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Research Article

Role of Predehydration as a Predictor of Dehydration: A Noninvasive Cross-Sectional Assessment of Elderly Individuals

Hideki Taniguchi[1*], Masuji Hattori[2], Tomoka Naruse[1], Sanae Matsuyama[1], Akemi Tanaka[1], Keiko Ushigome[1]

[1]*Department of Nutrition, Faculty of Human Services, Kanagawa University of Human Services, 1-10-1 Heisei, Yokosuka, Kanagawa 238-8522, Japan*

[2]*Department of Pediatrics, Hyogo College of Medicine, 1-1 Mukogawa, Nisinomiya, Hyougo 663-8501, Japan*

**Corresponding author:* *Dr. Hideki Taniguchi, MD, PhD, Department of Nutrition, Faculty of Human Services, Kanagawa University of Human Services, 1-10-1 Heisei, Yokosuka, Kanagawa 238-8522, Japan, Tel: +81-46-828-2660; Fax: +81-46-828-2660; Email: hstani@aol.jp*

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Abstract

Background

Mild dehydration can affect a person’s daily life, especially among the elderly. Although it is currently impossible to identify the state of predehydration (PD), we defined PD as the suspected loss of body fluids, not accompanied by subjective symptoms, in which the serum osmotic pressure is above the standard limit of 292 mOsm/kg H_2O. The goal of this study was to develop an assessment method based on the results of sensitivity testing among individuals from elder-care institutions.

Methods

We evaluated the serum osmotic pressure of 391 subjects who were >65 years old and who had been admitted to, or regularly visited, an elder-care institution. We then determined the association between serum osmotic pressure and various previously identified dehydration-related diagnostic factors.

Results

PD was confirmed in 89 subjects (22.8%) via serum osmotic pressure measurements. We conducted various optimization steps by evaluating the sensitivity, specificity, and predictive values of various patient parameters indicative of the presence of PD. The sensitivity of our noninvasive check sheet used to assess PD among the elderly subjects was high (0.99), but its specificity was low (0.16).

Conclusion

We found that 22.8% of our subjects had PD, and we used this data to develop an effective noninvasive tool for detecting PD among elderly individuals.

Keywords: Dehydration; Elderly; Predehydration; Noninvasive tool

Abbreviations

BUN/Cr: Blood Urea Nitrogen/Creatinine Ratio;
Cr: creatinine;
ICD: The International Statistical Classification of Diseases and Related Health Problems;
ICD10-E87.0: the International Statistical Classification of Diseases, Injuries, and Causes of Death;
N group: the Normal group;
PD: Predehydration;
RBC: Red Blood Cell Count;
TG: Triglycerides;
WBC: White Blood Cell Count

Introduction

Dehydration can be classified as either mild, moderate, or severe [1]. However, elderly individuals can be affected by a milder state of dehydration that does not correspond to any of these classifications. Therefore, we hypothesized that a predehydration (PD) state exists in elderly individuals that cannot be identified using objective findings or subjective symptoms. Based on this hypothesis, we defined PD as a loss of bodily fluids accompanied by a serum osmotic pressure that is above the standard levels, based on hematological findings. According to the International Statistical Classification of Diseases and Related Health Problems (ICD) from the International Statistical Classification of Diseases, Injuries, and Causes of Death (ICD10-E87.0), hypertonic dehydration (hyperosmolality) is diagnosed as a serum osmotic pressure of >300 mOsm/kg H_2O [2]. In contrast, the standard levels for serum osmotic pressure are 275–292 mOsm/kg H_2O. Therefore, we defined PD as the suspected loss of body fluids (not accompanied by subjective symptoms), in which the serum osmotic pressure is above the upper standard limit (292 mOsm/kg H_2O). Furthermore, we hypothesize that if PD is ignored in elderly individuals, various factors, such as lack of water intake, excessive fluid loss, and changes in the environment (e.g., heat or dryness), can cause PD to progress to dehydration (Figure 1).

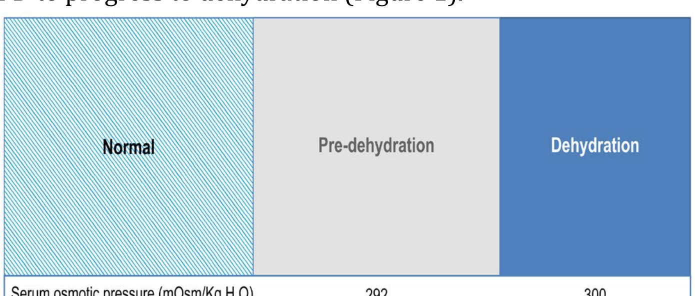

Figure 1. The definition of predehydration and its relationship with a normal or dehydrated status. Predehydration (PD) occurs prior to dehydration when the bodily fluids are below, and serum osmotic pressure is above, the standard levels according to normal hematological findings. PD is not identified by objective observations or subjective symptoms that indicate a loss of bodily fluids, and it can easily progress to pathological dehydration if not addressed.

Various adverse effects have been reported in elderly individuals who present with dehydration [3]. To detect dehydration, various parameters have been used in previous studies [3–7], and we restructured these into 54 detection measures. However, we also hypothesized that several of the parameters would not be correlated with PD detection. Therefore, the aim of this study was to produce an optimized check sheet (using a subset of the 54 parameters) for use as a noninvasive assessment tool to clarify the definition and prevalence of PD among elderly individuals. The hypotheses for this study were that PD would affect the health of elderly individuals, and that a noninvasive measure for detecting it would be useful in this population.

In this study, we first evaluated serum osmotic pressure in all subjects to detect PD. Second, among those identified as having PD, we investigated the presence of any previously reported dehydration parameters to select the best ones for use in describing PD. Finally, after we analyzed sensitivity, specificity, and the negative and positive predictive values, we finalized the PD check sheet.

We measured the serum osmolarity for all participants, and if the value was noted to be 292 mOsm/kgH_2O or more, this was regarded as reflecting PD. Additionally, we checked whether this applied to the 54 parameters and calculated the sensitivity and specificity for each. From the items related to physical changes and living environment, we chose the 5 most representative of sensitivity and specificity to create a sheet that that was able to noninvasively predict predehydration.

Methods

Study Population

This study's design was reviewed and approved by the Ethics Committee of the Kanagawa University of Human Services (approval number 24-32-011) and adhered to the tenets of the Declaration of Helsinki. Eleven elder-care institutions in Japan's Kanagawa prefecture participated in this study, and all the subjects provided their informed written consent. The subjects had either been admitted to, or regularly visited, the participating institutions, and were >65 years old at the time of their enrollment. The exclusion criteria included existing dehydration, the indicated inapplicability of the check sheet parameters, and the inability of the subjects to complete the check sheet (either alone or with assistance).

The sample size for the present study was estimated based on our previous work [8] and was selected to establish the clinical validity of our questionnaire. In that previous study, we determined that the standard serum osmotic pressure was 276–291 mOsm/kg H_2O in Japanese adults, and that a diagnosis of PD could be made at >292 mOsm/kg H_2O. Based on that criterion, we observed that 26% of the elderly subjects (who were not dehydrated) could be diagnosed as having PD. Therefore, to recruit at least 100 subjects with PD for the present study, a minimum sample size of 388 subjects was considered necessary. However, we recruited 400 elderly individuals to accommodate the possibility of incomplete assessments or abnormal cases in which assessment was not possible.

Study design

This cross-sectional observational study took place between May 2 and August 7, 2013. The main evaluation parameters were the sensitivity, specificity, and predictive values for PD of the 54 previously reported parameters of dehydration [3–7]. While these parameters are used for the detection of dehydration and not PD, we identified the characteristics that were suitable for detecting PD among elderly individuals and included the various relevant subevaluation parameters on the PD check sheet.

Definitive diagnosis

In this study, serum osmotic pressure values were used to make a definitive diagnosis of PD, based on the findings of Mange et al. and Thomas et al., who reported that serum osmotic pressure was the best measure for diagnosing dehydration [9, 10]. We defined PD as the suspected loss of body fluids not accompanied by subjective symptoms, in which the serum osmotic pressure was above the standard limit of 292 mOsm/kg H_2O.

Main Evaluation Parameters

The subjects were separated into groups according to the serum osmotic pressure of their venous blood samples. If the subject's serum osmotic pressure 2 h after eating was >292 mOsm/kg H_2O, that subject was assigned to the PD group. All other subjects were assigned to the normal (N) group. In both groups, the 54 previously reported parameters were administered as a series of questions in the form of a check sheet. Staff members aided the subjects where necessary, and the subjects were instructed to select "applicable," not applicable," or "I don't know" for each question. Objective questions regarding each subject's clinical condition(s) (e.g., the state of the subject's skin, or the presence of edema) were answered by a physician. The likelihood of an "applicable" answer in the PD group was considered to represent sensitivity (%) for that question, and the likelihood of a "not applicable" answer in the N group was considered to represent the specificity (%). The positive predictive value (%) for each question was defined as the number of subjects who were diagnosed with PD divided by the number of subjects who answered "applicable." The negative predictive value (%) for each question was defined as the number of subjects who were diagnosed as normal divided by the number of subjects who answered "not applicable." A response of "I don't know" was treated as a missing value.

Subevaluation Indices

We then used the PD check sheet to evaluate elderly individuals who fulfilled the criteria for a diagnosis of PD (Figure 2). First, the sensitivity, specificity, and positive and negative predictive values were calculated for all 54 questions, using a stepwise process. In Step 1, to ensure that the PD cases were correctly identified, we selected the 5 questions with the highest positive predictive values to maintain a sensitivity of >90%. In Step 2, we excluded the normal cases by selecting the 5 items with the highest negative predictive value for group N, thereby ensuring a sensitivity of >90%. In Step 3, we improved the diagnostic accuracy of our check sheet by reconfirming the 2 fixed factors with the greatest sensitivity.

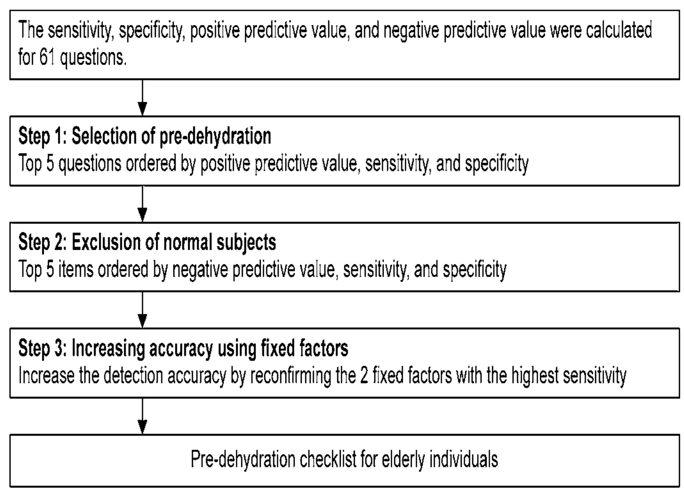

Figure 2. The search process for the optimized predehydration check sheet among elderly individuals.

Hematological findings

Venous blood samples were collected 2 h after the subjects consumed a meal. Peripheral blood tests evaluated the white blood cell count (WBC), red blood cell count (RBC), hemoglobin concentration, and hematocrit. Biochemical tests evaluated the levels of serum albumin, serum total cholesterol, triglycerides (TG), blood urea nitrogen (BUN), creatinine (Cr), blood urea nitrogen/creatinine ratio (BUN/Cr), sodium ions, chlorine ions, potassium ions, and serum osmotic pressure. The results for all tests were compared between the study groups.

Statistical analysis

Statistical analysis was performed using JMP 10.0.2 software (SAS Institute Inc. Cary, NC). The PD and N groups' clinical and biochemical characteristics were compared using Pearson's chi-square test or an unpaired Student's t-test, as appropriate. In addition, the participants' biochemical profile data were analyzed using the nonparametric Wilcoxon rank sum test. Values were reported as the mean ± standard deviation, and a difference of $P < 0.05$ was considered statistically significant. The methods for calculating sensitivity, specificity, and the positive and negative predictive values for each parameter are described in the "Main Evaluation Parameters" section above.

Results

Study flowchart

Of the 408 subjects who consented to participate in this study, 10 did not attend their examination, and 7 had insufficient or hemolyzed blood samples that precluded further analysis. These subjects were excluded from the analysis. The remaining subjects (n = 391) were divided into the PD group (n = 89, 22.8%) and the N group (n = 302, 77.2%) (Figure 3).

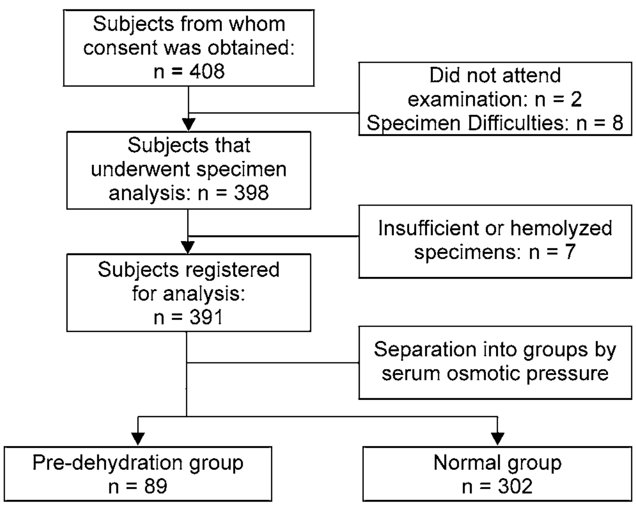

Figure 3. A flowchart of the selection process during subject recruitment and analysis.

Subjects' baseline characteristics

At baseline, the average height was significantly higher in the N group ($P = 0.04$), while significantly higher BMI ($P = 0.004$), systolic blood pressure ($P = 0.02$), and pulse pressure were observed in the PD group (Table 1). In addition, baseline levels of TG, BUN, Cr, sodium, chlorine, potassium, WBC, and serum osmotic pressure were significantly higher in the PD group ($P < 0.0001$) (Table 2). The serum osmotic pressure values (Figure 4) were used to classify 89 (22.8%) subjects as having PD (>292 mOsm/kg H_2O), while 33 (8.4%) subjects exhibited values lower than the standard value (<275 mOsm/kg H_2O).

Sensitivity, specificity, and positive predictive value

We analyzed each subject according to the search process and PD check sheet outlined in Figure 3, and the results of the sensitivity, specificity, and predictive values analysis for the 54 questions are shown in Table 3.

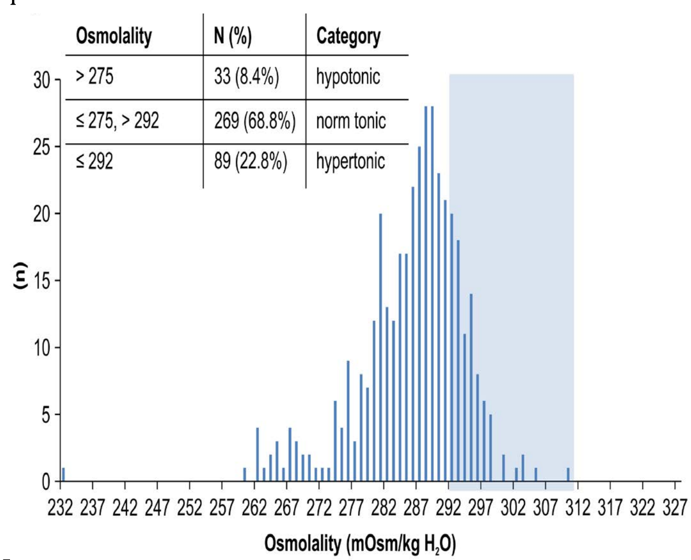

Figure 4. The distribution of serum osmotic pressure among the study subjects. The blue area of the graph (89 people, 22.8%) fits the predehydration group criteria.

Table 1. Demographic data for the study subjects.

	Total (N = 391)	Predehydration group (n = 89)	Normal group (n = 302)	P-value
Sex (male/female)	103/288	18/71	85/217	0.14
Age (years)	85.0 ± 7.5 [65–103]	86.1 ± 7.1 [67–103]	84.7 ± 7.6 [65–100]	0.13
Height (cm)	150.2 ± 9.4 [120–173]	148.3 ± 8.5 [120–167]	150.7 ± 9.5 [125–173]	0.04a
Weight (kg)	45.7 ± 9.2 [26.9–72.9]	46.5 ± 8.5 [28.4–68.9]	45.5 ± 9.4 [26.9–72.9]	0.41
BMI (kg/m^2)	20.3 ± 3.4 [13.1–32.8]	21.2 ± 3.4 [13.5–32.8]	20.0 ± 3.3 [13.1–30.6]	0.004b
Temperature (°C)	36.0 ± 0.4 [34.5–37.6]	36.0 ± 0.4 [35.0–36.8]	36.0 ± 0.5 [34.5–37.6]	0.76
SAP (mmHg)	135.7 ± 23.1 [83–250]	140.7 ± 27.1 [83–250]	134.3 ± 21.5 [87–209]	0.02a
DAP (mmHg)	80.1 ± 13.6 [46–143]	81.3 ± 13.5 [46–114]	79.8 ± 13.6 [53–143]	0.36
Pulse pressure (mmHg)	55.6 ± 17.1 [13–167]	59.4 ± 20.0 [29–167]	54.5 ± 16.0 [13–116]	0.02a
HR (beats per minute)	71.6 ± 12.0 [43–112]	71.6 ± 11.7 [43–96]	71.6 ± 12.1 [43–112]	0.99

Data are expressed as the mean ± standard deviation and [range], and were compared using Student's T-test. Pulse pressure is the difference between the systolic and diastolic pressure readings. $^aP < 0.05$, $^bP < 0.01$. BMI: body mass index, SAP: systolic arterial blood pressure, DAP: diastolic blood pressure, HR: heart rate.

Table 2. The subjects' biochemical profiles.

Parameters	Unit	Reference values	Total (N = 391)	Shapiro-Wilk *P*-value	Predehydration group (n = 89)	Normal group (n = 302)	Wilcoxon *P*-value
Albumin	g/dL	3.8–5.2	3.6 ± 0.5 [2.0–4.7]	<0.0001*	3.6 ± 0.4 [2.0–4.6]	3.7 ± 0.5 [2.0–4.7]	0.97
Total cholesterol	mg/dL	150–219	181.7 ± 37.6 [77–363]	<0.0001*	183.4 ± 38.3 [106–291]	181.2 ± 37.4 [77–363]	0.30
Triglycerides	mg/dL	50–149	112.4 ± 58.0 [27.7–435]	<0.0001*	134.9 ± 67.7 [27.7–435]	105.8 ± 53.2 [30–429]	0.0003*
Blood urine nitrogen (BUN)	mg/dL	8.0–22.0	18.1 ± 7.3 [6.0–56.1]	<0.0001*	23.6 ± 9.4 [9.2–56.1]	16.5 ± 5.7 [6–47.3]	<0.0001*
Creatinine (Cr)	mg/dL	M: 0.61–1.04 F: 0.47–0.79	0.77 ± 0.36 [0.22–2.74]	<0.0001*	1.02 ± 0.55 [0.47–2.74]	0.70 ± 0.24 [0.22–1.74]	<0.0001*
BUN/Cr ratio	mg/dL		24.9 ± 8.2 [0.3–74.2]	<0.0001*	25.5 ± 8.4 [10.4–53.4]	24.7 ± 8.1 [0.3–74.2]	0.38
Sodium	mEq/L	136–147	139.7 ± 3.8 [116–147]	<0.0001*	141.9 ± 2.3 [133–147]	139.1 ± 4.0 [116–146]	<0.0001*
Chloride	mEq/L	98–109	102.2 ± 4.3 [84–113]	<0.0001*	104.9 ± 3.7 [86–113]	101.5 ± 4.2 [84–110]	<0.0001*
Potassium	mEq/L	3.6–5.0	4.1 ± 0.5 [2.4–5.5]	0.0062*	4.3 ± 0.6 [3.2–5.5]	4.1 ± 0.5 [2.4–5.4]	0.044*
Leukocytes	/µL	M: 3,900–9,800	5,904.6 ± 1,898.3	<0.0001*	6,470.8 ± 2,486.1	5,737.8 ± 1,655.1	0.061

Note: Data are expressed as mean ± standard deviation and [range]. * $P < 0.05$

Table 3. Parameters for detecting dehydration from previous studies and their sensitivity, specificity, and positive and negative predictive values.

Parameters	Applicable	Not applicable	Sensitivity	Applicable	Not applicable	Specificity	Positive predictive value	Negative predictive value
Age >85 years	56	33	0.63	167	135	0.45	0.25	0.8
Chronic conditions (e.g., hypertension, diabetes, or heart disease)	72	16	0.82	188	109	0.37	0.28	0.87
Using diuretics	19	67	0.22	36	260	0.88	0.35	0.8
Lives in an environment with increased exposed to sunlight (e.g., a bed beside a window)	35	31	0.53	130	106	0.45	0.21	0.77
Loses concentration or cannot calm down	24	47	0.34	66	171	0.72	0.27	0.78
Loss of motivation or constantly sleepy	27	51	0.35	90	163	0.64	0.23	0.76
Constipated or continued constipation	25	49	0.34	59	186	0.76	0.3	0.79
Often has a dry throat	24	53	0.31	87	169	0.66	0.22	0.76
Wishes to eat cold foods, ice, or frozen desserts	38	41	0.48	112	143	0.56	0.25	0.78
The inside of the mouth feels sticky	20	59	0.25	70	180	0.72	0.22	0.75
The skin feels dry	18	61	0.23	47	194	0.8	0.28	0.76
Dislikes rehydrating before sleeping, as it induces the need to use the toilet	24	53	0.31	65	178	0.73	0.27	0.77
Swelling has been found or has worsened	43	46	0.48	100	202	0.67	0.3	0.81
The inside of the mouth is dry	3	86	0.03	21	270	0.93	0.13	0.76
Abnormalities found in subungual blood flow	6	79	0.07	36	255	0.88	0.14	0.76
Skin lacks elasticity	54	33	0.62	166	127	0.43	0.25	0.79

Step 1: PD selection

To maintain a sensitivity of >90%, the 5 parameters with the greatest positive predictive values were selected as questions for Step 1. Among the 391 subjects, 82 in the PD group (7 excluded subjects) and 252 in the N group (50 excluded subjects) answered "applicable" for at least 1 of the 5 questions from Step 1 (P = 0.04). These findings provided a sensitivity of 0.92, a specificity of 0.17, a positive predictive value of 0.25, and a negative predictive value of 0.88.

Step 2: Exclusion of the normal group

To maintain a sensitivity of >90%, the 5 parameters with the greatest negative predictive values were selected as questions for Step 2. Among the 334 subjects who responded with "applicable" to at least 1 question in Step 1, 74 in the PD group (8 excluded subjects) and 198 in the N group (54 excluded subjects) answered "applicable" for at least 1 of the 5 questions from Step 2 (P = 0.02). These findings provided a sensitivity of 0.90, a specificity of 0.21, a positive predictive value of 0.27, and a negative predictive value of 0.87.

Step 3: Increasing accuracy using fixed factors

We identified 2 fixed factors by calculating the sensitivity, specificity, and positive predictive value for all 54 questions: age (>85 years old) and having a chronic disease (e.g., hypertension, diabetes, or heart disease). Among the 272 subjects who responded with "applicable" to at least 1 question in Step 2, 73 in the PD group (1 subject excluded) and 166 in the N group (32 subjects excluded) had at least one of these fixed factors (P = 0.001). These findings provided a sensitivity of 0.99, a specificity of 0.16, a positive predictive value of 0.31, and a negative predictive value of 0.97. A summary of the various statistical findings for Steps 1–3 is shown in Table 4.

Table 4. The sensitivity, specificity, and positive and negative predictive values for various items among the study groups.

	Predehydration group			Normal group				Positive predictive	Negative predictive
	Applicable	Not applicable	Sensitivity[e]	Applicable	Not applicable	Specificity[f]	*P*-value	value[g]	value[h]
Applicable to any of the 5 Step 1 items[a]	74	8	0.9	198	54	0.21	0.02[d]	0.27	0.87
Applicable to any of the 5 Step 2 items[b]	74	8	0.9	198	54	0.21	0.02[d]	0.27	0.87
Applicable to any of the 2 fixed items[c]	73	1	0.99	166	32	0.16	<0.001[d]	0.31	0.97

[a]Recently became constipated; the inside of the mouth is sticky; the skin is dry; swelling has been identified (or has increased); the skin has no elasticity (loss of turgor) [N = 391 (predehydration group: 89, normal group: 302)]. [b] Is using diuretics; is living in a place with much exposure to sunlight; reduced concentration or inability to calm down; desire to eat cold foods, ice, or ice cream; refrains from rehydrating before sleeping to reduce the need to use the toilet [N = 334 (predehydration group: 82, normal group: 252)]. [c] Aged >85 years; has chronic conditions, such as hypertension, diabetes, or heart disease [N = 272 (predehydration group: 74, normal group: 198)]. [d]Pearson's chi-square test

[e] Sensitivity = applicable/(applicable + not applicable)

[f] Specificity = not applicable/(applicable + not applicable)

[g] Positive predictive value = applicable to PD/(applicable to PD + applicable to not PD)

[h] Negative predictive value = not applicable to PD/(not applicable to PD + not applicable to not PD)

Discussion

In the present study, PD was defined as the suspected loss of body fluids not accompanied by subjective symptoms or objective findings, in which serum osmotic pressure was above the upper standard limit of 292 mOsm/kg H_2O. Based on our results, 22.8% of the elder-care subjects were diagnosed with PD, and we developed a noninvasive check sheet for identifying PD among these individuals (Figure 5). Our results are in agreement with those of a previous study that reported that approximately 26% of subjects conform to a PD state [8]. In addition, our PD prevalence was evaluated at 11 institutions in the Kanagawa prefecture, and the varying environments of these institutions may make our results useful as a reference point for the incidence rate among residents of standard el der-care facilities.

Dehydration is known to increase patient discomfort, the burden on health care providers, and average hospital stay and related medical costs [11]. In addition, other studies have demonstrated that preventing dehydration among elderly individuals in hospitals and elder-care facilities is highly cost-effective [12–13]. However, there is currently no universal standard diagnosis or adequate method for preventing dehydration. Therefore, our PD check sheet may allow health care providers to reduce the incidence of dehydration among elderly individuals via early detection and treatment of PD, thereby reducing the related treatment costs.

Figure 5. The predehydration check sheet for elderly individuals facilitates screening, detecting, and assessing chronic hidden dehydration in this population.

Individuals without dehydration and > 65 years, please check the following items:

Step 1. Have you noticed any of the following changes to your body recently?

If so, please ☑ the appropriate items and proceed to Step 2.

Otherwise, please check ☑ the box to the right, and refer to Advice (1) below. At that point, you are finished. ☐ None apply

- ☐ Do your shins tend to become swollen? E.g., the impression of the rubber in your socks remains 10 minutes after removing them.
- ☐ Does your skin stretch less than before? E.g., the traces of pinching the back of your hand remain for more than 3 seconds after letting go.
- ☐ Do you have constipation, or is your constipation worse than before? E.g., the frequency of using laxatives (constipation drugs) has increased.
- ☐ Has the inside of your mouth become sticky? E.g., Food feels very dry, or you have so little saliva that it is difficult to swallow as normal.
- ☐ Has your skin become very dry? E.g., Your skin is dry and not glossy, or your skin flakes off readily.

Step 2. Are any of the following items applicable to you?

If so, please ☑ the appropriate items and proceed to Step 3.

Otherwise, please refer to Advice (2) below. At that point, you are finished.

- ☐ Are you using diuretics (including diet drugs)?
- ☐ Do you spend time outside, or in places where there is good sunlight (E.g., >1 hour per day)?
- ☐ Is your concentration worse than normal (E.g., do you feel iritated and unsettled, or are you prone to sleeping during the day)?
- ☐ Have you become more fond of cold foods (E.g., ice, ice cream, etc.) and cold drinks?
- ☐ Do you tend to refrain from rehydrating before sleeping to reduce your need for the toilet?

Step 3. For those who marked a ☑ to 3 questions in Step 2, please ☑ the following items where applicable.

Otherwise, please refer to Advice (3) below. At that point, you are finished.

- ☐ Are you over 85?
- ☐ Do you suffer from any chronic condition such as high blood pressure, diabetes, or heart disease?

⇒ for those with 1 or more ☑, please refer to Advice (4).

Advice (1) At present, your risk of pre-dehydration is low.
Advice (2) It is possible that you have pre-dehydration
Advice (3) It is likely that you have pre-dehydration
Advice (4) It is highly likely that you have pre-dehydration

※ This sheet is only to referencehidden dehydration. For a definitive diagnosis, an evaluation of serum osmotic pressure at a medical institution is necessary.

In the present study, our optimization of the PD check sheet used several criteria for dehydration that were established by the United Kingdom's Royal College of Nursing (RCN) [3–7]. These criteria are key indicators of dehydration among elderly subjects, and include dryness of the lips and tongue, enophthalmos, dryness or loss of skin elasticity/tension, loss of hair elasticity, deepening of urine color and deterioration in urine odor, dizziness, delirium, and constipation. However, our results indicate that enophthalmos, deepening of urine color, and deterioration in urine odor and delirium were not effective parameters for detecting PD. This finding likely reflects the minimal amount of body fluid that is lost during PD, which does not trigger the relevant physical observations. Similarly, other studies have reported that evaluating urine changes using visual inspection is not effective in diagnosing dehydration among elderly persons, as this method is complicated by diaper use, concomitant illness, medication, and food consumption [14].

We also found that dryness of the lips and tongue, loss of elasticity of the hair, and dryness of the skin were not effective parameters for detecting PD. However, this result is expected, as age, exposure to sunlight, oral respiration, and reduced thirst can obscure the diagnosis of PD among elderly individuals [15]. We believe this is because the degree of dehydration in PD is mild and was therefore observed in both sexes in the broad age group of >65 years.

Interestingly, several of our results are in agreement with the RCN's diagnostic criteria. These include loss of skin elasticity/tension (turgor) and constipation, which are parameters that provide a high sensitivity and positive predictive value. Although elderly individuals often have wrinkled skin and appear to have reduced turgor, it is possible to observe relative changes in the skin and diagnose PD by pinching the skin and measuring the time needed for normalization. In addition, dehydration causes and worsens constipation, while rehydration is an effective treatment for the constipation caused by dehydration [16]. Furthermore, the onset or worsening of pretibial edema, which is not listed among the RCN's diagnostic items, had a high sensitivity and positive predictive value in the present study. Edema did not occur in the PD group, and the PD group's serum albumin levels were not significantly different from those of the N group. Therefore, it is possible that our observed serum albumin levels were higher than were the subjects' actual values.

Consequently, as the serum albumin levels may be lower in individuals with PD, the colloid osmotic pressure may decrease, resulting in leakage of fluid from blood vessels and the onset of edema. In previous studies [10], prolonged nail capillary refilling time and cold limbs or pallor had both low sensitivity and positive predictive values, despite the fact that they are traditionally used as indices for peripheral circulatory failure accompanying dehydration. The reason for this discrepancy may be related to extended capillary refilling times and cold limbs being common among elderly individuals, or to the fact that assessment of these conditions is difficult for nonmedical staff who are not accustomed to evaluating these symptoms [17].

Five questions were selected in Step 1 for the PD check sheet, and the selection of 5 items with high sensitivity and negative predictive value was completed in Step 2 to separate the normal subjects from those who were extracted in Step 1. For example, previous studies have reported diuretic use, not rehydrating before sleeping, and exercising outdoors as being dehydration risk factors [5–7]. In addition, an elevated or depressed mood among elderly individuals may be an early sign of dehydration [7]. Although desire to consume cold foods, ice cream, or frozen desserts was not evaluated in previous studies, we observed that these criteria had a high sensitivity and predictive value, which may have been influenced by the fact that the present study was conducted during the early summer. However, as the elderly subjects typically lived in environments in which the temperature and humidity were controlled via air conditioning, it is likely that these parameters will be useful year-round measurements.

To improve the diagnostic accuracy among the subjects who were extracted in Step 2, reconfirmation was performed using the 2 fixed factors with the highest sensitivity. For analysis by age, an additional analysis was performed using a boundary set at the average age for all subjects (85.0 years). Furthermore, the sensitivity, specificity, and positive predictive values were higher for the group of subjects who were >85 years old, and a similar study demonstrated that the risk factors for dehydration increase as age increases [7]. In addition, we found that having a chronic disease (e.g., hypertension, diabetes, or heart disease) was a risk factor for PD, and a similar study also demonstrated that this is a risk factor for dehydration [3–7].

In the present study, a definitive diagnosis of PD was made based on the subjects' serum osmotic pressures. We also assessed whether the hematological criteria that were used to detect dehydration in previous studies were useful for detecting PD [3–7]. For example, previous studies have demonstrated that dehydration can be diagnosed using the BUN/Cr ratio, serum sodium concentrations, and serum osmotic pressure [18]. In contrast, our results indicate that the BUN/Cr ratio was not useful in detecting and diagnosing PD. While the PD group had a slightly elevated BUN/Cr value, there were no significant differences between the PD and N groups. This result may reflect the fact that approximately 30% and 40% of Japanese men and women, respectively, who are >65 years old have chronic renal disease [19]; therefore, it is common for them to have abnormal BUN and Cr levels. In addition, the decreased levels of Cr may be associated with the reduced muscle mass that is often observed in elderly individuals. Furthermore, we did not observe any subjects having a serum sodium concentration above 148 mEq/L, which made this parameter alone inadequate for detecting PD. Based on these results, we conclude that the use of serum osmotic pressure is appropriate for making a definitive diagnosis of PD in elderly individuals.

The following 3 points were identified as limitations of the present study. First, because the PD check sheet was developed with an emphasis on maximizing its sensitivity and predictive values, the probability of extracting false positives (i.e., a low specificity) is high. However, as the prevention of dehydration among elderly individuals focuses on early detection and treatment, this tool may still be useful, despite any possible overestimation. Second, because the standard diagnosis was carried out using only serum osmotic pressure, cases with hypotonic dehydration may have been included in the N group. It is possible that hypotonic PD cannot be defined using serum osmotic pressure alone, and it is likely that additional investigation with a larger number of cases is necessary to address this issue. Third, our investigation is limited by the relatively narrow age range and standard living environments, as PD likely exists in all age groups. Therefore, it is necessary to investigate a wider range of age groups. However, the chronic loss of body fluids that is often observed among elderly individuals was observed in the present study, and our results are highly significant since we have proposed an effective and noninvasive method to diagnose and define PD in elderly individuals. We hope to further evaluate our hypothesis that the diagnosis of PD may prevent progression to dehydration and the detrimental effects that are caused by fluid depletion, as we believe that reducing the incidence of conditions that are caused by dehydration will decrease the related burden on the health care system.

Conclusion

In this study, we defined PD as the suspected loss of body fluids not accompanied by subjective symptoms or objective findings, in which the serum osmotic pressure was above the upper standard limit of 292 mOsm/kg H_2O. Among the subjects who were >65 years old and residing in elder-care institutions, the prevalence of PD was 22.8%. Using this data, we developed a noninvasive PD check sheet suitable for detecting PD among elderly subjects.

Competing interests

The authors declare that there are no conflicts of interest.

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References

1. King CK, Glass R, Bresee JS, Duggan C. Centers for Disease Control and Prevention: Managing acute gastroenteritis among children: oral rehydration, maintenance, and nutritional therapy. MMWR Recomm Rep. 2003, 52(RR–16):1-16.

2. International Statistical Classification of Diseases and Related Health Problems: 10th Revision Version for World Health Organization. 2003. [Accessed on March 2, 2013]

3. Royal College of Nursing, National Patient Safety Agency: Water for Health: Hydration Best Practice Toolkit for Hospitals and Healthcare. London: RCN/NPSA. 2007. [Accessed on April 1, 2013]

4. Wakefield BJ, Mentes J, Holman JE, Culp K. Risk factors and outcomes associated with hospital admission for dehydration. Rehabil Nurs. 2008, 33(6): 233-241.

5. Wolff JL, Starfield B, Anderson G. Prevalence, expenditures, and complications of multiple chronic conditions in the elderly. Arch Intern Med. 2002, 162(20): 2269-2276.

6. Hodgkinson B, Evans D, Wood J. Maintaining oral hydration in older adults: a systematic review. Int J Nurs Pract. 2003, 9(3): S19-S28.

7. Wakefield BJ, Mentes J, Holman JE, Culp K. Postadmission dehydration: risk factors, indicators, and outcomes. Rehabil Nurs. 2009, 34(5): 209-216.

8. Taniguchi H, Okamoto R, Ueshima J, Taniguchi H, Okamoto R et al. Investigation into the safety and efficacy of long-term oral rehydration therapy in elderly care facilities - practical application to non-dehydration cases over 30 days. J JSPEN 2014, 29:733-739. [Japanese]

9. Mange K, Matsuura D, Cizman B, Soto H, Ziyadeh FN et al. Language guiding therapy: the case of dehydration versus volume depletion. Ann Intern Med. 1997, 127: 848-853.

10. Thomas DR, Tariq SH, Makhdomm S, Haddad R, Moinuddin A. Physician misdiagnosis of dehydration in older adults. J Am Med Dir Assoc. 2004, 4(5): 251-254.

11. Begum M, Johnson CS. A review of the literature on dehydration in the institutionalized elderly. Euro E J Clin Nutr Metab. 2010, 5 (1): e47–e53.

12. NHS Information Centre: Hospital Episode Statistics Online: HES on Constipation. 2011. [Accessed on March 25, 2013]

13. Bennett JA, Thomas V, Riegel B. Unrecognized chronic dehydration in older adults: examining prevalence rate and risk factors. J Gerontol Nurs. 2004, 30(11): 22-28.

14. Wakefield B, Mentes J, Diggelmann L, Culp K. Monitoring hydration status in elderly veterans. West J Nurs Res. 2002, 24(2): 132-142.

15. Kenney WL, Chiu P. Influence of age on thirst and fluid intake. Med Sci Sport Exerc. 2001, 33(9): 1524-1532.

16. Benharroch D, Ariad S. Mild dehydration - possible association with bladder and colorectal cancers - a review. J Food Process Technol. 2012, 3:142.

17. Shimizu M, Kinoshita K, Hattori K, Ota Y, Kanai T et al. Physical signs of dehydration in the elderly. Intern Med. 2012, 51(10): 1207-1210.

18. Robinson BE, Weber H. Dehydration despite drinking: Beyond the BUN/creatinine ratio. J Am Med Dir Assoc .2002, 3(6): 386–389.

19. Imai E, Horio M, Iseki K, Yamagata K, Watanabe T et al. Prevalence of chronic kidney disease (CKD) in the Japanese general population predicted by the MDRD equation modified by a Japanese coefficient. Clin Exp Nephrol. 2007, 11(2):156-163.