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Research Paper

Effect of banana intake on serum potassium level in patients undergoing maintenance hemodialysis: A randomized controlled trial

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ABSTRACT

Objective: This study aimed to assess the effect of banana intake during hemodialysis on serum potassium levels in maintenance hemodialysis (MHD) patients.

Methods: This study was a single-center, randomized controlled clinical trial conducted from September 15 to December 15, 2021, at a tertiary hospital in southern China. A total of 126 MHD patients were randomly assigned to either the intervention group ($n = 64$) or the control group ($n = 62$). Patients in the intervention group consumed approximately 250 g of bananas during hemodialysis, while those in the control group did not consume any food during hemodialysis. Demographic information and hemodialysis-related parameters were collected through case information collection before hemodialysis. Laboratory indicators (such as complete blood count, biochemical indicators, inflammation markers, liver function, kidney function, etc.) were evaluated by collecting pre-hemodialysis blood samples from patients. Serum potassium and blood glucose levels were measured at 2 h and 4 h of hemodialysis, as well as before the next hemodialysis session, and hemodialysis-related complications were recorded. The blood potassium and blood glucose indicators during hemodialysis were compared using repeated measures analysis.

Results: A total of 122 MHD patients completed the study (61 in each group). The results showed that there was no significant interaction between group and time on serum potassium levels. However, serum potassium levels in the intervention group were higher than those in the control group at 2 h (3.9 ± 0.5 mmol/L vs. 3.6 ± 0.3 mmol/L, $P < 0.01$) and 4 h (3.5 ± 0.4 mmol/L vs. 3.3 ± 0.3 mmol/L, $P < 0.01$) of hemodialysis. There was no interaction between group and time on blood glucose levels. The incidence of arrhythmias (8.2% vs. 29.5%, $P = 0.003$) and hypokalemia (52.5% vs. 80.3%, $P = 0.002$) during hemodialysis was significantly lower in the intervention group compared to the control group.

Conclusion: Consuming approximately 250 g of bananas at the start of hemodialysis does not lead to hyperkalemia. It can effectively reduce the incidence of hypokalemia and arrhythmias, and prevent a rapid decline in serum potassium levels during hemodialysis.

What is known?

- Excessive fruit intake in patients undergoing maintenance hemodialysis is not recommended to avoid adverse events caused by hyperkalemia.
- A strict restriction of fruit intake during hemodialysis may increase the incidence of hypokalemia.
- The amount of fruit intake in patients undergoing maintenance hemodialysis remains unclear.

What is new?

- Ingestion of 250 g of banana at the beginning of hemodialysis can effectively reduce the incidence of hypokalemia and

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arrhythmia and prevent the serum potassium level from falling too rapidly during hemodialysis.
- Nurses are advised to collaborate further with physicians and nutritionists to develop applicable dietary potassium management plans for patients undergoing maintenance hemodialysis.

1. Introduction

According to hemodialysis guidelines, excessive fruit intake in patients undergoing maintenance hemodialysis (MHD) is not recommended to avoid death and adverse events caused by hyperkalemia [1,2]. However, a strict restriction of fruit intake during hemodialysis may increase the incidence of hypokalemia [2]. As a common complication in patients undergoing MHD, hypokalemia has not received much attention. According to the previous literature, the prevalence of hypokalemia in patients undergoing MHD before hemodialysis was 0.4%–11%, while the incidence of hypokalemia after hemodialysis was as high as 54.59% [3,4]. Hypokalemia can trigger a variety of arrhythmias, including ventricular arrhythmias, and increase the risks of mortality in patients undergoing MHD [5–7]. Up to 70% of patients undergoing MHD have arrhythmias during hemodialysis, as indicated by wearable defibrillators [8]. Therefore, excessive fluctuations in the serum potassium level and hypokalemia during hemodialysis are important causes of arrhythmia and even sudden death in these patients [9]. Avoiding hypokalemia and excessive fluctuation of the serum potassium level during hemodialysis is critical to the stability of the vital signs of patients during hemodialysis and is an important clinical issue that should be addressed.

Fruits provide potassium and other micronutrients, which benefit potassium balance among patients undergoing MHD [10]. As recommended by the International Society for Renal Nutrition and Metabolism, supplementing fruit and food benefits nutrition status, quality of hemodialysis, and clinical prognosis among patients with stable hemodynamics and no dietary contraindications [11]. However, eating fruit or food during hemodialysis remains controversial in real-world practices. For example, a retrospective study demonstrated that although eating food during hemodialysis can control the blood phosphorus level and improve nutrition status, serum potassium can be high [12]. By contrast, an 8-day intervention study found that a daily intake of two apples improved antioxidant parameters and reduced the risk of death in patients undergoing MHD without affecting serum potassium levels [13,14]. A higher consumption of fruit was also associated with lower all-cause and noncardiovascular mortality in patients receiving MHD [15].

Despite this, strict fruit restriction for patients undergoing MHD is widely performed in clinical practices. A recent cross-sectional study showed that 97% of patients with MHD had dietary fiber intake far below the recommended 25 g/day [16]. Similarly, a prospective cohort study also found that only 4% of patients undergoing MHD consumed at least four servings of fruits or vegetables as recommended in the general population [15]. Nevertheless, an extremely low fruit intake was difficult to maintain and was negatively associated with health outcomes, including mental health, among patients undergoing MHD [17].

The current randomized controlled trial aimed to examine the effect of banana intake during hemodialysis on serum potassium levels in patients undergoing MHD. In particular, bananas contain 256 mg of potassium per 100 g, higher than other fruits. No conclusive evidence has been found regarding the time the human digestive tract takes to absorb the potassium ions in bananas. However, literature has shown that the average passage time of bananas in the gastrointestinal tract is within 6 h and that the small intestine rapidly absorbs the sugars. Given that blood potassium and blood sugar are both small molecules, it was speculated that their metabolism times in the gastrointestinal tract may be similar [18]. To verify this speculation, this rigorous randomized controlled trial explored whether banana intake was safe and helpful in preventing hypokalemia and improving health outcomes among patients undergoing MHD.

2. Method

2.1. Study design

We conducted a single-center, parallel, prospective, randomized controlled trial (Chinese Clinical Trial Registry: ChiCTR2300069559). This study report follows Consolidated Standards of Reporting Trials (CONSORT) [19].

2.2. Stuyd setting and participants

From September 15 to December 15, 2021, 122 patients undergoing MHD were recruited from a tertiary hospital in southern China. The study included patients undergoing MHD aged 18–80 years. In clinical practice, patients undergoing dialysis span a wide age range. It is necessary to confirm the safety of the intervention across this age spectrum. The patients should 1) have end-stage renal disease receiving maintenance hemodialysis treatment for more than one year to ensure patient adjustment to the dietary habits after initiating hemodialysis maintenance treatment; 2) have sufficient vascular access flow to allow the hemodialysis to be performed; 3) have no oral or gastrointestinal diseases or symptoms, and 4) can eat orally and take 250 g of food during hemodialysis. This study excluded patients who 1) had dietary contraindications for hemodialysis, 2) were allergic to fruits or did not eat bananas, 3) were unconscious, 4) coughed frequently or were at risk of choking; 5) patients underwent hemodialysis treatment for less than 3 h; 6) had taken food or drugs that affect serum potassium before hemodialysis; 7) those expected to have low blood pressure or diarrhea before hemodialysis.

Sample sizes were calculated based on information from the prior pilot study. In the pilot study, ten patients were enrolled in each group. The main observation indicator was the potassium levels at 2 h after initiating the hemodialysis and at the end of the hemodialysis. Based on the study results, 56 patients in each group were required, considering a standard deviation of 0.3 mmol between groups, a test efficiency 0.9, and a two-sided significant level of 0.05 [20]. Assuming a 10% loss-to-follow-up rate, the sample size in each group was determined to be 62 cases; thus, a total of 124 patients were needed in the two groups. A total of 126 patients were finally recruited and randomized.

2.3. Randomization and blinding

After the patients had signed the informed consent forms, they were randomly assigned to the intervention and control groups at a ratio of 1:1 based on their enrolment sequence and random sequence. An independent researcher generated the random sequence using a random number table. This study employed an open research design [21], meaning that researchers and participating patients were aware of their assigned treatment groups throughout the entire research process. Unlike single- or double-blind trials, this study did not employ methods to conceal the treatment grouping; rather, it utilized an open approach to random control. This design choice was based on a comprehensive consideration of the nature of the research question and ethical considerations regarding the study participants. The random sequence was sealed in opaque envelopes. The enrollment information of each patient (i.e., entry number, corresponding intervention method) was sealed in an opaque envelope before the study started. When the sealed envelope opened, the researcher and subject knew which group they were about to be assigned.

2.4. Intervention

Our research team included a nephrology specialist, a researcher, and a senior nurse of nephrology. The nephrology researcher is responsible for proposing and designing the overall research plan. The nephrology specialist is mainly responsible for reviewing the safety of the research plan and formulating measures to ensure the smooth implementation of the plan. The nephrology senior nurse was responsible for implementing the plan, which involved monitoring the vital signs of MHD patients throughout the trial process and documenting hemodialysis-related complications. The two patient groups received collaborative treatment and care from the same research team, encompassing undifferentiated hemodialysis, vital signs monitoring, ECG (Electrocardiographic) monitoring, and health education. Before the trial commencement, participants in both groups were advised to restrict the consumption of high-potassium foods, emphasizing the specific types of such foods. We reviewed relevant literatures early on and determined that the fruit was 250 g banana through preliminary experiments [22,23]. The research team purchased the bananas from the same source.

Previous studies have confirmed that among MHD patients, those with diabetes have a higher incidence of hypoglycemia during the hemodialysis process compared to non-diabetic patients [24,25]. Therefore, our study also focused on the status of diabetic patients.

2.4.1. The intervention group

Participants in the experiment group ingested approximately 250 g of bananas, containing about 640 mg of potassium, which did not exceed the maximum recommended amount of potassium intake per day (about 2,730 mg) for patients undergoing MHD [26]. All enrolled patients were scheduled for a 4 h hemodialysis session. The amount of banana intake was measured using an electronic scale. Researchers provided bananas to patients in the intervention group before hemodialysis, stipulating that these bananas must be consumed within 60 min after the commencement of hemodialysis. The banana could be consumed continuously or intermittently as they saw fit over 1 h. The remaining bananas taken by the patients were also measured. An error within 5 g was allowed, and patients who had taken approximately 245 g to up to 255 g bananas were included in the analysis. Participants were withdrawn from the study if they did not finish the prescribed amount of bananas after more than 1 h of dialysis. At the same time, participants were prohibited from consuming other fruits. Throughout the hemodialysis process, the researcher continuously monitored the intervention group patients with electrocardiography and vital signs monitoring.

2.4.2. The control group

Participants in the control group did not ingest any food during the hemodialysis. All the participants received health education from the same team of trained nephrologists and hemodialysis nurses in the hospital to reduce the bias between groups Before the start of the study, health education for MHD patients included: 1) low potassium diets, such as avoiding high potassium fruits, vegetables, soups, and refraining from using high potassium salt (low sodium salt) and other high potassium foods and seasonings; 2) prompt reporting of discomfort during the study, such as chest tightness, palpitations, muscle spasms, etc.; 3) paying attention to gastrointestinal issues, and promptly reporting any gastrointestinal abnormalities before the study begins; 4) informing the researchers if new medications are needed before the study; 5) strengthening home monitoring of vascular access, maintaining the patency of vascular access, especially arteriovenous fistulas, and promptly reporting any abnormalities in vascular access function to the researchers. Patients in the control group were instructed not to consume high-potassium foods before hemodialysis and prohibited from ingesting any food during the hemodialysis session. Throughout the hemodialysis process, individuals in the control group underwent continuous ECG monitoring and vital signs surveillance.

2.5. Data collection

Nephrology researcher oversaw the data collection. Before hemodialysis, demographic information (including age, gender, weight, and dialysis vintage, etc.) and parameters related to hemodialysis (including patient's vascular access type, dialysis mode, dialysis time, etc.) were collected through case information collection and laboratory indicators (such as complete blood count, biochemical indicators, inflammation markers, liver function, kidney function, etc.) were assessed by collecting pre-hemodialysis blood samples from patients. Previous studies have shown that blood glucose levels in MHD patients fluctuate the most within 2 h of hemodialysis and the incidence of hypokalemia is highest after hemodialysis [27,28]. The primary observational metrics for enrolled patients were blood potassium and blood glucose levels, collected respectively before the initiation of hemodialysis, 2 h into hemodialysis, and at the 4 h mark. Patients were prescribed a 4 h hemodialysis session, allowing for a comprehensive observation of changes in blood potassium and blood glucose throughout the hemodialysis process. Additionally, during dialysis, patients' electrocardiograms, respiration, and blood oxygen saturation are monitored in real-time, and their blood pressure, heart rate, and consciousness status are measured every half hour. Similarly, patients need to be assessed every half hour for any discomfort, such as chest tightness, palpitations, and muscle spasms. Patients underwent dialysis three times a week, with a gap of one day between each session. The study also collected blood potassium indicators before the next hemodialysis session to examine whether the intake of bananas would impact blood potassium during the subsequent interdialytic period. Of course, patients were informed in the informed consent form before the study that they should refrain from consuming any high-potassium foods during the interdialytic period to maintain the objectivity of the research.

2.5.1. Primary outcome

The serum potassium level was the primary study outcome. Participant blood samples were collected before (during blood extraction), 2 and 4 h after initiating the hemodialysis, and before the next hemodialysis. The collected blood samples were sent to the laboratory department of the hospital immediately for analysis.

2.5.2. Secondary outcomes

Serum glucose levels and complications, such as hypotension, muscle cramps, and chest tightness, were monitored closely during hemodialysis, and the patient's vital signs and associated symptoms were monitored closely.

2.6. Data analysis

All data were analyzed using the R language (version 4.0.3). For non-normally distributed variables, median (P_{25}, P_{75}) was used.

Mean and standard deviation (SD) were applied for normally distributed variables. For categorical variables, frequencies and proportions were used to describe the data. Continuous variables with a normal distribution in both groups were compared using an independent sample *t*-test, and non-normally distributed variables in both groups were analyzed using the Mann-Whitney *U* test. Categorical variables between groups were compared using the chi-square or Fisher's exact test. The change of each variable in each group at different time intervals was analyzed by one-way repeated measures analysis of variance (ANOVA). Post Hoc pairwise comparisons with Bonferroni correction were performed when a significant main effect was found. $P < 0.05$ was considered statistically significant.

2.7. Ethical considerations

This study was conducted on the ethical principles of the Declaration of Helsinki and has been approved by the institution's ethics committee (KY-Q-2021-172-02). All the participants had signed informed consent forms before participating.

3. Results

3.1. Baseline characteristics

A total of 126 participants were randomized, in which 122 of them completed the follow-up. The median hemodialysis day of the participants was 1,594 days. The majority of the participants had diabetes (27.0%) and hypertension (77.9%). The autogenous arteriovenous fistula was the most common vascular access type (88.5%). The baseline characteristics of the participants in this trial are shown in Table 1, which shows no statistically significant differences.

The proportion of diabetic patients in the two groups was approximately comparable (22.9% vs. 31.1%, $P > 0.05$). However, further investigation revealed that diabetic patients, compared to non-diabetic patients, showed significantly elevated glucose levels before hemodialysis (10.8 [7.9, 14.8] mmol/L vs. 6.9 [5.9, 7.9] mmol/L) at 2 h into hemodialysis (7.6 [6.5, 9.6] mmol/L vs. 5.8 [5.0, 6.7] mmol/L), and 4 h after hemodialysis (6.4 [4.9, 9.4] mmol/L vs. 5.4 [4.2, 6.8] mmol/L), while no statistically significant differences were observed in other complications when compared to non-diabetic patients ($P > 0.05$).

3.2. Primary outcome

Changes in serum potassium during hemodialysis are shown in Table 2. Compared to the control group, serum potassium levels were higher in the intervention group at 2 h (3.9 ± 0.5 mmol/L vs. 3.6 ± 0.3 mmol/L; $t = 3.920$; $P < 0.001$) and 4 h of hemodialysis (3.5 ± 0.4 mmol/L vs. 3.3 ± 0.3 mmol/L; $t = 3.840$; $P < 0.001$) (Table 2). No hyperkalemia was observed during dialysis in either of the groups. In addition, the decrease of serum potassium level in the intervention group at 2 h of hemohemodialysis was less than that in the control group (0.9 ± 0.5 vs.1.1 ± 0.4; $t = 2.030$; $P = 0.045$) (Table 3).

3.3. Secondary outcomes

There was no statistically significant difference in glucose levels between the two groups compared to each other during hemodialysis and before the next hemodialysis (Table 2). In addition, the glucose of the intervention group decreased less than that of the control group at 2 h (−0.8 [−2.5, 0.4] vs.−2.1 [−4.3, −0.4]; $Z = -2.830$, $P = 0.005$) and 4 h of hemodialysis (−1.2 [−2.5, 0.5] vs.−2.6 [−4.4, −1.2]; $Z = -3.141$; $P = 0.002$) (Table 3).

There was no significant difference in the incidence of hypokalemia and hypoglycemia at 2 h of hemodialysis and no statistically significant difference in the incidence of hypoglycemia at 4 h of hemodialysis when compared between the two groups. However, the incidence of hypokalemia at 4 h of hemodialysis was significantly higher in the control group than in the intervention group (80.3% vs. 52.5%, $\chi^2 = 9.404$, $P = 0.002$) (Table 4). Also, participants' heart rhythms during hemodialysis were monitored. It was found that the incidence of arrhythmias was higher in the control group ($n = 18$, 29.5%) than in the intervention group ($n = 5$, 8.2%) ($\chi^2 = 9.055$; $P = 0.003$).

4. Discussion

This study investigates the impact of consuming a defined quantity of bananas during hemodialysis on serum potassium and glucose levels in MHD patients and whether it increases dialysis-related complications in MHD patients. The results indicate that consuming 250 g of bananas at the beginning of hemodialysis is safe, as it neither induces post-dialysis hyperkalemia nor increases the incidence of hypokalemia and hypoglycemia during the hemodialysis process. Moreover, it does not increase the occurrence of related complications during hemodialysis in MHD patients.

Based on the theoretical basis, diffusion in the hemodialysis process will remove about 80% of potassium ions and about 22 g of glucose [29]. This study compared the serum potassium levels at 2 h and the end of hemodialysis between participants in the two groups who ingested 250 g of bananas and who didn't take any food (control group) during hemodialysis. Our data shows that although the average serum potassium levels of patients in the intervention group were higher than those in the control group at 2 h and 4 h into hemodialysis, the potassium levels in both groups gradually decreased with increasing hemodialysis time, reaching their lowest point at 4 h of dialysis. This was consistent with previous literature that dietary potassium intake did not significantly predict higher serum potassium levels in hemodialysis patients [30]. Simultaneously, we counted the drop in serum potassium during hemodialysis. The decrease in serum potassium level in the intervention group was smaller than that in the control group at 2 h of the hemodialysis, whereas this decrease was the same at the end of the hemodialysis.

Additionally, we found that the serum potassium levels for all patients were within the normal range before the next hemodialysis session. Therefore, hyperkalemia did not occur at the end of dialysis or before the subsequent session. This observation may be related to compliance with potassium restriction during non-hemodialysis treatment, as the psychological needs of the patients for eating fruits have been fulfilled. Bananas are high in potassium and might increase serum potassium levels at the beginning of the hemodialysis. It could also increase the amount of feces through dietary fiber, thereby promoting the entry of potassium into cells and the excretion of potassium in feces [31].

More importantly, our study found that consuming 250 g of bananas at the start of hemodialysis can effectively reduce the incidence of arrhythmias. This may be related to the intervention group having lower rates of serum potassium reduction during hemodialysis and a lower incidence of hypokalemia than the control group. Many factors can lead to excessive fluctuation of serum potassium level and hypokalemia during hemodialysis, including strict restriction of high-potassium diets, low-potassium dialysate, hyperkalemia before hemodialysis (serum potassium ≥5.5 mmol/L), acid-base changes, glucose, insulin level, and catecholamine activity that can affect the potassium transmembrane transport [32]. Many studies have shown that rapid potassium clearance and

Table 1
Comparing general data between two groups.

Variables	Overall (n = 122)	Intervention group (n = 61)	Control group (n = 61)	χ^2/Z	P
Sex				3.280	0.070
Male	62 (50.8)	26 (42.6)	36 (59.0)		
Female	60 (49.2)	35 (57.4)	25 (41.0)		
Days of hemodialysis	1,594 (828, 3265)	1,811 (860, 3,787)	1,534 (798, 2,894)	−0.878	0.380
Diabetes				1.040	0.308
No	89 (73.0)	42 (68.9)	47 (77.1)		
Yes	33 (27.0)	19 (31.1)	14 (22.9)		
Hypertension				1.190	0.276
No	27 (22.1)	16 (26.2)	11 (18.0)		
Yes	95 (77.9)	45 (73.8)	50 (82.0)		
Ever had cerebral infarction/hemorrhage				–	1.000[a]
No	116 (95.1)	58 (95.1)	58 (95.1)		
Yes	6 (4.9)	3 (4.9)	3 (4.9)		
Heart disease				1.440	0.230
No	101 (82.8)	53 (86.9)	48 (78.7)		
Yes	21 (17.2)	8 (13.1)	13 (21.3)		
Age (years)	54 (47, 64)	54 (41, 62)	54 (48, 67)	−1.863	0.150
Dry weight (kg)	56.8 (48.3, 67.0)	54.0 (47.0, 64.8)	58.0 (50.0, 69.5)	−1.636	0.100
Hemodialysis mode				0.361	0.548
HD	87 (71.3)	42 (68.9)	45 (73.8)		
HDF	35 (28.7)	19 (31.1)	16 (26.2)		
Complications during hemodialysis				–	1.000[a]
Low blood pressure	9 (7.4)	4 (6.6)	5 (8.2)		
Muscle cramps	5 (4.1)	3 (4.9)	2 (3.3)		
None	107 (87.7)	53 (86.9)	54 (88.5)		
Chest tightness	1 (0.8)	1 (1.6)	0 (0)		
Vascular access				–	0.716[a]
AVF	108 (88.5)	54 (88.5)	54 (88.5)		
AVG	7 (5.7)	4 (6.6)	3 (4.9)		
NCC	2 (1.6)	0 (0)	2 (3.3)		
TCC	5 (4.1)	3 (4.9)	2 (3.3)		
Serum potassium level before hemodialysis (mmol/L)	4.7 (4.3, 5.2)	4.9 (4.3, 5.4)	4.6 (4.3, 5.0)	−1.508	0.130
Glucose level before hemodialysis (mmol/L)	7.5 (6.3, 9.2)	7.3 (6.1, 8.8)	7.7 (6.3, 10.6)	−1.726	0.084
Leukocyte (*10^9/L)	5.7 (4.7, 7.3)	5.6 (4.7, 6.7)	5.9 (4.8, 7.5)	−0.914	0.361
Hemoglobin (g/L)	106 (98, 117)	108 (97, 120)	106 (98, 114)	−0.502	0.616
Neutrophil ratio (%)	0.7 (0.6, 0.7)	0.6 (0.6, 0.7)	0.7 (0.6, 0.7)	−0.443	0.658
Glycated hemoglobin (%)	5.6 (5.2, 6.1)	5.7 (5.3, 6.1)	5.5 (5.2, 6.1)	−0.608	0.543
Alanine aminotransferase (U/L)	11.0 (8.0, 14.8)	11.0 (8.0, 16.0)	10.0 (8.0, 13.0)	−0.906	0.365
Albumin (g/L)	37.7 (35.7, 39.3)	38.1 (36.7, 39.6)	37.5 (35.5, 38.8)	−2.087	0.059
Low-density lipoprotein (mmol/L)	2.7 (2.1, 3.2)	2.8 (2.1, 3.3)	2.5 (2.0, 3.1)	−1.101	0.271
Biochemical calcium (mmol/L)	2.3 (2.2, 2.5)	2.3 (2.2, 2.5)	2.3 (2.2, 2.5)	−0.231	0.818
Urea (mmol/L)	25.7 (20.3, 30.0)	25.5 (19.8, 28.6)	26.1 (22.6, 30.2)	−1.303	0.193
Creatinine (mmol/L)	974.6 (852.3, 1,113.8)	963.6 (850.7, 1,113.8)	979.1 (885.2, 1,113.7)	−0.871	0.384
Ferritin (ug/L)	173.0 (69.2, 394.1)	213.9 (53.8, 395.3)	159.8 (79.0, 353.9)	−0.023	0.982
Creactive protein (mg/L)	1.6 (0.9, 4.8)	1.5 (0.6, 2.6)	1.8 (0.9, 6.6)	−1.295	0.195

Note: Data are n (%) or *Median* (P_{25}, P_{75}). [a] Fisher's exact test. AVF = autogenous arteriovenous fistula. AVG = arteriovenous graft. HD = hemodialysis. HDF = hemodiafiltration. NCC = non-cuffed catheter. TCC = tunnel-cuffed catheter.

Table 2
Changes in the serum potassium and glucose levels during hemodialysis in the two groups.

Varibles	Group	Baseline	2 h HD	4 h HD	Next HD	F for time	F for group	F for time×group interaction
Serum potassium (mmol/L)	Intervention group (n = 61)	4.8 ± 0.8	3.9 ± 0.5[a]	3.5 ± 0.4[a]	4.7 ± 0.7			
	Control group (n = 61)	4.6 ± 0.6	3.6 ± 0.3[a]	3.3 ± 0.3[a]	4.5 ± 0.7	171.320	18.861	0.408
	t	1.25	3.92	3.84	1.53			
	P	0.213	<0.001	<0.001	0.128	< 0.001	< 0.001	0.747
Glucose (mmol/L)	Intervention group (n = 61)	7.3 (6.1, 8.8)	6.4 (5.3, 7.5)[a]	5.8 (4.8, 7.4)[a]	7.3 (5.7, 8.5)			
	Control group (n = 61)	7.7 (6.3, 10.6)	6 (5.2, 7.0)[a]	5.2 (4.1, 6.8)[a]	7.3 (6.2, 9.4)[a]	17.516	0.158	1.348
	Z	-1.73	-0.84	-1.78	-0.44			
	P	0.084	0.400	0.075	0.663	< 0.001	0.691	0.258

Note: Data are *Mean* ± *SD* or *Median* (P_{25}, P_{75}). Baseline = before the initiation of hemodialysis. 2 h HD = 2 h after initiating hemodialysis. 4 h HD = 4 h after initiating hemodialysis. Next HD = before the next hemodialysis.
[a] significant changes in the respective outcomes compared to the baselines level (P < 0.05).

hypokalemia due to hypokalemic dialysate are important causes of ventricular arrhythmias and sudden cardiac death [5,33–36]. This study found that the average serum potassium level of the patients in the intervention group was higher than that in the control group at 2 hand 4 h after hemodialysis. Moreover, the average serum potassium level of patients in the intervention group was not lower than 3.5 mmol/L, whereas it was lower than 3.5 mmol/L among participants in the control group at the end of hemodialysis. Regarding the incidence of hypokalemia, it was lower in the intervention group than in the control group at 2 h and 4 h of

Table 3
The decrease levels of blood potassium and blood glucose at 2 h and 4 h into hemodialysis, as well as before the next hemodialysis session for both groups of patients.

Variables	Intervention group (n = 61)	Control group (n = 61)	t/Z	P
Serum potassium (mmol/L)				
Within-group difference (2 h HD-Baseline)	−0.9 ± 0.5	−1.1 ± 0.4	2.030	0.045
Within-group difference (4 h HD-Baseline)	−1.3 (−1.7, −0.9)	−1.4 (−1.6, −1.1)	−0.660	0.507
Within-group difference (Next HD-Baseline)	−0.1 (−0.3, 0.2)	−0.1 (−0.5, 0.2)	−0.200	0.844
Glucose (mmol/L)				
Within-group difference (2 h HD-Baseline)	−0.8 (−2.5, 0.4)	−2.1 (−4.3, −0.4)	−2.830	0.005
Within-group difference (4 h HD-Baseline)	−1.2 (−2.5, 0.5)	−2.6 (−4.4, −1.2)	−3.141	0.002
Within-group difference (Next HD-Baseline)	0.2 (−1.7, 1.0)	−0.5 (−1.9, 0.9)	−1.220	0.223

Note: Data are *Mean* ± *SD* or *Median* (P_{25}, P_{75}). Baseline = before the initiation of hemodialysis. 2 h HD = 2 h after initiating hemodialysis. 4 h HD = 4 h after initiating hemodialysis. Next HD = before the next hemodialysis.

Table 4
Incidence of hypokalemia and hypoglycemia at 2 h and 4 h of hemodialysis in the two groups.

Variables	2 h HD				4 h HD			
	Intervention group (n = 61)	Control group (n = 61)	χ^2	P	Intervention group (n = 61)	Control group (n = 61)	χ^2	P
Serum potassium (mmol/L)			1.873	0.171			9.404	0.002
≥3.5	46 (75.4)	38 (62.3)			29 (47.5)	12 (19.7)		
<3.5	15 (24.6)	23 (37.7)			32 (52.5)	49 (80.3)		
Glucose (mmol/L)			–	0.619[a]			0.344	0.557
≥3.9	60 (98.4)	58 (95.1)			56 (91.8)	53 (86.9)		
<3.9	1 (1.64)	3 (4.92)			5 (8.20)	8 (13.1)		

Note: Data are n (%). [a] Fisher's exact test. 2 h HD = 2 h after initiating hemodialysis. 4 h HD = 4 h after initiating hemodialysis. 3.5 mmol/L ≦ Serum potassium ≦ 5.5 mmol/L.

hemodialysis. At the same time, the decrease in serum potassium levels during hemodialysis in the intervention group was smaller than that in the control group, avoiding a rapid drop in the serum potassium level during the hemodialysis.

Therefore, consuming 250 g of bananas at the start of hemodialysis neither induces post-dialysis hyperkalemia nor increases the incidence of hypokalemia and arrhythmias during hemodialysis.

Hypoglycemia is a common complication of hemodialysis, with an incidence of up to 20% [37]. Hypoglycemia in MHD patients can lead to poor prognosis, with a mortality rate as high as 30% [38]. Previous studies have pointed out that the incidence of hypoglycemia in patients who eat food during hemodialysis is lower than that of patients who do not eat food during hemodialysis. Using glucose intravenously or eating food during hemodialysis is recommended to prevent hypoglycemia [39]. Surprisingly, in our study, although patients in the control group did not eat food during hemodialysis, their glucose levels were not significantly different from those in the intervention group, and no hypoglycemia occurred during hemodialysis in either group. The two groups had no difference in the glucose level during hemodialysis. This observation may be because the loss of glucose during hemodialysis can maintain appropriate glucose levels through enhanced gluconeogenesis and glycolysis. However, we counted the drop in glucose during hemodialysis and found that the decrease in glucose level in the intervention group was lower than that in the control group at 2 h and 4 h of hemodialysis. This may be because the sugar in bananas is ingested at the beginning of hemodialysis and needs to be slowly absorbed through the digestive tract to ensure that patients can continue to have an exogenous glucose supply during hemodialysis. Therefore, taking 250 g of bananas at the beginning of hemodialysis can avoid the rapid drop of the blood sugar level during hemodialysis, which is significant for maintaining blood sugar stability.

The intake of 250 g of banana at the beginning of hemodialysis did not increase the incidence of complications during hemodialysis. This study showed no statistical difference in the incidence of four complications, including hypotension, muscle spasm, and chest tightness during hemodialysis between the two groups. No other complications during hemodialysis were observed. Consistent with the current study, previous randomized controlled trials have also shown that a quantitative high-protein diet during hemodialysis increased the blood albumin level, patient energy, and satisfaction while controlling the phosphorus level and did not increase the incidence of hypotension during hemodialysis [12,40]. By contrast, some interventional studies have observed that eating food during hemodialysis can increase the incidence of hypotension during hemodialysis [32,41], which might be due to the increase of postprandial blood supply to the gastrointestinal circulation caused by the redistribution of vascular volume.

This study has limitations. First, this is an open-label, single-center study, which needs to be evaluated by more rigorous multicenter trials. Second, since most of the patients were recruited from southern China, the generalizability of this study to different ethnicities may be limited. Third, since bananas were the only fruit tested, the generalizability of this study to other fruits may also be limited. Fourth, this study did not follow up on long-term outcomes, including nutritional and psychological status. Fifth, this study did not evaluate the effects of various medications used by MHD patients. Finally, fruit intake during hemodialysis must be for patients without dietary contraindications, whereas it cannot replace drug potassium supplementation if the patient has hypokalemia.

5. Conclusion

Ingestion of 250 g banana at the beginning of hemodialysis does not lead to hyperkalemia and can effectively reduce the incidence of hypokalemia and arrhythmias, preventing too rapid a decrease in serum potassium levels during the hemodialysis process. An appropriate dietary potassium intake, such as bananas, reduces dietary plan limitations and brings health benefits to patients undergoing MHD by reducing hypokalemia and complications of hemodialysis. Nurses are advised to collaborate further with physicians and nutritionists to develop applicable dietary potassium management plans for patients undergoing MHD. The recommended amount of dietary potassium intake should be further examined in future large-scale randomized controlled trials to improve safety and health benefits in patients undergoing MHD.

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CRediT authorship contribution statement

Zilin Quan: Conceptualization, Methodology, Formal analysis, Writing - original draft, Writing - review & editing. **Caixia Li:** Methodology, Writing - original draft, Writing - review & editing. **Liyan Zhao:** Investigation, Writing - review & editing. **Dongmei Cui:** Investigation, Writing - review & editing. **Shuangxin Liu:** Investigation, Writing - review & editing. **Yan Yin:** Investigation, Writing - review & editing. **Qi Tang:** Investigation, Writing - review & editing. **Dehan Zeng:** Investigation, Writing - review & editing. **Li Song:** Conceptualization, Methodology, Writing - original draft, Writing - review & editing. **Xia Fu:** Conceptualization, Methodology, Writing - original draft, Writing - review & editing.

Data availability statement

The datasets generated during and/or analyzed during the current study are available from the corresponding author upon reasonable request.

Declaration of competing interest

The authors declare that they have no competing interests.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ijnss.2024.03.016.

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