Sodium Diet Self-Management Interventions: Secondary Analysis of the ESMO and SUBLIME Trials

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Abstract

Background Patients with chronic kidney disease are often requested to engage in self-monitoring sodium (i.e. salt) intake, but it is currently unknown how self-monitoring would empower them. This study aims to assess: (1) how frequent self-monitoring tools are being used during low-sodium diet self-management interventions; (2) whether self-efficacy (i.e. trust in own capability to manage the chronic disease) is associated with self-monitoring frequency; and (3) whether higher self-monitoring frequency is associated with an improvement in self-efficacy over time.

Method Data from two multicenter randomized controlled trials (ESMO [$n = 151$] and SUBLIME [$n = 99$]) among adult Dutch patients with chronic kidney disease (eGFR ≥ 20–25 mL/min/1.73 m^2) were used. In both studies, routine care was compared to a 3-month low-sodium diet self-management intervention with several self-monitoring tools (online food diary, home blood pressure monitor, and urinary sodium measurement device [only ESMO]). Data was collected on usage frequency of self-monitoring tools. Frequencies during the interventions were compared between low and high baseline self-efficacy groups using the Mann-Whitney *U* test and *T*-test and associated with changes in self-efficacy during the interventions using Spearman correlation coefficients.

Results Large variations in self-monitoring frequency were observed. In both interventions, usage of self-monitoring tools was highest during the first month with sharp drops thereafter. The online food diary was the most frequently used tool. In the ESMO intervention, low baseline self-efficacy was associated with a higher usage frequency of self-monitoring tools. This finding was not confirmed in the SUBLIME intervention. No significant associations were found between usage frequency of self-monitoring tools and changes in self-efficacy over time.

Conclusion Patients with low self-efficacy might benefit most from frequent usage of self-monitoring tools when sufficient guidance and support is provided.

Keywords Chronic kidney disease · Randomized controlled trial · Reducing dietary sodium intake · Self-efficacy · Self-managment and lifestyle support · Self-monitoring tools

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Introduction

Pursuing a healthy lifestyle is important for patients with chronic kidney disease to improve health outcomes [1, 2]. Increasingly, studies provide evidence for beneficial effects of a limited sodium (i.e. salt) intake in patients with chronic kidney disease, for example by decreasing blood pressure (BP) and protein excretion [3–10], and by reducing risks for cardiovascular complications and progression towards kidney failure [11–15].

Unfortunately, most patients with chronic kidney disease do not succeed in adhering to the low-sodium diet of 2–2.4 g/day [3, 10, 16, 17]. Previous studies have shown that patients with chronic kidney disease face multiple barriers when trying to reduce their sodium intake, with a perceived lack of feedback on their sodium intake as one of the main barriers [18, 19]. Literature also shows that self-management interventions encompassing multiple behavior change techniques can provide patients with the necessary support and can improve health outcomes in various patient populations including chronic kidney disease [20–29]. Within such self-management interventions, self-monitoring is considered an essential behavior change technique: not only can self-monitoring provide the much-needed feedback (e.g. on sodium intake, but also on blood pressure, diet, and progress over time) but it can also trigger people to (re)focus their attention towards their lifestyle goals and guide selection of adequate coping strategies [21, 23, 30–32].

However, until now, little is known about how self-monitoring tools are being used during self-management interventions aimed at sodium reduction among patient with chronic kidney disease. This is important to explore because literature suggests that patients' willingness and responses to self-monitor can vary greatly, and depend on many factors (e.g. educational level, disease symptoms, monitoring complexity, and outcome expectancy) [33–36]. Another potential important factor to take into account is patients' level of self-efficacy: the level of trust in one's own capability to manage their chronic disease [37]. For example, a previous study has shown that chronic kidney disease patients with previous experience on salt lowering, especially the patients with low levels of self-efficacy, believed that the lack of feedback on their sodium intake is an important barrier for successful sodium reduction [38]. Moreover, studies among patients with chronic kidney disease and diabetes suggest that higher self-efficacy scores are associated with a higher frequency of blood glucose monitoring and engagement in appropriate general self-care activities (e.g. tracking treatment progress, monitoring symptoms, and pursuing a healthy lifestyle) [39–41]. In contrast, in a Dutch study including patients with different chronic diseases, including chronic kidney disease, overall self-efficacy was not associated with willingness to self-monitor [33]. Taken together, contradictory results have been found so far and none of the studies explored whether self-efficacy is associated with actual self-monitoring behavior during low-sodium diet self-management interventions in chronic kidney disease.

Finally, to support patients adequately, it seems imperative that self-management interventions not only target the perceived lack of feedback (e.g. on sodium intake) but also strengthen patients' self-efficacy [3, 10, 20, 21, 30, 42]. Studies have shown that interventions focusing on self-monitoring can improve self-efficacy, for example, daily self-monitoring of diet and exercise in the general population [43]. It is also evidenced that self-efficacy can be improved by means of a multicomponent low-sodium diet self-management intervention which includes self-monitoring [44, 45]; however, little is known about real-time data on usage of self-monitoring tools and whether a higher frequency of self-monitoring is also associated with improvements in self-efficacy.

Therefore, this study aims to explore (1) the frequency in usage of self-monitoring tools during two low-sodium diet self-management interventions among Dutch patients with chronic kidney disease; (2) to investigate whether self-efficacy at baseline is associated with frequency of self-monitoring during the intervention; and (3) to examine whether a higher frequency of self-monitoring is associated with an improvement in self-efficacy over time. Exploring these association between self-monitoring behavior and self-efficacy could provide important information about which patients could benefit most from self-monitoring support.

Methods

Study Design

In this study, data was used from two multicenter open randomized controlled trials in The Netherlands in which routine care was compared to a low-sodium diet self-management intervention: the 'Effects of Self-Monitoring on Outcome of Chronic Kidney Disease' (ESMO; Netherlands Trial Registry: NTR2917) and the 'SodiUm Burden lowered by Lifestyle Intervention: self-Management and E-health technology' (SUBLIME; ClinicalTrials.gov: NCT02132013) studies. The main focus of both studies was to reduce salt intake by means of a self-management intervention. In both studies, 24-h urinary sodium excretion was a primary outcome and both studies showed an effect of the intervention on sodium excretion at 3 months, but the effects diminished after the intervention periods. At the follow-up measurements, no significant differences were observed compared to the control groups. Written informed consent was obtained from all participants before inclusion. Both studies were approved by the Medical Ethics Committees of all centers (P10.056 and METc2014/075) and comply with the Declaration of Helsinki. Study details are described elsewhere [44, 45].

ESMO/SUBLIME Participants

In both studies, Dutch-speaking adult patients (≥ 18 years) with moderate decreased kidney function (estimated glomerular filtration rate (eGFR) of ≥ 20–25 mL/min/1.73 m^2; chronic kidney disease stages 1–4) and hypertension (BP > 135/85 mmHg or well-controlled BP with antihypertensive therapy) were included if they ate too much salt (2 recent urinary sodium excretions of > 120–130 mmol/day). In total, 151 patients were included in the ESMO study from June 2011 to August 2014 at outpatient nephrology clinics of 4 Dutch hospitals (control group: 76 and intervention group: 75), of whom 138 patients started the allocated group (control group: 71 and intervention group: 67). Dropout was 23% in the control group (17/71) and 12% (9/67) in the intervention group. In total, 99 patients were included in the SUBLIME study from June 2014 to March 2015 at outpatient nephrology clinics of 4 Dutch hospitals (control group: 47 and intervention group: 52) of whom 94 started the allocated group (control group: 44 and intervention group: 50). Dropout was 0% in the control group (0/47) and 10% (5/50) in the intervention group. The patient flow is shown in Fig. 1.

ESMO/SUBLIME Intervention and Self-Monitoring

All participants received regular care according to the Dutch Federation of Nephrology treatment guidelines (based on Kidney Disease Improving Global Outcomes and Kidney Disease Outcomes Quality Initiative guidelines) [1, 2, 46]. Regular care consisted of consultations with a nephrologist every 3 to 6 months and, if necessary, consultation with a dietician. Patients in both intervention groups additionally received a low-sodium diet self-management intervention based on self-regulation theory [47, 48], encompassing various evidence-based behavior change techniques [20, 21, 30, 42, 49], and with a strong focus on barrier identification, problem solving, goal-setting, action planning, feedback, and strengthening intrinsic motivation, self-efficacy, and social support. The 3-month ESMO intervention consisted of education, face-to-face motivational interviews, coaching by telephone, and self-monitoring of dietary intake (online food diary; Bonstato), 24-h urinary sodium excretion (sodium measurement device; Medimate) [50], and BP (Microlife WatchBP Home). Patients were instructed to self-monitor at least once a week in the first half of the intervention and thereafter, once every 2 or 3 weeks (depending on patients' preferences). The 3-month SUBLIME intervention comprised a face-to-face intake, a web-based self-management program, coaching via telephone or email, group meetings, and self-monitoring of dietary intake (interactive food diary, designed to visually show effects of different food choices; Bonstato), and BP (Microlife Watch BP Home), followed by e-coaching during a 6-month maintenance period. Participants were instructed to self-monitor as frequently as they preferred.

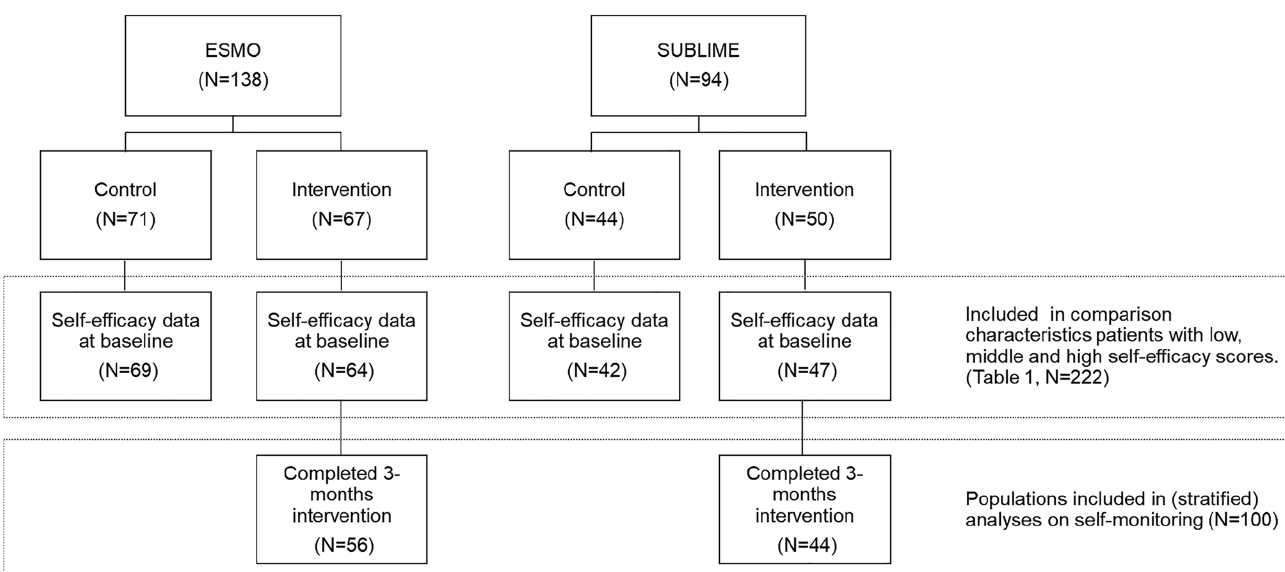

Fig. 1 Participant flow of (data used from) the ESMO and SUBLIME trials

Measurements, Definition, and Outcomes

Data were collected at baseline, directly after the 3-month interventions, and at follow-up after 6 months (ESMO) or 9 months (SUBLIME). Biochemical data were periodically extracted from electronic hospital information systems. Anthropometry and medical data were collected during hospital visits using a secured online Case Report Form (eCRF). Sociodemographic and psychosocial measures were acquired using self-report questionnaires.

Anthropometry, Medical, and Biomedical Measurements

Sodium excretion and protein excretion were estimated from 24-h urinary samples. Comorbidities were classified as diabetes mellitus (DM; type 1 or type 2) and cardiovascular disease (CVD; angina pectoris, coronary disease, and/or myocardial infarction). BP was measured at outpatient clinics by taking the average of three measurements using Microsoft WatchBP Home after 5 min of rest. Primary kidney disease (PKD) was classified into four categories according to the codes of European Renal Association registry (https://www.era-edta-reg.org/prd.jsp). Body weight was measured with shoes removed using the hospitals' calibrated digital scales and used, together with height, to calculate body mass index (BMI). Kidney function was presented as eGFR using 4-variable MDRD Study equation (ESMO) and Chronic Kidney Disease Epidemiology Collaboration formula (SUBLIME) [51, 52].

Sociodemographic and Psychosocial Measurements

Questionnaires included sociodemographic factors and various psychosocial factors. First, in the ESMO study, self-efficacy was assessed by the Chronic Disease Self-Efficacy Scales - Manage Disease in General Scale, with a total score ranging from 1 to 10 [53]. In SUBLIME, self-efficacy was measured using the Partner in Health (PIH) questionnaire, with a total score ranging from 0 to 104 [54]. Both self-efficacy questionnaires assess the degree to which patients have confidence in their ability to manage their chronic disease, and in both questionnaires, a higher score indicates a higher level of self-efficacy. Health-related quality of life (HRQOL) was measured using the 36-item (ESMO) and 12-item (SUBLIME) Short Form Health Survey questionnaires [55, 56]. Scores for physical and mental HRQOL range from 0 to 100, with higher scores indicating a better HRQOL. Motivation for sodium reduction was assessed using the Treatment Self-Regulation Questionnaire (TSRQ) [57]. Two subscales were created representing autonomous motivation (hereafter referred to as intrinsic motivation) and controlled motivation (hereafter referred to as extrinsic motivation). Total scores for both subscales range from 1 to 7, with higher scores indicating a stronger intrinsic and extrinsic motivation. All questionnaires had good Cronbach's alpha values (>0.7) with the exception of the moderate Cronbach's alpha value of 0.63 for the TSRQ autonomous motivation scale.

Usage Frequency of Self-Monitoring Tools

Usage frequency of the self-monitoring tools was estimated by counting the number of days the patients used the tools. This was performed for the consecutive months of the total study period, namely 6 months for the ESMO study and 9 months for the SUBLIME study. Additionally, the cumulative use over the first 3 months (i.e. the intervention period) was calculated. In the ESMO study, the use of three different tools was recorded: the online food diary, home BP monitor, and urinary sodium measurement device. In the SUBLIME study, frequency of use of two different tools: the online food diary and home BP monitor were reported by the patients using the web-based self-management program. Additionally, the SUBLIME participants reported the frequency of using the home BP monitor (times per day/week/month) in self-administered questionnaires (i.e. at baseline, 3 months, and 9 months follow-up) and this was expressed as days per month on which a home BP monitor was used. In both studies, food diary records with a very low energy intake (i.e. ratio of energy intake to basal metabolic rate <0.5) were regarded as incomplete and therefore not counted. Basal metabolic rate was estimated using the Schofield equation [58].

For both studies, a summary score of self-monitoring tool usage during the first 3 months was created. For this purpose, patients were first given scores ranging from 1 to 3 for the frequency of using the individual tools based on tertiles of the (study specific) distributions of that tool. The score for ESMO was based on 3 tools (i.e. the online food diary, home BP monitor, and the urinary sodium measurement device) and for SUBLIME on 2 tools (i.e. food diary and BP monitor (online registered)). This score was expressed as percentage of the maximum study-specific score (i.e. 9 for ESMO and 6 for SUBLIME, respectively) resulting in comparable scales. The questionnaire-based use of the home BP monitor in the SUBLIME study was not included in the summary score because of overlap with the registered use. The correlation coefficient between the questionnaire-based use and the online-registered use of the home BP monitor was 0.68 ($P<0.001$).

Statistical Analysis

To compare characteristics of patients with low, middle, and high levels of self-efficacy, patients were categorized according to the study-specific tertiles of the self-efficacy scores. For this analysis, all patients with available baseline self-efficacy data were included: 133 ESMO patients (69 control group and 64 intervention group) and 89 SUBLIME patients (42 control group and 47 intervention group). The control and intervention groups were combined for optimal power (see also Fig. 1). Dichotomous characteristics were presented as percentages, and continuous variables were presented as mean (standard deviation (SD). Differences between the groups were tested using ANOVA and Pearson chi-square tests.

For the analyses concerning the use of self-monitoring tools, only patients from the intervention groups who completed the first 3 months of the intervention were included (ESMO: $N = 56$; SUBLIME: $N = 44$). For this purpose, patients were grouped into two self-efficacy groups based on the study-specific median self-efficacy scores of the intervention groups. The frequency of using the separate self-monitoring tools during the first 3 months (i.e. the intervention period) and the summary score were compared between patients with low and high levels of self-efficacy at baseline using either the Mann-Whitney *U* test (separate self-monitoring tools) or a *T*-test (summary score).

The overall effects of the interventions on self-efficacy were previously published [44, 45]. However, to provide insight into the effects of the interventions on self-efficacy in the context of self-monitoring, we repeated these analyses in the present patient selections. To enhance comparability between the two interventions, a slightly different linear-mixed model was used in the SUBLIME study than in the previous publication (see the Supplement for details (Tables S3)). Spearman correlation coefficients were calculated between the usage frequency of self-monitoring tools during the first 3 months and changes in self-efficacy during this intervention period. A *p*-value of less than 0.05 was considered statistically significant. IBM SPSS Statistics version 26 was used for all analyses.

Results

Baseline Characteristics and Self-Efficacy Scores

In both studies, the results showed that patients believed to a relatively high extent that they were able to manage their kidney disease. In the ESMO study, the mean baseline self-efficacy score was 7.7 (SD = 1.1) on a scale ranging from 0 to 10. The mean baseline self-efficacy score in the SUBLIME study was 75 (SD = 20) on a scale ranging from 0 to 104. Patients were categorized into 3 groups (i.e. low, middle, and high) based on the study-specific tertiles of the self-efficacy scores. Baseline characteristics of the total study population (i.e. ESMO and SUBLIME combined) stratified by the three self-efficacy categories are shown in Table 1. Patients in the lowest self-efficacy category were older, more often had low education level, had a higher BMI, and scored lower on both physical and mental HRQOL. A history of dialysis and kidney transplant was more common in patients with higher self-efficacy.

Table 1 Baseline characteristics of the total study population (i.e. the ESMO and SUBLIME study populations combined) stratified for three self-efficacy categories ($N = 222$)

	Self-efficacy*			*P*-value
	Low $N = 73$	Middle $N = 83$	High $N = 66$	
Demographic factors				
Age, years	59 (11)	54 (14)	55 (14)	0.04
Gender, male	64 (88%)	66 (80%)	54 (82%)	0.39
Married or cohabiting	59 (81%)	70 (84%)	55 (83%)	0.84
Ethnicity, Dutch	66 (90%)	76 (92%)	64 (97%)	0.28
Education level, low	56 (77%)	47 (57%)	32 (49%)	0.002
Clinical factors				
Diabetes mellitus	24 (33%)	23 (28%)	14 (21%)	0.31
Cardiovascular disease	19 (26%)	21 (25%)	11 (17%)	0.35
History dialysis	10 (14%)	16 (19%)	20 (30%)	0.05
History kidney transplant	14 (19%)	23 (28%)	29 (44%)	0.01
Blood pressure (mmHg)[a]				
Systolic	139 (18)	140 (17)	139 (19)	0.97
Diastolic	82 (10)	86 (10)	84 (11)	0.15
eGFR (mL/min/1.73 m^2)[b]	46 (22)	52 (28)	53 (23)	0.23
Body mass index (kg/m^2)[c]	30 (5)	29 (5)	28 (5)	0.03
Psychosocial factors				
Intrinsic motivation (1–7)[d]	5.3 (0.9)	5.5 (0.8)	5.5 (1.0)	0.58
Extrinsic motivation (1–7)[e]	4.4 (1.2)	4.2 (1.3)	4.0 (1.5)	0.25
Physical HRQOL (0–100)[f]	62 (28)	72 (20)	73 (23)	0.01
Mental HRQOL (0–100)[g]	68 (23)	76 (16)	82 (15)	< 0.001

Data is presented as mean ± SD for continuous variables and as *N* (%) for categorical variables. Differences between groups were tested with ANOVA or chi-square tests

*Based on study-specific tertiles of the self-efficacy scores (ESMO [score ranging from 0 to 10: < 7.5; 7.6–8.3; > 8.3]; and SUBLIME [score ranging from 0 to 104: < 69; 69–86; > 86])

Missing for: [a]$n = 1$ (1/0/0); [b]$n = 19$ (6/10/3); [c]$n = 2$ (1/0/1); [d]$n = 7$ (4/2/1); [e]$n = 7$ (2/4/1); [f]$n = 5$ (3/1/1); [g]$n = 6$ (4/1/1)

Baseline characteristics for the two studies separately are shown in Table S1 (ESMO study) and Table S2 (SUBLIME study). Due to the relatively lower numbers, patients were categorized into 2 self-efficacy groups (i.e. 'low' and 'high' based on the median split) instead of 3 groups. Overall, SUBLIME patients had more often a history of kidney replacement therapy (i.e. dialysis and/or kidney transplant;

SUBLIME: 45% and ESMO: 20%), and ESMO patients had a lower mean HRQOL than SUBLIME patients (physical HRQOL difference of 4 points; mental HRQOL difference of 6 points). Interesting to note is that SUBLIME patients seem to have a stronger intrinsic motivation and a weaker extrinsic motivation, especially in the high self-efficacy group (extrinsic motivation score: 3.5 in SUBLIME versus 4.4 in ESMO). All other characteristics were comparable across both studies.

Usage Frequency of Self-Monitoring Tools in the ESMO and SUBLIME Intervention Groups Over Time

The food diary was the most frequently used self-monitoring tool in the intervention group of the ESMO study, followed by the home BP monitor (Fig. 2, the left panels). During the first month of the intervention, the median (Q1–Q3) number of days on which a food diary was filled out was 5 (3–12) days. For the home BP monitor and the urinary sodium measurement device, this was 3 (0–5) and 3 (2–4) days, respectively. Large variation in usage frequency of tools existed, with the range during the first month being: food diary 0–31 days; home BP monitor 0–30 days; and urinary sodium measurement device 0–7 days. Two participants (4%) did not use any of the tools during the first month of the intervention. For all three tools, a decrease in frequency of tool usage was observed over the first 3 months, followed by a sharp drop after the intervention was completed after 3 months. Usage frequencies of self-monitoring tools in the SUBLIME intervention over time is also shown in Fig. 2 (the right panels). During the first month, median use was 7 (2–16) and 0 (0–4) days for the food diary and the home BP monitor,

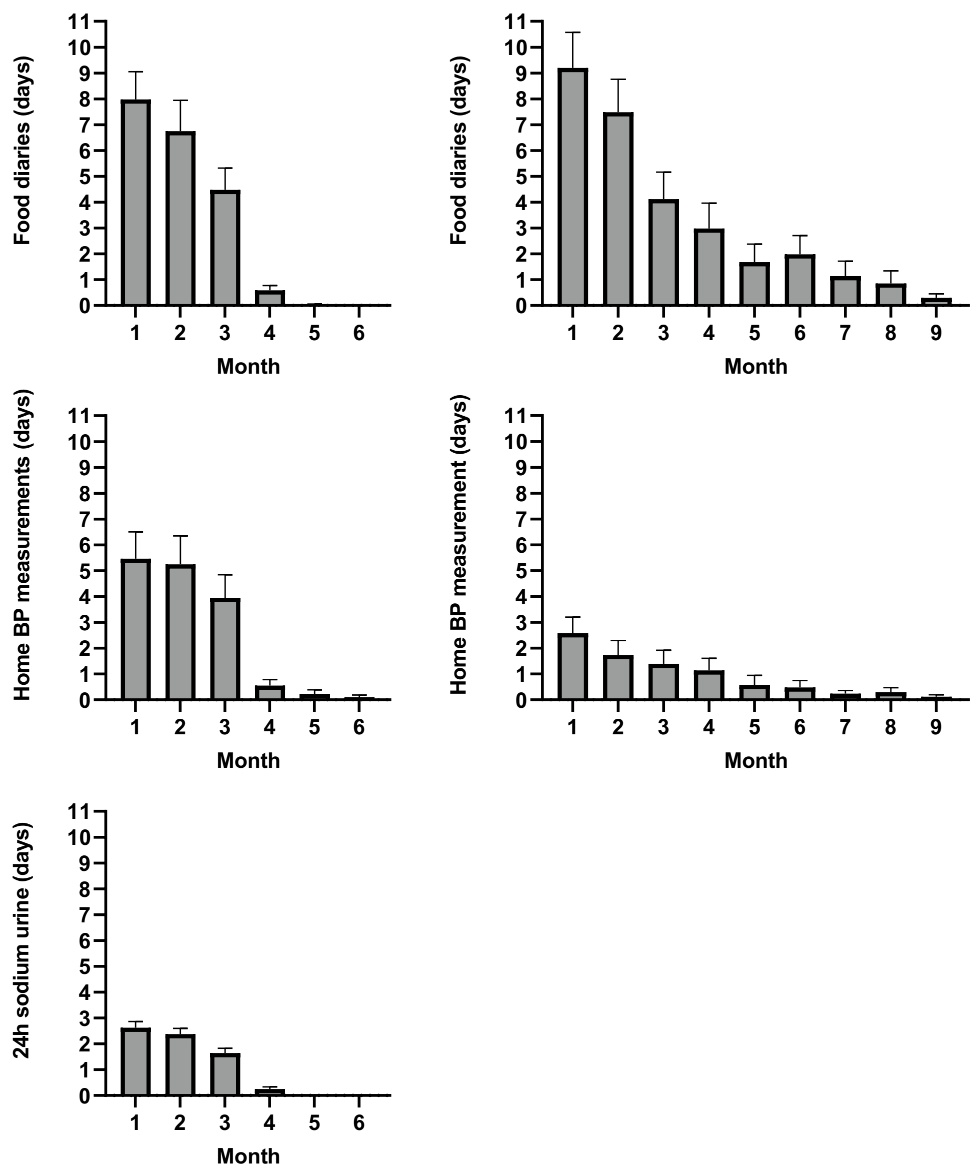

Fig. 2 Usage frequency of self-monitoring tools during the ESMO (left panel) and SUBLIME (right panel) interventions (months 1–3) and follow-up periods (months 4–6 in ESMO and 4–9 for SUBLIME). Data is presented as mean with standard error of the mean

Table 2 Association between baseline self-efficacy scores and usage frequency of self-monitoring tools during month 0–3 of the intervention in the ESMO intervention group (N=56)

	Low self-efficacy[a] $N=28$	High self-efficacy[a] $N=28$	P-value[b]
Food diaries (#days)	12 (8–33)	8.5 (5–20)	0.16
Home BP (#days)	11 (6–18)	7.5 (0–9)	0.01
Sodium 24-h urine (#days)	8 (6–11)	6 (0.5–8)	0.02
Summary score of self-monitoring tool usage (range 0–100)	63 ± 32	39 ± 31	0.01

Data is presented as median with interquartile range for the separate tools. The summary score is presented as mean ± SD

A T-test was used for the summary score

[a]Categorized based on the median self-efficacy score of 7.8 of the ESMO intervention group

[b]Differences in medians were tested with the Mann-Whitney U test

respectively. Nine participants (20%) used neither tool during the first month. Frequency of usage showed a steady decrease over time in the SUBLIME intervention group.

Baseline Self-Efficacy and Usage Frequency of Self-Monitoring Tools

In the combined intervention groups of ESMO and SUBLIME, no significant differences were found in the overall summary score of self-monitoring usage (range 0–100) for the subgroups with a self-efficacy score below or above median (summary scores of 55 [IQR = 31] and 45 [IQR = 27] respectively, $P = 0.08$). However, a significant interaction was observed for study ($P_{interaction} = 0.003$) indicating different effects across the two interventions. Therefore, further results are presented separately for the ESMO study (Table 2) and SUBLIME study (Table 3). In the ESMO intervention, frequency of use was higher for all tools in the low-efficacy group. This pattern was also reflected in a higher summary score of self-monitoring tool usage for the low self-efficacy group compared to the high self-efficacy group (6.8 ± 0.4 versus 5.3 ± 1.9, $P = 0.01$). However, the difference was not statistically significant ($P = 0.16$) for the number of days participants recorded their food intake. In the SUBLIME intervention, a difference was only observed for the food diary with more frequent usage in the high self-efficacy group (median 26 versus 12 days, $P = 0.03$).

Usage Frequency of Self-Monitoring Tools and Changes in Self-Efficacy

As previously reported [45], patients in the ESMO intervention group had significantly higher self-efficacy levels after 3 months of intervention compared to baseline (see also Table S3A). Changes in self-efficacy scores were not significantly associated with usage frequency of self-monitoring tools (Table 4). However, slightly positive trends were observed for the individual tools with Spearman correlation coefficient ranging from 0.14 ($P = 0.32$) to 0.27 ($P = 0.06$). In SUBLIME, no changes in self-efficacy levels over time were observed in the intervention group (see [44] and Table S3B). Also, no associations were found with frequency of use of the self-monitoring tools.

Discussion

To the best of our knowledge, this study is the first to examine usage frequency of multiple self-monitoring tools during low-sodium diet self-management interventions

Table 3 Association between baseline self-efficacy and usage frequency of self-monitoring tools during month 0–3 of the intervention in the SUBLIME intervention group (N = 44)

	Low self-efficacy[a] $N=22$	High self-efficacy[a] $N=22$	P-value[b]
Food diaries (#days)	12 (2–20)	26 (7–56)	0.03
Home BP (#days, registered)	0 (0–6)	1.5 (0–9)	0.38
Home BP (#days, reported)	4 (1–8)	4 (1–9)	0.73
Summary score of self-monitoring tool usage (range 0–100)	46 ± 27	54 ± 17	0.24

Data is presented as median with interquartile range for the separate tools. The summary score is presented as mean ± SD

A T-test was used for the summary score

[a]Categorized based on median self-efficacy score of 75 of the SUBLIME intervention group

[b]Differences in medians were tested with the Mann-Whitney U test

Table 4 Spearman correlation coefficients of usage frequency of self-monitoring tools during month 0–3 with changes in self-efficacy scores in the intervention groups during 3 months

	ESMO ($N=56$)	SUBLIME ($N=44$)
Food diaries (#days)	0.27 ($P=0.06$)	−0.11 ($P=0.47$)
Home BP (#days, registered)	0.14 ($P=0.32$)	0.06 ($P=0.68$)
Home BP (#days, reported)	N.A	−0.01 ($P=0.96$)
Sodium 24-h urine (#days)	0.24 ($P=0.09$)	N.A
Summary score of self-monitoring tool usage (range 0–100)	0.24 ($P=0.09$)	−0.08 ($P=0.63$)

among patients with chronic kidney disease and to explore its relationship with self-efficacy. Usage frequency of self-monitoring tools varied largely between patients and decreased substantially with time. In the ESMO intervention, low self-efficacy was associated with a higher usage frequency of the self-monitoring tools. However, this finding was not confirmed in the SUBLIME intervention in which patients with low self-efficacy used the online food diary less often. No significant associations were found between usage frequency of self-monitoring tools and changes in self-efficacy.

Our results showed that the frequency of tool usage was highest at the beginning of both interventions. Thereafter, a sharp drop in usage was observed in the ESMO study at the end of its 3-month intervention while a more gradual decrease in usage frequency over time was found in the SUBLIME study. This usage pattern is in agreement with the set-up of both studies: ESMO patients were instructed to monitor at least once a week in the first half of the intervention and thereafter once every 2 or 3 weeks (depending on patients' preferences). SUBLIME patients were instructed to monitor as frequently as they liked.

From a psychoeducational perspective, the observed pattern also makes sense as patients are likely to benefit most from the provided feedback early in the intervention (e.g. learn which products contain the highest or lowest amount of salt, identify the link between behavior and outcomes such as blood pressure and sodium excretion) while later in the intervention, self-monitoring could function as a reminder (e.g. refocus attention towards your lifestyle goals), to provide feedback about progress (e.g. 'Am I still on the right track?') and guide subsequent coping strategies [21, 23, 30–32]. The food diary can be regarded an educational tool; i.e. it provides knowledge on the salt content of the diet. After patients gained this knowledge, they may not need to keep a diary at regular intervals anymore, but still be able to adhere to a healthier diet. For chronic kidney disease patients, it is advised to measure BP regularly and continuously.

The online food diary was the most used self-monitoring tool in both studies. This might indicate that patients experience a higher need for feedback on their dietary intake than is commonly offered in usual care. Overall use was higher in SUBLIME than in ESMO. A potential explanation could be that the food diary used in SUBLIME was more interactive than the earlier version used in the ESMO intervention; this newer SUBLIME version visually showed the effects of different food choices on patients' daily salt intake and was more user-friendly. In the ESMO study, also a high frequency of blood pressure measurements was recorded, while this was much lower in the SUBLIME study. It should be noted that patients in ESMO received specific and directed instructions on the use of self-monitoring. In SUBLIME, it was recommended to regularly self-monitor blood pressure, but no specific instructions were given on the frequency of self-monitoring. Finally, ESMO's urinary sodium measurement device required 24-h urine collection and hence was the most time- and energy-consuming tool which is likely the reason why this tool was used less frequently compared to the other tools.

As previously described [44, 45], participants of both studies greatly appreciated the self-monitoring tools: patients believed that the urinary sodium measurement device and online food diary were very useful and insightful, especially SUBLIME's interactive food diary. However, both tools also gave frustration and were considered time-consuming: not all food items were available or hard to find in the online database and the urinary sodium measurement device [50] regularly failed which meant the procedure had to be repeated. Further improving the quality and ease of use of the self-monitoring tools might advantage their use and effectiveness.

In both the ESMO and SUBLIME study populations, patients believed to a relatively high extent that they were capable to self-manage their disease (i.e. high levels of self-efficacy) prior to the start of the intervention. Our results showed that ESMO patients with lower levels of self-efficacy used the self-monitoring tools more frequently than patients with higher levels of self-efficacy. A higher usage frequency of self-monitoring tools tended to go together with increases in self-efficacy during the 3-month ESMO intervention. However, these results were not statistically significant, possibly caused by the relatively small patient group. Nevertheless, these findings might support our hypotheses that self-monitoring can improve patients' self-efficacy, and that patients with lower levels of self-efficacy are likely to use the offered self-monitoring tools more frequently. This is also supported by previous research in a chronic kidney disease population [38] in which patients with lower levels of self-efficacy perceived to a higher extent that a lack of feedback on their daily sodium intake is an important barrier for successful reduction of sodium intake. This suggests that patients with lower self-efficacy have a stronger need for feedback and support.

However, our hypotheses were not confirmed in the SUBLIME population, in which low self-efficacy was not associated with a higher frequency of use of self-monitoring tools. In contrast, patients with higher levels of self-efficacy used the interactive online food diary more frequently. We hypothesize that differences in the nature of the interventions and participants could potentially explain these contradictory findings. First, compared to the SUBLIME intervention, the ESMO intervention had a strong focus on strengthening patients' self-efficacy, for example: ESMO patients received a 1-h motivational interview session which focused on, among other things, setting personal sodium goals, discussing barriers and strategies for sodium reduction, and strengthening self-efficacy. Second, the ESMO study had a stronger focus on self-monitoring with more self-monitoring tools and also with instructions on usage of these tools, while in the SUBLIME study the frequency of use of the interactive tools was more on patients' own initiative to foster autonomous motivation [59]. Thus, for our results, this could mean that: patients with low self-efficacy might benefit most from self-monitoring tools when they are being provided with strict instructions, while patients with high self-efficacy might be more inclined to use self-monitoring tools in situations without strict instructions. In the ESMO study, patients with low self-efficacy also reported lower mental well-being which might be related to an increased desire/need to be in control and support and hence, the willingness to self-monitor. In the SUBLIME study, patients with high self-efficacy also engaged in sodium reduction by themselves and to a lesser extent by external factors (i.e. relatively high levels of intrinsic motivation and lower levels of extrinsic motivation), which might be related to their inclination to use self-monitoring tools without strict instructions from professionals. Improved insight into the associations between self-efficacy and self-monitoring might be useful in tailoring future interventions to the individual needs of patients. Patients with low self-efficacy might benefit most from self-monitoring but may need more support and guidance (e.g. self-monitoring combined with coaching, goal-setting, and feedback) than patients with higher self-efficacy. Willingness to use self-monitoring tools is known to vary largely among chronic diseases [33] and also depends on other factors such as education level and complexity of the tools. Studies in different settings are therefore needed to test our different hypotheses.

A major strength of this study is the availability of actual data on self-monitoring behavior from two intervention studies. Previous studies measured willingness to monitor using questionnaires [33, 35, 39, 40] but willingness to use might not translate into actual use. Furthermore, in both interventions, patients filled out the food diaries online and usage frequency of this tool is thus complete. However, registration of self-measured BP might be incomplete and the same holds, albeit to a lesser extent, for the urinary sodium measurements in the ESMO study. By using summary scores to quantify overall use of self-monitoring tools, the influence of personal preferences for specific tools is limited. A final strength of this study is that we were able to provide extensive data from two high-quality randomized multicenter trials in The Netherlands [44, 45]. Main characteristics of the ESMO and SUBLIME intervention studies are comparable which made it possible to combine the data. The intervention of SUBLIME was also largely based on the experiences in the ESMO study and both studies succeeded in lowering sodium intake after 3 months.

A main limitation of this study is the relatively small sample size. The trials were not designed to answer our current research questions and for the analyses concerning usage frequency of self-monitoring tools in which only patients from the intervention groups could be included. Thus, the power of this study could be considered relatively low, especially for the research question whether a higher usage frequency of self-monitoring tools would be associated with an improvement in self-efficacy. It should also be noted that for these analyses, patients who dropped out during the first 3 months were excluded. Finally, different self-efficacy questionnaires were used in the two studies: the Chronic Disease Self-Efficacy Scales Manage Disease in General Scale [53] in the ESMO study and the PIH [54] in the SUBLIME study. However, both questionnaires have been validated, are commonly used in the chronic kidney disease population, and measure the same construct, i.e. whether patients are able to manage their chronic disease.

In conclusion, large variations in usage frequency of self-monitoring tools were found in two self-management intervention studies targeting sodium intake in patients with chronic kidney disease. Low self-efficacy at baseline was associated with higher frequency of self-monitoring among ESMO participants during the intervention period. This association was not confirmed in the SUBLIME study. No evidence was found that a higher frequency of self-monitoring is associated with an improvement in self-efficacy over time. We hypothesize that patients with low self-efficacy might benefit most from frequent use of self-monitoring tools under the condition that sufficient guidance and support is provided.

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Declarations

Ethical Approval All procedures performed in studies involving human participants were in accordance with the ethical standard of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed Consent Informed consent was obtained from all individual participants included in the ESMO study and the SUBLIME study.

Statement Regarding the Reference of Animals This study does not contain any studies with animals performed by any of the authors.

Conflict of Interest The authors declare no competing interests.

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