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Implementing Screening Questionnaires and a Fish Bone Diagram-Based Program to Enhance the Ability of Hemodialysis Dry Body Weight Education in Hemodialysis Nurses

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Implementing Screening Questionnaires and a Fish Bone Diagram-Based Program to Enhance the Ability of Hemodialysis Dry Body Weight Education in Hemodialysis Nurses

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Background:

Dry body weight evaluation to detect high and low hydration status is paramount in daily hemodialysis practice. Our aim is to implement screening questionnaires and fish bone diagram-based program to improve the ability of dry body weight education of hemodialysis nurses.

Methods:

This pioneer research by four staff members was initially authorized by the medical quality and patient safety talent training project and competition meeting initiated by the administrative units of Taipei City Hospital and then approved by Taipei City Hospital Research Ethics Committee with the case number of TCHIRB-11206015.The study began with screening questionnaires of educational test about dry body weight education. Subsequently, teams composed of nurse faculty were evaluated for three domains of dry body weight evaluation, such as hemodialysis nurse's knowledge and education skills on dry body weight, body components and body weight assessment equipment and tools. A fish bone diagram for root cause analysis was implemented with improvement of knowledge and skills of dry body weight evaluation of nurse

faculty, methods of dry body weight evaluation, equipment for dry body weight evaluation, tools of dry body weight evaluation, environment of dry body weight evaluation, and materials of dry body weight evaluation.

Results:

Wilcoxon Signed Ranks Test are used to identify statistically significant differences in the scores of between the domain 1 and domain 2, between domain 1 and domain 2A, and between domain 1 and domain 2B. The screening questionnaires revealed. A Fish bone diagram was completed and presented to improve the ability of dry body weight education of hemodialysis nurses with dry body evaluation education sheet, poster and ever scam education software. In addition, suggestions for improving the ability of dry body weight education include inclusion of nutritional staff involvement, post- dialysis cardiac echo for inferior vena diameter, chest ultrasound for B lines, Crit-Line for blood volume monitor, DEXA for body composition evaluation, and selection of topics of food salt and water content, techniques and environment of dry body weight evaluation, bio-impedance, and upper arm anthropometry.

Conclusions:

Accurate evaluation of dry body weight by clinical evaluation, equipment and tools not only can prevent hemodialysis patients from deterioration of cardiopulmonary function and the chance of emergency dialysis due to high hydration status but also prevent patients from hospitalization due to shock and thrombotic complications due to low hydration status, and therefore reduce their medical costs and improve patient satisfaction and trust in the hospital.

Key words: Dry body weight, Hemodialysis, fish bone diagram, questionnaires

Introduction

Clinical decisions related to volume management are virtually all based on the assessment of fluid status. Individual trends in weight and blood pressure have been used as practical surrogate indicators of fluid status. Although blood pressure-based monitoring of target weight is still widely used, this may lead to insufficient volume and accelerated loss of residual renal function. Clinical signs such as elevated jugular venous pressure and lower extremity edema are easy to observe, but their diagnostic accuracy is poor and there is significant inter-observer variability, limiting their reproducibility for fluid assessment in clinical trials. Bioelectrical impedance analysis has a strong scientific basis for assessing extracellular fluid volume and is closely related to clinical outcomes[1].

A previous study used single channel bioelectrical impedance analysis (BIA) to determine percentage fat mass(%FM), fat mass (FM), lean body mass (LBM), and total body water (TBW). Percentage fat mass (%FM) is the better suitable fat marker for non-diabetic hemodialysis patients in Taiwan than fat mass (FM). For obese non-diabetic hemodialysis patients in Taiwan, protein malnutrition indicators, such as lean body mass by BIA should be measured to assess protein reserves in maintenance hemodialysis patients[2].

A previous study used the time- average over-hydration range of 0.5–0.75 liters as optimal fluid status based on bioelectrical impedance spectroscopy. The average of pre- and post-dialysis fluid status was calculated as the time-averaged fluid status. Post-dialysis weight was adjusted weekly in chronic hemodialysis patients to maintain this optimal target fluid status. Most chronic hemodialysis patients achieved the target average fluid overload value. Active fluid management guided by bioelectrical impedance spectroscopy was associated with significant improvements in overall fluid status and blood pressure[3].

Most hemodialysis patients have volume-dependent hypertension, and correcting over-hydration is crucial for controlling hypertension and reducing cardiovascular mortality in maintenance hemodialysis patients. Achieving optimal dry weight is a key issue of restoring extracellular fluid balance in maintenance hemodialysis

patients. Adjustments of dry body weight mainly rely on the clinical subjective and objective assessment by nephrologists. New bedside non-invasive tools, such as bioelectrical impedance analysis (BIA) monitors, will provide more objective information on volume status and can guide nephrologists in determining dry body weight. However, it is important to note that this advanced tool cannot replace the clinical assessment and judgment by expert nephrologists[4].In MHD patients with comorbidity of pericardial effusion[5] and nephrogenic and cardiogenic ascites[6], clinical metrics with ultrasound cardiothoracic ratio[7] are better than BIA tool.

Dry body weight (DBW) is the body weight of maintenance hemodialysis (MHD) patients under normal hydration. MHD patients with symptoms of under- hydration, such as hypotension, nausea, vomiting, dizziness, etc. must discuss with caregivers to perform dry weight adjustments. MHD patients with symptoms of over-hydration, such as edema of body, shortness of breath while walking or climbing stairs, cough while lying down, symptoms of heart failure such as orthopnea, red or pink frothy sputum, must also discuss with caregivers to execute dry weight adjustments. MHD patients with normal hydration have no edema, no pulmonary edema and normal blood pressure.

Modern medical care frequently implemented questionnaires for survey of many issues of healthcare, for example, quality of healthcare[8], satisfaction of patients[8], and reinforcement of ability dry boy weight education of healthcare providers as in our study. Fluid control principles and goals are as follows: The recommended daily water intake varies depending on comorbidities. For hemodialysis patients, the suggestion for volume of water intake is about add on daily urine output by approximately 500 cc. Prepare your daily water intake in a container and distribute it evenly. Do not replace your daily water intake with sugary drinks. When experiencing dry mouth or thirst, rinse your mouth with water and spit it out. In hot weather, you can suck on ice cubes to moisten your mouth and promote saliva production. Eat food or snacks without high water content. Avoid drinking broth. Avoid eating pickled and processed foods with high content in sodium or sugar to prevent elevated serum osmolarity induced thirst. The target weight gain between dialysis sessions should ideally be controlled to 5% of dry body weight[9]. Symptoms and signs of fluid overload, heart failure, pulmonary edema include shortness of breath or dyspnea, especially when

lying flat or bending forward, paroxysmal nocturnal dyspnea, peripheral edema of the feet, ankles, and legs, ascites and jugular vein engorgement, decreased exercise capacity, cough with pink and frothy sputum[10].

24 The current research aims to elevate the ability of hemodialysis nurses to prevent MHD patients not only from experiencing cardiopulmonary edema due to over-hydration which increases their risk for emergency dialysis, but also to prevent MHD patients from experiencing hypovolemic shock, thrombotic complications which increases hospitalization rates due to under-hydration. Therefore, improving caregivers' knowledge of dry body weight is crucial for healthcare for hemodialysis patients and reducing their healthcare costs.

Methods

The project management plan was initiated between August 1, 2022 and December 1 31,2022. This research project management plan was approved by Taipei City Hospital Research Ethics Committee with case number of TCHIRB-11206015.

Study Participants:

A total of 45 dialysis nurses from the Zhongxiao Campus, including retired or transferred nurses and dialysis head nurses from other campuses, were included in the study.

Dry Body weigh Questionnaire

Dry body weight scale was implemented with 20 single-choice questions in a questionnaire (multiple-choice questions with only one correct answer).

Response Process:

The dialysis nurse participants first signed the Taipei City Hospital Research Project Respondent First Edition or Second Edition Consent Form, and then completed the Chinese version of the dry weight education scale. All 45 complete questionnaires were collected, representing a 100% response rate. There were no missing values in any item of domains of the questionnaire.

Dry body weight education scale and fishbone diagram

This study employed a questionnaire survey and constructed a fishbone model to implement knowledge management and refinement in organizations. We collecting 45 questionnaires from HD nurses of Zhongxiao campus. Based on the research results of dry body weight survey, a fishbone model was constructed. The spine of this fishbone model represents the positions of knowledge management activities as the first output level, the second output level as the novel innovations, thus influencing agility of organization, and ultimately correlated with metrics of performance, which serves as the head of this fishbone model. The different key factors driving the organizations are illustrated as the ribs of the fishbone model[11].

Statistical analysis

The analyses were executed in SPSS IBM. Descriptive statistical methods were used to analyze the data, including the mean and standard deviation. The Pearson correlation test was used to assess the relationship between the item scores and the total score on the scale. Factor analysis was used for validity. Internal consistency reliability was evaluated using Cronbach's α coefficient, split-half reliability, Cronbach's α coefficient after item deletion, and item total correlation scores[12]. Shapiro-Wilk test was used to test normality in case of small to medium sample sizes (n <50). Domain 1 and domain 2 scores were compared.

Split-half reliability and Cronbach's alpha coefficient

In view of split-half reliability, we divided the items of questionnaires into two parts: one part containing odd-numbered items and the other containing even-numbered items, and then calculate the interrelatedness among the items of the two parts, respectively. The interrelatedness among items was evaluated with Cronbach's alpha coefficient.

Factor analysis

The Kaiser-Meyer-Olkin (KMO) test, Bartlett's test of sphericity, chi-square value, total explained variance, and degrees of freedom were analyzed after different item sampling simulations. The situations of item sampling simulation are as follows: Items 6 and 9, which are indistinguishable, were removed; items whose "α value after deletion" is significantly higher than the current standardized total reliability were further removed; items whose "α value after deletion" is significantly higher than the

current unstandardized total reliability were further removed; and items with no statistically significant correlation to the total score were further removed.

Kaiser-Meyer-Olkin (KMO) test and P value of Bartlett's test of sphericity were used to evaluate sampling adequacy of all items. Total variance explained were calculated through exploratory factor analysis[13].

Comparison of the means of domain 1 and domain 2, domain 1 and domain 2A, domain 1 and domain 2B, and domain 2B and domain 2A

Item number 1-10 and item number 11-20 were categorized as domain 1 and domain 2, respectively. Levene test was used to test the hypothesis of homogeneity of variance of domain 1 and 2. Due to the difference in number of the three domains of dry body weight questionnaire, the score for each domain of the hemodialysis nurse respondent must be standardized before statistical analysis. Percentage of score rate is calculated as follows: score of the domain divided by total number of items in that domain × 100%. Since the score for each item is dummy variables (0 and 1), the Friedman test was used to test for if there are differences between Domains 1, 2A, and 2B. The Wilcoxon signed-rank test was then used in the post-hoc test to analyze pairwise differences between Domains 1, 2A, and 2B.

Results

The unstandardized Cronbach α, standardized Cronbach's α, and split half reliability coefficient of the questionnaire is 0.646, 0.65 and 0.70, respectively. The item-total correlations for all items are above 0.146. The Cronbach's α coefficient after item deletion indicates that most items should be retained (Table 1). The Chinese version of the dry weight scale contains two dimensions and a total of 20 items. Items 1-10 constitute the first dimension, and items 11-20 constitute the second dimension. The two categories of domains were described in Table 2. Although the results of the KMO (Kaiser-Meyer-Olkin measure of sampling adequacy) value to test the adequacy of the sampling adequacy for factor analysis was noted to be at an unacceptable level (0.377), the p value of Barlett's test result was highly statistically significant. ($p < 0.001$). The results of Bartlett's test of sphericity and the KMO value did not justify the use of factor analysis for 20 items. Because of indiscrimination of item 6 and 9, we delete item 6 and item 9 for exploratory factor analysis. The extraction method

was principal component analysis with three most common factor rotation techniques (varimax, promax, direct oblimin). Exploratory factor analysis accounted for 74.179 % of the revised dataset variance. The result of Levene test is statistical nonsignificant. Test of normality revealed significant(P<0.05). Therefore, Wilcoxon Signed Ranks Test is suitable for comparison of domain 1 and domain 2. The P value of Wilcoxon Signed Ranks Test is <0.001(Table 3). According to the Friedman test, there were differences in the scores rate of the three domains (Domain 1, Domain 2A, and Domain 2B) of the dry weight education questionnaire of hemodialysis nurse respondents. Post-hoc Wilcoxon signed-rank test analysis (Table 3) revealed statistical differences between all pairs of domains 1, 2A, and 2B (p > 0.05).

The different simulations of KMO, Bartlett test, approximate chi- square, degree of freedom and cumulative explained variation if items deleted were showed in the table 4.

Discussion

This study identified potential focus through the DBW education scale and then implementation of 5M1E (Man/People, Machine/Equipment, Material, Method/policy/process, Measurement/tools, Environment) ribs framework of fishbone (Cheng et al. BMC Health Services Research) to reinforce the ability of HD nurses to provide dry body weight health education for MHD patients. This research is systematically optimized, and a dynamic KPI (key performance index) management strategy is implemented in each rib concept, such as percentage of MHD patients with Interdialytic Weight Gain (IDWG%) more than 5 % of dry body weight. This approach helps prevent increased healthcare costs for maintenance hemodialysis patients due to complications from overhydration and under hydration[14].

The RCA framework was performed for all mistakes in the achievement of target, beginning from one domain step by step, until all domains were explored. Then a utilization of the 5 Whys techniques to evaluate the rationales and causes for the lower-than-anticipated performance[15]. Five main lapse categories were elucidated as ribs of fishbone diagram as follows: documentation, patient care, environment, knowledge, and individuals. Sub-categories were also using the 5 Whys methods as

further targets of performance in each category using key performance indicators (KPI)[16].

Previous research regarding health literacy in cardiovascular disease management found interaction between categories of fishbone diagram. In case of this study, execution techniques at individual (educating and training of healthcare providers about health literacy), interactional between individual and healthcare providers and between individual and organization (patient participation in the health literacy interest group, creating a health literacy improvement plan, systematic patient experience feedback process, engaging patients and their family), and organizational level (creating a multidisciplinary healthcare providers interest group dedicated to health literacy) can be constructed[17].

A previous project management plan uses the fishbone diagram continuous quality improvement tool to illustrate the potential causes, effects, and consequences of personal, interpersonal, cultural, and school policies and procedures factors that may affect the accuracy of student performance assessment[18]. A previous study used culture, costs and limited resources, bias, systems, lack of standards, lack of alignment as ribs of fishbone diagram (Ishikawa diagram) for the root cause analysis of undergraduate to graduate medical education transition[19]. Previous research also used graduate medical education (GME) program, student, medical school administration, clerkship directors, undergraduate medical education (UME) faculty, patients and society as ribs of fishbone diagram for root cause analysis of challenges to the competency-based paradigm in medical school[20]. Our fishbone diagram was conducted with the competence of knowledge and health education as fish head and encompassing environment, people, process, material, equipment, and tools as ribs. Questionnaire survey analyzed the issues of knowledge and health education to improve the dry weight of healthcare providers for MHD patients. This paper will outline several recommendations from the root cause analysis of fishbone diagram, examining the interactions between root causes using systems thinking principles, and proposing improvement suggestions. Continuous monitoring of quality indicators is crucial to ensure that interventions drive this process, thereby better healthcare of MHD patients.

Previous research compares different tools of measuring body compositions. Gold

standard methods such as underwater weighing for body density and isotope dilution for total body water (DEXA) provide very accurate assessments, but they are not suitable for routine clinical practice. Bioelectrical impedance analysis (BEI) has great potential as a supplement to standard anthropometric techniques in MHD patients due to its ease of use and simple operation. In dialysis patients, accuracy depends on stable hydration status, consistency of technique, and standardization of bioelectrical impedance analysis equipment, which are crucial for the reproducibility of results. Multiple studies have confirmed that total body water measured by BIA in dialysis patients can serve as an alternative indicator to isotope dilution; the results are similar to those obtained using underwater weighing. Bioelectrical impedance analysis is a practical bedside body composition assessment tool that provides more consistent and reproducible results compared to standard anthropometric methods[21].

Underwater weighing, also known as hydro-densitometry measures body volume is a raw datum. This gold standard of measuring body composition is a two-compartment model, indirectly calculating fat mass and fat-free mass. This technique measures body volume based on Archimedes' principle, which states that when an object is submerged in water, the buoyant force is equivalent to the weight of the water which displaces. The Seri equation used for calculating percentage fat mass is as follows: Percentage fat mass equals to (495/BD) – 450 in which body density is calculated by body weight divided by body volume[22,23].

An Independent t-test was used to evaluate the mean knowledge, attitude, and practice scores of effects of dental health professionals toward dental impression disinfection protocol during the COVID-19 pandemic in Saudi Arabia[24].The current study also use independent t test to compare the mean score of domain 1 and domain 2.

The discrepancy of KMO value and P value of Barlett's test may be due to non-discrimination of item 6 and item 9 in the dry body weight education scale. A low KMO value indicates that the correlation patterns are too scattered, weak, or isolated, making it impossible to extract different, common factors through factor analysis. Therefore, factor loading of items were not demonstrated. As part of the analysis, we performed the Kaiser-Meyer-Olkin (KMO) test to assess the suitability of the items sampling. The results showed that if items 6 and 9, which were indistinguishable,

were removed, the Kaiser-Meyer-Olkin (KMO) score was below 0.5. If we further removed two items whose "α value after deletion" was significantly higher than the current standardized total reliability, the KMO score remained below 0.5. If we further removed items whose "α value after deletion" was significantly higher than the current unstandardized total reliability, the KMO score was below 0.5. Inclusion of item 2 in the scale instead of item 10 results in more than 0.5 of KMO value which can be explained by better item total correlation coefficient of item 2 than item 10. If we further removed items with no correlation to the total score, the KMO score was higher and above 0.5. The KMO score greater than 0.5 indicates that exploratory factor analysis (EFA) can be performed. Furthermore, Bartlett's test of sphericity and its chi-square value also showed significance after removing items 6 and 9. In addition, the total explained variances of all simulations were all greater than 60%, indicating good validity of the scale and its suitability for research purposes. Notably, the standardized total reliability was 0.65 and the split-half reliability was 0.70, indicating that the scale has internal consistency and its homogeneity is sufficient to assess the expected measurement outcomes.

Previous studies have compared Pearson and Spearman correlation coefficients across different distributions and sample sizes. Through simulations ranging from small to large sample sizes, for normal distributed datasets, the expected values of Pearson and Spearman correlation coefficients are similar. Pearson correlation coefficients are more suitable for measurement datasets with symmetrical and light-tailed distributions because their variability is lower than that of Spearman correlation coefficients. In measurement datasets with high kurtosis, heavy-tailed distributions, and extreme values (maximums or minima), Spearman correlation coefficients show lower variability than Pearson correlation coefficients[25].

The principle of bioimpedance assumes that body composition is though as a geometry of cylindrical model. Physical properties of relationship between Impedance(Z), resistance (R) and reactance(X) are as follows: $Z^2 = R^2 + X^2$. The resistance (R) of a uniformly cylindrical conductive material is directly proportional to its length (L) and inversely proportional to its cross-sectional area (A). Therefore, resistance (R) is calculated by $pL/A = pL^2/V$ where R is the resistance of the conductive material, p(resistivity) is the resistivity of the conductive material, and

Volume is calculated by area (A) multiplied by length(L)[26].

Multifrequency bioelectrical impedance analysis (BIA) shows significant potential for monitoring fluid loss, separately measuring extracellular fluid (ECF) compartment volume, intracellular fluid (ICF)compartment volume, and total body water (TBW)compartment volume, fluid volume changes and distribution of these compartments, and cross-compartmental fluid volume transfer. Segmented and online multifrequency BIA techniques appear promising for predicting and preventing post-dialysis hypotension[27].

The mid-arm muscle area (MAMA, cm^2) was calculated based on the triceps skinfold thickness (TSFT, cm) and upper arm circumference (MAC, cm). The mid-arm muscle area was compared with measurements taken using computed tomography (CT). The results of comparison showed that the approximate calculation formula has errors. The errors result from the following four assumptions: 1. The cross-section of the midarm structure is circular. 2. A concentric band of fat surrounds the muscles. 3. The midarm muscle septa are circular. 4. The proportion of bone in the midarm structure is constant. The correctable sources of error are assumptions 1 and 4[28].

Dual-energy X-ray absorptiometry (DEXA) measures three major body components, namely fat mass, lean body mass (including muscle, internal organs, and total body water), and bone mineral content. Fluid loss during dialysis is positively correlated with a decrease in DEXA-derived lean body mass. This paper concludes that DEXA is an effective tool for assessing these three major body components in MHD patients[29].

The tracer dilution technique is one of the gold standards and scientific technique for assessing dry body weight in MHD patients. The human body is approximately 60% water, which was divided into intracellular fluid (ICW) and extracellular fluid (ECW). Intracellular fluid (ICF) equals to two thirds (2/3) of TBW while extracellular fluid (ECF) is equivalent to one third (1/3) of TBW. Furthermore, Interstitial fluid (ISF) is identical to three fourth (3/4) of ECF while Intravascular blood volume (BV) equals to one fourth (1/4) of ECF. The tracer dilution method involves injecting a known dose of a non-metabolic tracer (usually an isotope) into the body. After it mixes evenly in the body fluids, blood is drawn to measure its diluted concentration,

thereby inferring the target body volume (TBW, or ECW, or intravascular blood volume). To assess total body water (TBW), heavy water (D_2O, deuterium oxide) or tritium water (^3H_2O) is commonly used as tracers because they can freely penetrate cell membranes and distribute evenly throughout the body's water[30]. To evaluate extracellular fluid (ECW), sodium bromide (NaBr) is commonly used because it does not enter cells[30]. To calculate intravascular blood volume (BV), radioactive isotope-labeled iodine-labeled albumin (RISA) is commonly used to directly measure blood volume[31].

Cardiac ultrasound observation of collapsibility index (CI) of inferior vena cava (IVC) diameter (CI) is a useful metrics of central venous pressure (CVP) and intravascular volume, which can be calculated by (maximum diameter of IVC minus minimum diameter of IVC) divided by maximum diameter of IVC. If IVC-CI < 50% usually indicates high CVP and abundant intravascular fluid volume. During forced inspiration, we can observe if the inferior vena cava collapses or not. If it does not collapse, or its diameter does not decrease by at least 50%, then we can know that the pressure in the right atrium is high[32]. This index can reliably assess intravascular volume, predicts dry body weight, predicts hypotension during dialysis, and assesses and manages volume overload[33].

The normal value of N-terminal pro-B-type natriuretic peptide is below 125 pg/mL. Higher threshold for high-altitude residents is below 130 pg/mL. This volume biomarker is related only to intravascular volume and not related to tissue hydration. [34]. The European society of Cardiology (ESC) suggest NT-proBNP assay uses age-corrected thresholds of risk of heart failure (≥125 pg/mL for <50 years, ≥250 pg/mL for 50-74 years, and ≥500 pg/mL for ≥75 years) and a high-risk threshold (≥2000 pg/mL). The ESC recommends lowering these thresholds for obese individuals, but there is no need for gender-based adjustments[35].

Kerley lines (CXR) are a radiographic finding in the chest, typically seen in interstitial pulmonary edema. A drawback is the need for chest imaging equipment. A previous study included scanning locations in the right second to fifth intercostal spaces and the left second to fourth intercostal spaces, specifically the parasternal, midclavicular, anterior, and midaxillary lines, for a total of 28 locations per complete examination. This protocol confirmed a correlation between B-line ultrasound

findings and assessment of extravascular lung water (EVLW) in hemodialysis patients. Ultrasound B-lines are a novel bedside diagnostic tool for congestive heart failure[36]. Normal lung tissue without congestive heart failure does not show ultrasound B-lines (also known as lung comets). Ultrasound B-lines become more prominent when the lung interstitium and alveoli are filled with fluid. Another study described the dynamic changes in the disappearance of B-lines in hospitalized patients undergoing hemodialysis. Patients underwent three chest ultrasound examinations before, during, and after dialysis, and the number of visible B-lines in 28 lung regions was counted[37]. In hemodialysis patients with visible B-lines, the disappearance of B-lines due to fluid removal and volume status changes was statistically significantly reduced from pre-dialysis to mid-dialysis scans and from pre-dialysis to post-dialysis scans. Ultrasound signs of pulmonary edema indicated by B-lines resolved within hours after treatment.

The CRIT-LINE instrument used trans--photometry to determine absolute hematocrit based on the absorptive and scattering properties of the erythrocytes as they passed through the chamber. Prior to hemodialysis, a sterile plastic disposable blood chamber was placed between the arterial line and the dialyzer. The first phase of the research assessed the time dependence of vascular compartment refill after hemodialysis to determine the hematocrit threshold[38]. Hemodialysis patients were monitored with for 10, 20, or 30 minutes after ultrafiltration with a non-invasive continuous monitoring instrument (CRIT-LINE) to measure changes in hematocrit (Hct) and blood volume in real time. In the experiment phase, the hemodialysis team initially increased the ultrafiltration (UF) rate by 25% at the beginning of dialysis and adjusted it in real time during the process to maintain the patient's real-time hematocrit below 2 units of the hematocrit threshold. The UF rate was decreased or increased in the amount of 250 mL/h as the hematocrit above or below the hematocrit threshold, respectively. Sometimes, staff need to adjust the ultrafiltration rate within 15 minutes to maintain the actual hematocrit near the threshold within the prescribed treatment time. During the experiment, the patient reaches the initial ultrafiltration target before the end of the prescribed treatment period, staff are instructed to continue fluid removal at the same ultrafiltration rate, provided the hematocrit does not exceed the threshold. Researchers recorded patient symptoms while dialysis center staff made all ultrafiltration rate adjustments. Throughout all

treatment sessions, a continuous curve of hematocrit over time was plotted for each patient, and the relationship between patient symptoms and time, blood pressure, and hematocrit was also recorded. This protocol successfully reduced the incidence of dialysis discomfort symptoms (clinical manifestations of hypovolemia, post dialysis fatigue, dizziness, cramps, and nausea)[39]. This method, which dynamically adjusts the ultrafiltration rate by monitoring hematocrit (Hct), achieves nearly twice the symptom improvement without shortening treatment time or reducing the total amount of fluid that must be removed.

Conclusion

This fishbone model may become a standard model, serving as a reference for academia and practitioners to help assess when and which knowledge management level needs to be emphasized, and which key factors managers should focus on and maximize organizational outcomes at each stage of the fishbone model.

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Author Contributions

Conceptualization: WJY; Data curation: WJY, TYT, HJC; Formal analysis: WJY; Funding acquisition: WJY; Investigation: WJY, TYT; Methodology: WJY; Project administration: WJY; Resources: WJY; Software: WJY; Validation: WJY; Visualization: WJY, TYT, CCJ, HJC, LYF, LSJ; Writing– original draft: WJY

Declarations

Ethical approval

This study received ethical approval of Taipei City Hospital Research Ethics Committee with the case number of TCHIRB-11206015. The authors confirm that this study was conducted in accordance with the principles of academic integrity and research ethics.

Consent to publish Not applicable.

Competing interests The authors declare no competing interests.

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Data Availability

The deidentified dry body weight education questionnaire data generated in this study was obtained from the principal investigator under the consent of the Taipei City Hospital Research Ethics Committee. All original raw data requests were promptly reviewed by Taipei City Hospital Research Ethics Committee and the corresponding author to determine whether the request was subject to any confidentiality obligations. Other data supporting the results of this study can be found in the text, tables.

Legends of Tables and Figure

Table 1 Internal consistency reliability and item statistics of the Dry body weight Education Scale(N=45)

Table 2. Main themes from dry body weight education survey

Table 3A Independent sample t test between domain 1 and domain 2 (n = 45).

Table 3B Results of Wilcoxon signed ranks test between pairwise comparison between domain 1, domain 2A and domain 2B

Figure1. A fishbone diagram of comprehensive root cause analysis of competence of healthcare workers in domains of DBW education

Abbreviations: IDWG, intra-dialytic weight gain; AV shunt, arterio-venous shunt; DBW, dry body weight, DEXA, Dural- energy X- ray absorptiometry; BIA, bio-impedance analysis; MAC, mid-arm circumference; TSFT, triceps skinfold thickness; MAMC, mid-arm muscle circumference; MAMA, mid-arm muscle area; BP, blood pressure; IVC, inferior vena cava; NT-proBNP, N-terminal pro-B-type natriuretic peptide

Table 1 Internal consistency reliability and item statistics of the Dry body weight Education Scale(N=45)

	Item statistics Score, mean (SD)	Item total correlation	Internal consistency reliability Item statistics α if item deleted
Item 1	.80± .405	.379[e]	.631
Item 2	.89± .318	.257(NS)	.647
Item 3	.91±.288	.439[d]	.625
Item 4	.87± .344	.290(NS)	.640
Item 5	.96± .208	.322[e]	.636
Item 6	1±0	NA	NA
Item 7	.56± .503	.448[d]	.625
Item 8	.76± .435	0.147(NS)	.663
Item 9	1±0	NA	NA
Item 10	.98± .149	.225(NS)	.642
Item 11	.33±.477	.569[c]	.603
Item 12	.40±.495	.202(NS)	.663
Item 13	.56± .503	.541[c]	.608
Item 14	.62± .490	.318[e]	.645
Item 15	.60±.495	.330[e]	.630
Item 16	.56± .503	.573[c]	.602
Item 17	.22±.420	.300[e]	.643
Item 18	.62± .490	.493 [d]	.617
Item 19	.42±.499	.384[d]	.636
Item 20	.24±.435	.501[c]	.615

Unstandardized Cronbach α=0.646; Standardized Cronbach α=0.65; split-half reliability=0.70; The overall scores of items of the Dry Body Weight Education Scale range between 0 and 20;

Abbreviations: NS, not significant.NA, Not applicable

[a]P<0.0001;[b]P<0.0005;[c]P<0.001;[d]P<0.01;[e]P<0.05.

Table 2. Main themes from dry body weight education survey

Categories and nomenclatures of domains	Main themes	Included items per domain
Domain 1: knowledge and education skills on DBW	High salt content food High water content food Symptoms of over-hydration Symptoms of under-hydration Diet planning	Item 1-10
Domain 2: body composition and DBW assessment equipment and tools	Bioelectrical impedance Cardiac echocardiography N-terminal pro-brain natriuretic peptide (NT-pro-BNP) Dual Energy x-ray absorptiometry (DEXA) scans Upper arm anthropometry Radioisotope dilution techniques Underwater weighing	Item 11-20 (Domain 2A: DBW assessment equipment and tools Domain 2B: body composition)

,

Table 3 Results of Wilcoxon signed ranks test between pairwise comparison between domain 1, domain 2A and domain 2B

Evaluation domain	Number of items in each domain	Mean± standard deviation of each domain	Wilcoxon T value	Wilcoxon Z value
domain 2 and Domain 1	10 versus 10	4.578±2.179 8.71±1.079	-1035	-5.866**
domain 2A versus Domain 1	5 versus 10	53.78±31.572(%) 87.11±10.79(%)	-770.00	-5.319**
domain 2B versus Domain 1	5 versus 10	37.78±23.44(%) 87.11±10.79(%)	-1035	-5.865**
domain 2B versus domain 2A	5 versus 5	37.78±23.44(%) 53.78±31.572(%)	-181.50	-2.784*

Note: Wilcoxon signed ranks test between pairwise comparison between domain 1, domain 2A and domain 2B of dry body weight questionnaire of hemodialysis nurse respondents

Table 4 KMO and Bartlett test (Scale if items deleted)

	Scale if item 6,9 deleted	Scale if item 6,9, 8,12,2	Scale if item 6,9, 8,12, 10 deleted	Scale if item 6,9, 8,12, 10, 2 deleted	Scale f item 6, 9, 8,12, 10, 2, 4 deleted
KMO	0.377	0.485	0.517	0.551	0.576
Bartlett test	<0.001	0.003	0.016	0.012	0.004
Degree of freedom	153	105	105	91	78
Approximate Chi-Square	217.551	149.069	138.506	124.093	115.305
Cumulative Explained Variation	74.197	72.597	64.486	66.340	68.713

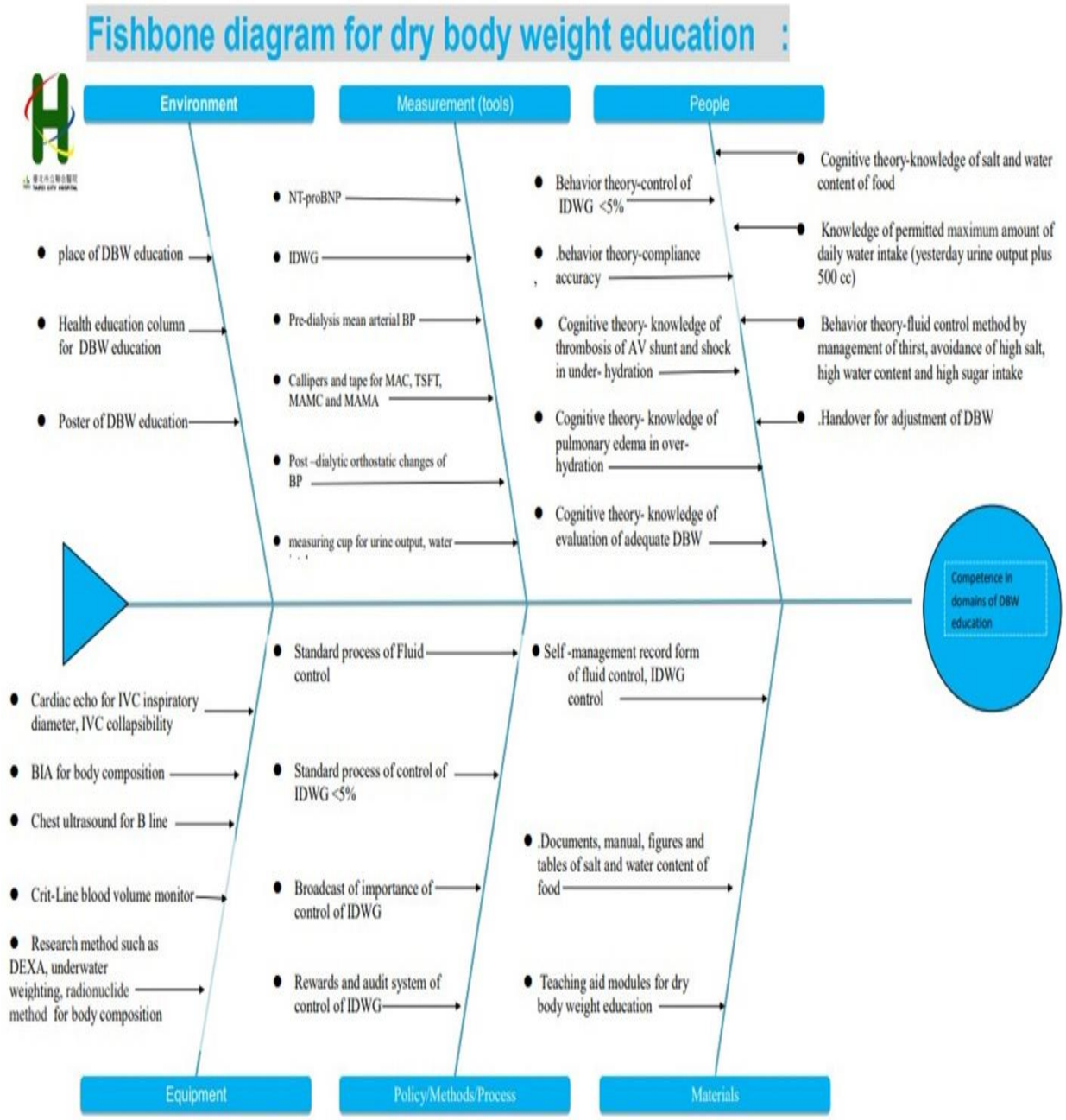

Fishbone diagram for dry body weight education :
Environment
Measurement (tools)
People
NT-proBNP
IDWG
Pre-dialysis mean arterial BP
Callipers and tape for MAC, TSFT, MAMC and MAMA
Post –dialytic orthostatic changes of BP
measuring cup for urine output, water
Behavior theory-control of IDWG <5%
.behavior theory-compliance , accuracy
Cognitive theory- knowledge of thrombosis of AV shunt and shock in under- hydration
Cognitive theory- knowledge of pulmonary edema in over-hydration
Cognitive theory- knowledge of evaluation of adequate DBW
Cognitive theory-knowledge of salt and water content of food
Knowledge of permitted maximum amount of daily water intake (yesterday urine output plus 500 cc)
Behavior theory-fluid control method by management of thirst, avoidance of high salt, high water content and high sugar intake
.Handover for adjustment of DBW
place of DBW education
Health education column for DBW education
Poster of DBW education
Competence in domains of DBW education
Standard process of Fluid control
Standard process of control of IDWG <5%
Broadcast of importance of control of IDWG
Rewards and audit system of control of IDWG
Self -management record form of fluid control, IDWG control
.Documents, manual, figures and tables of salt and water content of food
Teaching aid modules for dry body weight education
Cardiac echo for IVC inspiratory diameter, IVC collapsibility
BIA for body composition
Chest ultrasound for B line
Crit-Line blood volume monitor
Research method such as DEXA, underwater weighting, radionuclide method for body composition
Equipment
Policy/Methods/Process
Materials

Figure1

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