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Original article

Dietary Food Record Charts and digital photography effectively estimate hospital meal consumption

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Background & aims: Optimal nutritional intake is essential to support nutritional status and improve recovery in hospital patients. To monitor adequate food intake in patients, reliable and accessible methods to quantify patient food intake accurately are needed. The present study aims to compare the accuracy of two methods, Food Record Charts (FRCs) and Digital Photography (DP), in estimating food intake with the gold standard of Weighed Food Records (WFRs).
Methods: Thirty nurses, healthcare assistants, and researchers participated in a single-blind, prospective study to estimate food consumption using both FRCs and DP for 27 different hospital meals (6 breakfasts, 6 lunches, 6 dinners, and 9 snacks) consisting of 108 different food items. FRCs and DP estimates were compared to WFRs using the average estimations of all participants. Bland–Altman plots were used to identify any discrepancies in the accuracy of food intake estimation.
Results: FRCs overestimated food consumption by 3.2 ± 14.7 % and DP by 4.7 ± 15.8 % compared to WFRs. The Bland–Altman plots showed limited variation. Similar results were found when analyzing energy and protein content subcategories, the consumed amount, food categories, and food consistency. The inter-rater agreement was W = 0.733 (P = 0.000) and W = 0.682 (P = 0.000) for FRCs and DP, respectively.
Conclusions: FRCs and DP are accurate methods for quantifying food consumption in hospital meals compared to WFRs, with an overestimation of food consumption by less than 5 %.

1. Introduction

Poor nutritional intake during hospitalization leading to malnutrition, prevalent in up to 40 % of patients, is associated with impaired clinical outcomes such as increased length of hospital stay, readmissions, and mortality [1–3]. Nutritional intake is essential to support nutritional status and improve recovery during illness [1]. In particular, energy and protein in the diet are essential to support recovery, improve the immune system, and build and maintain muscle mass [4,5]. Hospitalized patients at risk of malnutrition may benefit from individualized nutritional support during hospital stay [6]. Food consumption in hospital patients often falls below prescribed targets [7–9]. In addition, ordered food charts do not necessarily reflect actual food intake levels [10–12]. Previous studies have shown that ~30–40 % of hospital meals are not being consumed, affirming the necessity to quantify food consumption rather than measuring provision [8,9]. Accessible and accurate methods to quantify patients' food intake in the hospital setting are warranted to assess nutritional intake adequately [13,14]. Weighed Food Records (WFRs) are considered the most reliable method involving weighing the food items before and after consumption to determine the exact quantity consumed [15,16].

Abbreviations: DP, Digital Photography; FRCs, Food Record Charts; WFRs, Weighed Food Records.

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However, WFRs are highly time-consuming and demanding for healthcare staff, resulting in low compliance rates, making them less applicable on a large scale in daily practice [12,16,17], highlighting the need for easy-to-use methods to assess food consumption in hospital meals [18]. Digital photography (DP), comparing pictures of before and after food consumption, has been validated as a reliable method to quantify the amount consumed in clinical settings [14,16,19], and in a real-life environment [20–22]. We have previously used digital photography, with ward nurses and food service assistants taking photos, to quantify patients' meal intake in post-intensive care patients, resulting in complete food intake data for 83 % of the patients [11]. Another widely used method in clinical practice is Food Record Charts (FRCs), filled in by patients, nursing staff, dietitians, or healthcare assistants. FRCs are currently used in daily practice in many hospitals, including ours, by healthcare staff to estimate patients' daily food consumption. Several versions of FRCs have been validated [16,23–25]. However, the compliance to fill in FRCs varies substantially, with compliance rates ranging from 7 % [25] to 100 % [23] in hospital settings leading to underestimation of actual energy and protein intake compared to WFRs [17,20,24]. It is plausible that the low compliance is attributable to the lack of comprehensive investigation into the reliability of FRCs. Therefore, this single-blind, prospective study aims to evaluate the accuracy of FRCs and DP compared to WFRs among healthcare professionals in quantifying food consumption of hospital meals.

2. Materials and methods

2.1. Study participants

The study was conducted at a university-affiliated hospital Gelderse Vallei in Ede, the Netherlands, in November 2022. Recruitment was carried out through flyers and the local hospital intranet, aiming to recruit adult healthcare professionals or hospital staff, working in a hospital ward or medical department, or involved in the patient food service system in the Gelderse Vallei hospital, available on a pre-set date for FRCs assessment. A total of 30 participants from different hospital wards, comprising 16 nurses, 10 healthcare assistants, and 4 researchers participated in the study. The study did not fall under the scope of the Medical Research Involving Human Subjects Act. Therefore, no ethical approval was needed to conduct the study. Oral informed consent was obtained from every participant before the commencement of the study. In gratitude for their involvement, participants received a voucher for a hot meal at the hospital following their participation. Participants' data were collected under the Personal Data Protection Act and was pseudo-anonymized.

2.2. Study design

On two occasions (one pre-set date for FRCs assessment for all participants and one flexible date for DP), participants were asked to quantify the food consumption of 27 hospital meals. A random amount of the weighed meal portion was removed by the research team from every tray to simulate patient meal consumption. The objective was to remove a different random portion from each food item, mimicking daily food consumption in hospital patients. We deliberately chose to simulate patient meal consumption rather than use real patient plate waste as this allows for a more controlled set-up, avoiding variability due to preferences, appetite and dietary restrictions, while ensuring the reproducibility of the study results. The nursing staff, healthcare assistants, and researchers were instructed to complete FRCs for each meal tray individually by observing the meals without communicating with one another. No supplementary training was provided to reflect everyday practice. The participants assessed food leftovers using FRCs from 27 food trays (including 6 breakfasts, 6 lunches, 6 dinners, and 9 snacks) comprising 108 food items, specifically selected to represent the full range of available hospital meals and beverages in the hospital food service system, including protein and/or energy rich food items. A list of all food items is presented in the supplementary material. One week later, pictures of the same trays with the same 108 food items were assessed by DP via an online form on a computer or smartphone received via email personally directed to the participants. The DP assessment was done individually without any interaction with other participants or possibility to recall the quantity estimated during FRC assessment. The meals were prepared and delivered by the hospital kitchen in a manner identical to those served to patients. Total energy and protein content were calculated using product specifications provided by the food suppliers and the Dutch Food Consumption Database 2016 (NEVO; RIVM, Bilthoven, the Netherlands) [26].

2.3. Food consumption estimations

Food consumption was assessed by weighing the food trays using WFRs and visual observation by participants using FRCs, and DP. In total, 28 participants completed both the FRCs and the DP. Two participants only completed the FRCs and did not complete the DP. For WFRs, each food item was weighed once in grams before and after simulated consumption by removing a portion of the standard food item's serving size, using an electronic scale (Kern EMB 2000-2). A single researcher (CSMS) conducted all weighing measurements to ensure consistency. FRCs, paper scoring forms that are part of standard clinical care in our hospital, consisted of a six-point scale (0, $^{1}/_{8}$, ¼, ½, ¾, and 1) for each food item (Supplementary material). The present six-point scale is equivalent to 0 %, 12.5 %, 25 %, 50 %, 75 %, and 100 % of food consumption for each individual food item. Participants were instructed to complete the FRCs, by observation to estimate the amount of food that was 'eaten', with all the actual meal trays presented on tables in a room. They were allowed to touch the packaging, for instance to see whether it was empty or not. For DP, each meal tray was photographed before and after simulated food consumption at a ~45° angle and ~50 cm distance from the tray by one of the research members (CSMS) [19] (Supplementary material). The researcher was not provided with formal training in food photography, intentionally mimicking the conditions of daily practice in a hospital setting. To ease in estimating food consumption, packages were photographed opened, lids removed, and empty containers inverted. Participants were then sent the simulated post-consumption photos and instructed to indicate the consumed quantity by visual observation of the photos on a computer or smartphone screen, using the identical six-point scoring system as for FRCs. Subsequently, the six-point scale was converted to the number of grams relative to the pre-weighed product, thus facilitating comparison to WFRs.

2.4. Statistical analyses

The accuracy of food consumption assessment was calculated by the difference between the estimated and actual consumption in the three different methods using the formula: accuracy estimated food consumption (%) = estimated food consumption with DP or FRCs (%) - actual food consumption with WFRs (%) [27]. The distribution of the mean differences for all food items was normal, for both DP and FRCs estimations. A Bland–Altman analysis was performed to evaluate the discrepancy between the reference method, WFRs, and FRCs or DP, with each food item included individually.

The inter-rater reliability of FRCs and DP was assessed based on the six-point scale estimations of participants using Kendall Concordance Coefficient W with inter-rater agreement ranging from 0 being no agreement between independent raters to 1 being perfect agreement [28]. We considered an agreement of >0.6 as acceptable [29]. Subgroup analyses (energy and protein content, consumed quantity, consistency of the food products, and food categories based on the Dutch Wheel of Five [30]) were performed to determine differences between FRCs, DP, and WFRs estimations. All data are presented as means and SD of the percentage differences. All calculations were performed using the statistical software program SPSS (version 28.0, IBM Corp., Armonk, USA). Statistical significance was set at $P < 0.05$.

3. Results

The FRCs were completed by 30 participants, while the DP estimations were completed by 28 participants. A total of 10 estimations for different food items were missing from the FRCs (0.3 % of the total food items to be assessed), while there were no missing data for the DP, except for the two participants who did not complete them at all. Food consumption estimation for all food items using FRCs was 3.2 ± 14.7 % higher than food consumption assessed by WFRs; for DP, this was 4.7 ± 15.8 % higher compared to WFRs. Bland–Altman plots of the three methods are presented in Fig. 1. The food items that fell outside the limits of agreement were 4.6 % for FRCs and 7.4 % for DP.

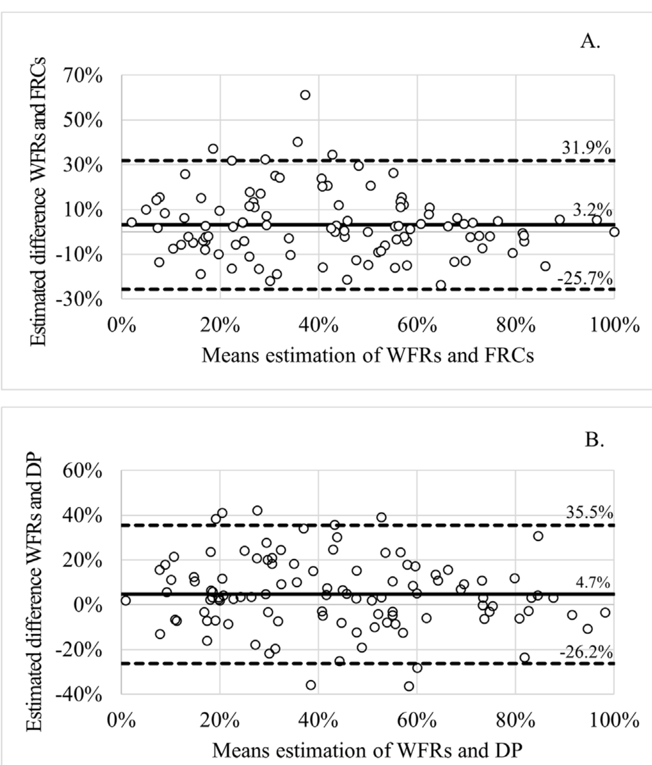

Fig. 1. Bland–Altman plots of WFRs and FRCs (A) and WFRs and DP (B). Legend: black line = mean difference, dashed lines = limits of agreement = bias ± (1.96xSD) = precision. FRCs (A): mean = 3.2 ± 14.7 % (ULA = 31.9 %; LLA = −25.7 %), DP (B): mean = 4.7 ± 15.8 % (ULA = 35.5 %; LLA = −26.2 %). Each dot in the figure represents the mean estimation of a single food item (a total of 108). WFRs: Weighed Food Records; FRCs: Food Record Charts; DP: Digital Photography.

3.1. Inter-rater reliability

The inter-rater agreement (Kendall's coefficient of concordance) between the participants for all food items estimations taken together was W = 0.733 for FRCs ($P = 0.00$) and W = 0.682 for DP ($P = 0.00$) [28].

3.2. Energy and protein content of the food items

Food consumption estimations based on energy and protein content are presented in Table 1. For all food items, the difference in food consumption estimation averaged −4.9 ± 92.0 kJ for FRCs and +1.0 ± 108.8 kJ for DP compared to WFRs. The sub analysis based on the energy content categories showed only slight variation between groups. For protein content, food consumption estimations resulted in a difference of −0.2 ± 1.3 g protein using FRCs and −0.1 ± 1.3 g protein using DP. In the low protein groups (<1 g and 1.0–5.0 g protein/100 g), food consumption was overestimated by +7.3 ± 14.8 % and +3.9 ± 16.3 % for FRCs and +9.0 ± 16.4 % and +3.4 ± 16.0 % for DP, respectively. Only a minor underestimation was observed in the protein group containing 5.1–10.0 g protein/100 g (−1.7 ± 9.7 % for FRCs and −0.6 ± 11.3 % for DP). In the high protein group (>10.1 g protein/100 g), a −0.2 ± 14.4 % difference was observed using FRCs and +3.5 ± 16.4 % using DP.

3.3. Consumed amount

Food items consumed <50 % were overestimated using FRCs (+9.9 ± 16.1 % for food items consumed 0.0–25.0 % and +3.0 ± 15.8 % for food items consumed 25.1–50.0 %) and DP (+11.5 ± 14.0 % for food items consumed 0.0–25.0 % and +6.4 ± 16.0 % for food items consumed 25.1–50.0 %). In contrast, products with >50 % consumption were underestimated for both FRCs (−2.2 ± 9.2 % for food items consumed 50.1–75.0 % and −5.1 ± 8.4 % for food items consumed 75.1–100.0 %) and DP (−1.2 ± 15.2 % for food items consumed 50.1–75.0 % and −6.7 ± 11.5 % for food items consumed 75.1–100.0 %) (Table 2).

3.4. Food groups

The categorization into food groups (Fig. 2), based on the Dutch Wheel of Five [30], showed a difference of +2.1 ± 12.7 % (nuts and animal products) to +8.9 ± 13.5 % (spreading and cooking fats) using FRCs and +3.8 ± 16.5 % (fruit and vegetables) to +9.5 ± 10.8 % (spreading and cooking fats) using DP, except for bread, grains, and potatoes, which was underestimated by −2.3 ± 14.4 % using FRCs and −2.4 ± 15.3 % using DP.

3.5. Consistency of food items

Food consumption estimations based on consistency are presented in Fig. 3. Food items in the liquid or semi-solid group were more frequently overestimated than solids, with a difference of +2.3 ± 8.1 % for liquids, +6.4 ± 19.2 % for semi-solids, and +1.7 ± 14.4 % for solids using FRCs compared to WFRs. This overestimation occurred also when using DP, with a difference of +6.9 ± 8.7 % for liquids, +7.8 ± 20.2 % for semi-solids, and +1.8 ± 15.5 % for solids when using DP.

4. Discussion

In the present exploratory study, we assessed the accuracy of Food Record Charts and Digital Photography compared to Weighed Food Records in quantifying hospital meals consumption in a group of 30 nurses, healthcare assistants, and research staff.

Table 1
Food consumption estimations using Food Record Charts and Digital Photography based on protein and energy content per product compared to Weighed Food Records.

	Energy content (kJ/100 g)				Protein content (g/100 g)			
	0.0–200.0 kJ ($n = 28$)	200.1–500.0 kJ ($n = 26$)	500.1–1000.0 kJ ($n = 26$)	>1000.1 kJ ($n = 28$)	<1 g ($n = 36$)	1.0 g–5.0 g ($n = 29$)	5.1 g–10.0 g ($n = 16$)	>10.1 g ($n = 27$)
FRCs estimation difference, % (SD)	+3.2 (12.2)	+3.6 (17.4)	+0.3 (15.7)	+5.4 (13.7)	+7.3 (14.8)	+3.9 (16.3)	−1.7 (9.7)	−0.2 (14.4)
DP estimation difference, % (SD)	+5.9 (12.3)	+2.7 (17.9)	+4.5 (18.4)	+5.6 (15.0)	+9.0 (16.4)	+3.4 (16.0)	−0.6 (11.3)	+3.5 (16.4)

The values are presented as means and standard deviation (SD). Positive values refer to an overestimation of the food intake and negative values refer to an underestimation of the food intake in comparison to Weighed Food Records. There are 108 food items in total and 'n' in the table refers to the number of foods items in a category. FRCs: Food Record Charts ($n = 30$); DP: Digital Photography ($n = 28$).

Table 2
Food consumption estimations using Food Record Charts and Digital Photography based on the amount consumed compared to Weighed Food Records.

	0.0–25.0 % consumed ($n = 38$)	25.1 %–50.0 % consumed ($n = 30$)	50.1%–75.0 % consumed ($n = 27$)	75.1%–100.0 % consumed ($n = 13$)
FRCs estimation difference, % (SD)	+9.9 (16.1)	+3.0 (15.8)	−2.2 (9.2)	−5.1 (8.4)
DP estimation difference, % (SD)	+11.5 (14.0)	+6.4 (16.0)	−1.2 (15.2)	−6.7 (11.5)

The values are presented as means and standard deviation (SD).Positive values refer to an overestimation of food intake, and negative values refer to an underestimation of food intake in comparison to Weighed Food Records. There are 108 food items in total and 'n' in the table refers to the number of food items in a category. FRCs: Food Record Charts ($n = 30$); DP: Digital Photography ($n = 28$).

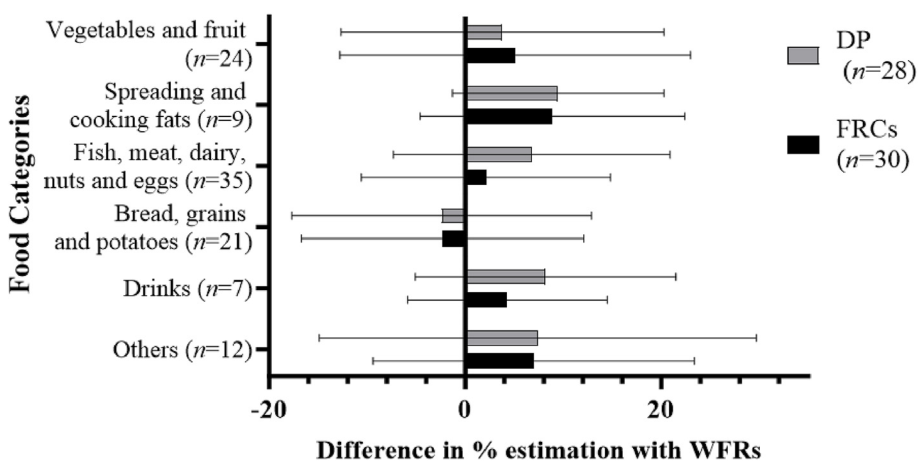

Fig. 2. Food consumption estimations based on food groups. Nutritional categories are based on food groups from the Dutch Wheel of Five [30] and are represented as boxplots with whiskers. Positive values refer to an overestimation (%) of food intake, and negative values refer to an underestimation (%) of food intake in comparison to Weighed Food Records. There are 108 food items in total and 'n' in the figure refers to the number of food items in a category. FRCs: Food Record Charts; DP: Digital Photography; WFRs: Weighed Food Records.

Nutritional intake is essential to support nutritional status and improve recovery during illness. Individualized nutritional support during hospital stay can improve clinical outcomes, including survival in medical inpatients at nutritional risk. Therefore, accurate methods to quantify food intake in hospitals are paramount. This is the first study to compare FRCs and DP to estimate food consumption of hospital meals by healthcare staff and researchers. We now also stratified for specific factors that might influence estimations and/or nutritional intake, such as the consumed amount, food groups, and food consistency. Overall, the use of DP and FRCs resulted in a difference of <5 % for all food items compared to food consumption assessed by WFRs. Food consumption estimations using FRCs and DP were consistently higher than consumption assessed by WFRs. Previous studies that used cut-off values for the accuracy of food estimations range from 10 % to 20 %, based on the weight of the product [27] or the energy and protein content [23]. Therefore, the overestimation of ~3 % using FRCs and ~5 % using DP observed in the present study can be considered clinically negligible.

Furthermore, our findings indicated that inter-rater variability among the 30 participants was significant with both FRCs and DP when estimating food consumption, meaning that the participants were consistently ranking the items in a similar order. The agreement between the participants was most robust with FRCs ($W_{FRCs} = 0.733$). At the same time, a lower inter-rater agreement was observed with digital photography ($W_{DP} = 0.682$), which may be attributed to nurses' lower experience in our hospital with this method and the inability to interact physically with the food during assessment. The inter-rater agreement of DP may have been influenced by the FRCs being completed two weeks before the DP assessment, introducing potential recall bias. The relatively low inter-rater variability in FRCs and DP may be attributed, at least in part, to significant differences in familiarity and experience with the methods among the participants. For example, in our cohort of participants, some were frequent users of the FRCs method (18 participants), while others had little to no experience (12 participants), which depended on the department where they worked and their exposure to the method.

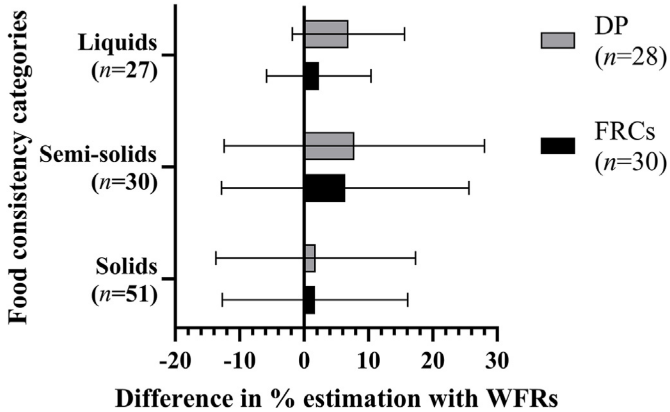

Fig. 3. Food consumption estimations based on food consistency. Positive values refer to an overestimation of food intake, and negative values refer to an underestimation of food intake in comparison to Weighed Food Records. There are 108 food items in total and 'n' in the figure refers to the number of food items in a category. FRCs: Food Record Charts; DP: Digital Photography.

Adequate protein and energy intake is critical for hospitalized patients [4,31] to reduce the risk of malnutrition, attenuate muscle wasting, and support muscle quality and strength loss [32,33]. To investigate whether the overestimations of food intake observed in the study affect protein and intake levels, food items were classified based on protein and energy content and compared between food estimation methods. Both FRCs and DP did not affect the accuracy of estimating the protein and energy content consumed in the hospital meals. Previous research reported an underestimation of protein intake of ~4 g, which was more pronounced in patients with higher food intakes [23]. Our sub-analyses indicate that the overestimation of food consumption of low-protein items (up to 9 %) and slight overestimation of high-protein items (~3.5 %) only have minimal impact on the overall estimation of protein intake. The use of FRCs and DP showed no differences in energy content. Consequently, it is crucial to accurately assess nutritional status daily and enable accessible bedside methods to assess food intake throughout a hospital stay. We demonstrate that both FRCs and DP provide a reliable estimation of the actual protein and energy content of the amount of a hospital meal consumed. This further supports the clinical relevance of these methods.

Previous studies have shown discrepancies between the amount of food provided and food consumption in hospitalized patients [8,9]. Therefore, we further examined the difference in estimations based on the amount of food consumed. Notably, products that were consumed under 50 % were overestimated, while products consumed above 50 % were more often underestimated. These observations can result in an overestimation of the actual intake of patients with a low overall food intake and an underestimation in patients with a higher intake. Specifically, estimates of food items consumed under 25 % had the most considerable difference compared to WFRs (~10 %), even though participants could choose from three options (0, 1/8, and 1/4). Food products with >50 % consumption were overestimated with both FRCs and DP, likely because the 6-point scale used did not include an option between 3/4 and 1. The hypothesis is proposed that food estimations could become more accurate if the paper scoring form were augmented with the addition of a 7/8 option (87.5 %). Moreover, food consumption estimation was less accurate for liquids and semi-solids than solids. Accurate assessment of fluid intake may pose different challenges, such as the influence of packaging [34]. The results suggest that estimating food intake may be challenging for patients with low food intake and those who consume mainly liquids and semi-solids, which may lead to overestimation of intake. Further research could investigate whether the FRC and DP methods could be improved in this respect.

To apply DP in practice, adjustments to improve the method's accuracy have been described in previous research [19,34]. For example, placing lines on food cups to indicate the level of the remaining fluids [25], systematically turning down the empty cups, analyzing both before and after consumption photographs [19], and placing empty packages on the side of the tray have been suggested as practical strategies to improve accuracy. It is possible that a learning effect occurred due to participants completing the FRCs prior to the DP, which may have led to enhanced accuracy in food consumption estimation compared to the clinical hospital setting, where healthcare staff assess the meal only after it is photographed and have not previously evaluated it. Consequently, future research could consider conducting a crossover study in a random order of food assessment to more accurately account for this potential effect. As the researcher who took the photographs had no formal training in food photography, this approach reflects everyday hospital practice, where photographs are taken by a number of staff with varying levels of expertise. Recently, DP has advanced with automation of food quantification via software or artificial intelligence being under development [35,36]. It is probable that future advancements in machine learning will improve the accuracy of food consumption analysis. However, in the meantime, efficient use of DP in daily practice remains essential, hence the validation of DP in this study.

For the FRCs to be applied in practice, high compliance in completing the charts should be secured. In previous studies, the main challenge of adequate food consumption in clinical practice has been the low compliance of staff to complete FRCs assessments [13,25], which could be a matter of lack of adequate training of nursing staff resulting in low efficiency and increased time demands when using the method. Therefore, it is crucial to implement staff training to improve the compliance and completeness of FRCs recording. Another way to improve the rate of completion would be to involve patients in FRCs or DP assessment [37] and thus reduce the workload of health care staff. Future research in hospital settings is needed to further explore the applicability of this methodology.

5. Conclusion

In the present study, we demonstrate the accuracy of Food Record Charts and Digital Photography in estimating the food consumption of hospital meals. We show that FRCs and DP can be used as practical tools by healthcare professionals and researchers to quantify food consumption of hospital meals with less than 5 % variation compared to WFRs. FRCs and DP are reliable methods for clinical practice, thereby not affecting protein and energy intake estimations. However, both methods are less accurate when estimating food intake in individuals with low food intake.

Author contributions

Clémence Séverine Marie Schumacker: Investigation, Data curation, Formal analysis, Writing – original draft, Writing – review. Michelle Carmen Paulus: Data curation, Formal analysis, Writing – original draft, Writing – review. Yente Florine Niké Boelens: Conceptualization, Investigation, Writing – review. Arthur Raymond Hubert van Zanten: Conceptualization, Writing – review, Funding acquisition, Supervision. Imre Willemijn Kehinde Kouw: Conceptualization, Data curation, Formal analysis, Writing – original draft, Writing – review, Supervision.

All authors approved the final version of the manuscript.

Ethical approval

The study did not fall under the scope of the Medical Research Involving Human Subjects Act. Therefore, no ethical approval was needed to conduct the study.

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Declaration of competing interest

Prof. Dr van Zanten reported receiving honoraria for advisory board meetings, lectures, research, and travel expenses from AOP Pharma, Abbott, Baxter, Cardinal Health, Danone-Nutricia, Dutch Medical Food, Fresenius Kabi, GE Healthcare, InBody, Mermaid, and Rousselot. The other authors have nothing to declare.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.clnesp.2025.01.034.

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