THE TUFTS NUTRIENT CALCULATION SYSTEM

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ABSTRACT

A computerized nutrient calculation system has been developed for research-quality evaluation of food records and 24-hour recalls. There are three components to the system: nutrient database, coding/data entry, and calculating and generating reports of individual and group nutrient intake. The nutrient database consists of USDA data (1987) supplemented with data from manufacturers, foreign food composition tables and periodical literature. Imputed and missing values are identified, as are sources for each food item and nutrient value. Coding and data entry occur simultaneously. Coders can edit the data file created by the program and can display nutrient calculations for foods as needed during the coding process. Individual and group nutrient calculation reports and summary statistics are produced. Quality control features include computerized checks for invalid food codes or amounts and outliers, on-line coding rules, recording instances of inadequate documentation of food or amount, review of coded records, and standardized training of interviewers and coders.

Keywords: Dietary assessment, nutrition surveys, epidemiology.

Investigators studying the relationship between diet and disease often require precise estimates of the food and nutrient intakes of individuals. Several dietary assessment techniques are available, including weighed food records, diet histories, food frequency questionnaires, 24-hour recalls, and food balance sheets; among these, the weighed food record is considered the most accurate (James et al., 1984). Other methods are useful for estimating the nutrient intake of groups, but they too frequently over- or under-estimate nutrient intake on an individual basis (Beaton et al., 1979). The problem areas involve consumption of modified or specialized foods, variations in food preparation techniques and consumption of unusual portion sizes. When calculating nutrient intakes in such circumstances, it is particularly important to use a method such as a food record which is sensitive enough to detect such practices so that meaningful estimates are obtained.

In an NCI-funded trial, the Women's Health Trial, (1984-1988), four-day food records were used to calculate the nutrient intake of women at high risk for breast cancer, ages 45-69. Women, selected at random for the intervention, were instructed to follow a low-fat diet (20% of calories from fat). The determination of individual intakes was critical because the baseline evaluation was used to establish individualized "fat gram goals" for the intervention (low-fat) participants and for monitoring individual progress. In addition to the

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food records, food frequency questionnaires, 24-hour recalls, and biochemical markers were used to provide independent measures of nutrient intake and to monitor group progress.

The compliance with the intervention will be of interest to many researchers and professionals who see dietary intervention as a means to reduce risk of disease. Comparisons of the results with other nutrition surveys and interventions must be anticipated.

Historically, comparisons of nutrient intake data produced by different nutrient calculation systems have been complicated by variations in data collection and documentation techniques, nutrient database characteristics, and data coding procedures (Hoover and Perloff, 1984; Hoover, 1986; Danford, 1981; Jacobs et al., 1985; Dwyer and Suitor, 1984; Hoover, 1983; Adelman et al., 1983). It is critical that database developers and users focus on the importance of some key issues when developing, selecting or describing a nutrient calculation system, including:

* Data collection techniques - Are instructions to participants and probes used by interviewers standardized?
* Documentation of food descriptions and amounts - Is focus and level of detail appropriate for study and coding requirements?
* Size and specificity of database.
* Number and type of nutrients in the database.
* Nutrient data sources - Are sources documented and reputable?
* Missing nutrient values - How many are there, can they be distinguished from zeroes, are they filled in with imputed values?
* Database updating procedures and age of data.
* Recipes in database - How are nutrient values calculated?
* Coding rules - Are coding procedures clearly documented to decrease intercoder variability?
* Quality control -- What procedures exist to assure quality control in the database development and coding processes?
* Computational procedures for reports of individual and group data.

The purpose of this report is to document the characteristics of the Tufts Nutrient Calculation System, which has been developed with these issues in mind, by the Nutrition Coordinating Unit (NCU) at Tufts University School of Medicine in collaboration with Image Analysis Laboratory at Tufts-New England Medical Center.

THE NUTRIENT DATABASE

The nutrient database was developed in 1986 with the following goals: tight quality control, ease of updating, flexibility for the addition of food items and nutrients, appropriateness for use in large scale epidemiological research, and comparability with other widely used databases.

The following characteristics of the Tufts Nutrient Database distinguish it from other nutrient databases (Hoover and Perloff, 1984; Hoover, 1986; Danford, 1981; Jacobs et al., 1985; Dwyer and Suitor, 1984; Hoover, 1983; Adelman et al., 1983) and make it especially appropriate for research-quality nutrient calculations:

1) The database contains approximately 5,000 foods and recipes. The relatively large number of foods allows great specificity in the coding process, in which the coder must match the food described in the food record with a database entry of similar description and nutrient content. If an exact match cannot easily be made, one of 650 coding rules is used to guide the matching process.

2) Each food entry in the database has a five digit identification number, a three digit food group code, a short 20-character description, a more detailed 80-character description, and a reference number indicating the source of the nutrient data.

3) Each food has up to 71 nutrients associated with it. Other nutrients can be added to the database with ease to meet the needs of specific studies or when new bodies of nutrient data become available. Nutrient values are stored on the basis of 100 grams of food, edible portion. The state-of-the-art analytical methods for 55 of these nutrients are described by USDA as "adequate" or "substantial", while methods for other nutrients are less reliable. (Beecher, 1986).

4) Missing nutrient values in the database have values of -1 to distinguish them from zeroes. In reports which refer to individual foods in the database, missing values are left blank, while true zero values are displayed as such. Missing values are treated as zeroes, however, in nutrient calculations. Missing values are replaced by new data or by imputed data when possible (Holden, 1985).

5) Each nutrient value for each food is characterized as follows:
   * Data is identified as empirical, imputed, or from manufacturer's claims.
   * The specific data source is identified with a reference number corresponding to a separate, extensive bibliography.
   * The sample size and standard deviation are included when available.

6) The primary nutrient data source is the USDA Nutrient Data Base for Standard Reference Release 6, 1987 (U.S. Department of Agriculture, 1987). Additional data are obtained as needed from food manufacturers, the periodical literature, foreign food tables, and other US Government Publications. Priority is usually given to nutrient values available from the USDA, a common practice among nutrient database developers (Buzzard et al., 1986).

7) When the database is updated or missing values are filled in, computer routines which check the validity of the data are automatically invoked. For example, the weight of proximate components is summed and compared to the total weight, usually 100 grams. If the discrepancy exceeds programmed limits, the user is notified (Buzzard et al., 1986; Murphy, 1986).

8) The database stores the gram weight of up to 20 portion options for each food, so that amounts may be entered in household measures, dimension or ounces as well as grams. The data source for the weight of each portion code is identified with a reference number.

9) Printed reports can be produced which sort the data base according to food label, food code or food group. One or more nutrient values can be displayed for either 100 gram portions of each food or for each portion of each food.

10) The master database is continually updated and made more complete in response to changes in the American food supply and the availability of new or better nutrient data. However, food records for a particular study are coded using a "frozen" version of the database and coding system for the duration of the study. The purpose of freezing the database is to assure that food records are coded the same way over the course of the study. When the database and coding system are frozen, the following conditions are observed:

* Existing coding rules cannot be changed.
* New coding rules can be added if they pertain to a new food item on the market or if they reflect past practice.
* Existing database recipes cannot be changed.
* No food items can be removed from the database; description of existing food items cannot be modified.
* Missing nutrient values can be filled in for foods in the database.
* New study-specific recipes can be added to the database.
* New products on the market or revised formulations of old products can be added to the database.
* New portion choices can be added to the database if they reflect past practice.

The number of new foods and beverages added is kept to a minimum so that the database can be adequately maintained. However, new foods, beverages, or supplements which appear frequently in food records and which differ substantially in nutrient content from any existing database item are added to the database.

CODING/DATA ENTRY

Coding and data entry occur simultaneously using a interactive computer program. A one-day food record containing 30 food items is coded in an average of thirty minutes; thus the four day food records used in the WHT require approximately two hours to code. There is a slight decrease in the time per day required for coding when the same meals or recipes are consumed repeatedly. Coding/data entry time compares favorably with other systems utilizing highly detailed food records and detail-oriented, standardized coding procedures; this represents a substantial time savings over coding similar records by hand using a code book and keypunching the code numbers.

Since the interactive program provides easy access to food choices of all descriptions, it encourages the use of the appropriate food items; food code selection in a manual system can be biased by the coder's memory of some food codes which are used in preference to others. The on-line coding index contains a subset of the most frequently used foods in the database (approximately 3800 foods). Using the scheme developed by the USDA for the National Food Consumption Survey (Pao et al., 1982), items are arranged according to food groups in a three-level branching menu. The coder can select and enter a food code in one of several ways:

* Move through the menus one-by-one reading the choices on each menu; after reaching the '"selection screen" containing detailed food descriptions, one food is selected. The program, rather than the coder, enters the five-digit food code in the data file.
* If the "path" to the selection screen is familiar, the coder can move there directly without looking at any of the intervening menus.
* Food codes can be entered directly without using the menu system at all. Experienced coders use this approach for standard and commonly consumed food items.
* Search function allow the coder to search for food code matching a particular description. The search can be within the coding index subset or the entire database. Foods not in the coding index ca be entered by simply typing in the five-digit food code after the brief search.

After the food is selected or the food code is entered, the available portion options for the food are displayed. The coder selects one, and then indicates the number of multiples of that portion that were consumed. (See Figure 1 for examples of the menu and selection screens.)

A carefully developed set of 650 coding rules complements the database and is a integral part of the coding program. The coding rules are used in two situations: 1) the food description or amount contains missing or conflicting information that requires interpretation by the coder (Example: milk,% fat unknown: Code as whole milk); 2) the food consumed cannot be exactly matched with an item in the database (Example: Laughing Cow Lo-Cal cheese/: Code a 1-3/4 oz. wedge as 13g of part-skim mozzarella cheese plus 9g of skim milk). Each coding rule is dated and the source of the data is referenced. New coding rules are added at the beginning of new studies to focus on study-specific parameters or at the discretion of the database manager, to standardize existing coding practices. For example, a hypertension trial might require code rules regarding the amount of salt to code when the amount used is unknown. Or, coders have developed a method for coding a new product on the market, such as chocolate pudding with aspartame, and the method is formalized and communicated to other coders via a coding rule.

All of the 650 coding rules are on-line within the coding index. To see the code rules associated with menu or selection screen, a coder types a one-letter symbol.

Quality control features of the coding/data entry program include the computerized checks for invalid food and portion codes as well as extraordinary amounts of food, sophisticated on-line editing ability, and availability of nutrient displays for individual foods or all foods in the food record.

The coding index has great flexibility with regard to the food-grouping scheme, food-item descriptions and, with some modifications, even the underlying database that ca be used with it. An interactive editing program allows changes and correction to be made with ease.

CALCULATING AND GENERATING REPORTS

Several types of nutrient calculation reports for individual food records can be generated, varying in complexity and focus. A typical report contains average nutrient consumption, nutrient intake sorted according to food group (Fanelli and Samonds, 1986), and average nutrient intake graphically compared to 1980 Recommended Dietary Allowances (National

Research Council, Food and Nutrition Board, 1980) for the participant's age-sex category. This is followed by an itemized account of the individual foods and beverages consumed, their amounts, and values of key nutrients in the portion consumed.

Reports can be customized to emphasize the nutrients of interest in a particular study. Visual elements such as bar graphs and layout make it possible for study subjects to P.D. interpret the printouts with the assistance of a dietitian or a detailed handout. One specialized feature is the ability to plot nutrient intake over time, utilizing nutrient intake data from subjects' previous food records in addition to the current one. See Figure 2 for sample pages from the individual four-day food record report. Figures 3 and 4 show summary data in a chart and a graph, respectively.

Group data are generated as printed reports or on magnetic tape. The following types of reports are currently produced:

* Summary statistics for group intake by nutrient and by food group.
* Comparison of mean nutrient intakes of two study groups.
* Comparison of mean baseline nutrient intakes with those calculated at a later date.
* Comparison of mean nutrient intake from four-day food records and other dietary assessment methods such as food frequency questionnaires.
* Frequency of food code use, which reflects food, beverage and dietary supplement consumption.

QUALITY CONTROL

Protocol for Food Record Handling: Dietary assessment forms received at the Tufts Nutrient Database are logged in and processed on a first-in, first-out basis. When required, there is a two-week turnaround time for coding food records or 24-hour recalls, including calculations ad report generation. Food records are coded by the first coder; a small sample (5-10%) of coded food records is checked by a second coder for errors, which requires a average of 8 minutes for a one day food record, 30 minutes for a four-day food record. The nutrient report for the food record is printed out and briefly reviewed by the coding supervisor before being returned to the clinic in the same batch it was received in.

Internal quality control. The Tufts Nutrient Database takes a number of precautionary steps to insure quality control in the coding/data entry system. Careful training and supervision of coders in a centralized location is the foundation. Full-time coders with academic and practical backgrounds in food and nutrition undergo a standardized training program before coding study records. The 1-week training program emphasizes appropriate use of portion amounts. After the initial training period, coders receive written notice of errors discovered by the checker or the coding supervisor so that they may continue to improve their performance.

Errors are minimized, however, by the presence of numerous portion options to reduce the need for calculation and conversion of portion sizes, and by computerized checks for invalid food codes, portion codes and portion sizes.

Comparison of our coding system with other databases, particularly the Nutrition Coding Center at the University of Minnesota, is undertaken periodically to identify discrepancies which may require investigation or reveal errors in the data base or coding system (Catsos, et al., 1986).

External quality control. Several studies using the Tufts Nutrient Calculation System, including the Women's Health Trial, employ blinded, multiple coding of duplicate records over time as an external quality control measure. During the first six months of our operation, thirty-six four-day food records coded repeatedly failed to reveal any changes in average nutrient calculations over time, although some discrepancies appeared in coding of individual food items. Similarly, there were no significant differences between nutrient calculations for duplicate food records coded by different coders (Henry, et al., 1987).

DIETARY DATA COLLECTION

Quality control studies have illustrated the importance of accurate and thorough documentation by the study participants and the nutritionist (Catsos et al., 1986; Henry et al., 1987). In the Women's Health Trial, a fifteen-minute, professionally produced videotape entitled "Keeping Track of What You Eat" was used in conjunction with a workbook to teach weighing, measuring and food description techniques to participants. The nutritionist then assessed the participant's understanding of the tape, reviewed a one-meal recall with the participant, emphasized key points, and referred the participant to the instructions that appeared inside the food record booklet. All study participants received a food weighing scale, a clear measuring cup, and a ruler to assist with weighing and measuring. The potential bias that may be introduced by this training must be accepted in exchange for the high quality of the food records it produces.

Training and Certification of Clinic Nutritionists. Before clinic nutritionists may collect dietary data for submission to the Tufts Nutrient Database, they must be trained ad certified. The first step is attendance at a workshop during which techniques are demonstrated and practiced. Nutritionists complete written exercises before and after the workshop, and collect dietary data from "practice participants"' at their clinic. All work is evaluated in writing by the Tufts Nutrient Database.

New nutritionists receive memos regarding problematic trends in the food records they send for coding, ad general memos to all nutritionists are issued as necessary.

Missing or conflicting information in the food record can cause significant inaccuracies in the estimates of nutrient intake. When this occurs, a code number which identifies the type of missing or conflicting information is entered into the computer along with the food item. Reports summarizing these problems are issued periodically. In this way, the validity of the nutrient data can be assessed. Nutritionists can be informed about specific problems related to the collection of dietary data.

The particular strengths of the Tufts Nutrient Calculation System are its careful documentation of data sources and coding procedures, adherence to quality-control procedures at every level, ease of updating, and flexibility. Along with other databanks using USDA as a primary data source, Tufts overcomes numerous missing nutrient values by relying on imputation. Developers continue to seek ways of decreasing coding/data entry time without sacrificing quality, since cost issues profoundly influence the selection of dietary assessment techniques in large research efforts.

The Tufts Nutrient Calculation System was initially designed to meet the rigorous demands of the large-scale Women's Health Trial. Its design, however, is flexible enough to permit application to many research and clinical situations.

LEGEND

Figure 1. Menus and selection screen from the interactive coding/data entry program used for coding 1% fat milk. Coders advance through the first three menus by entering the number which corresponds to the appropriate food grouping. Coders select the appropriate food description from the final selection screen.

Figure 2. Four Day Food Record Report from the Women's Health Trial, page 1.

Figure 3. Four Day Food Record Report from the Women's Health Trial, page 2.

Figure 4. Four Day Food Record Report from the Women's Health Trial, page 6. This page shows the average daily intake of calories and nutrients, and compares them to the RDA for those nutrients.

Figure 5. Four Day Food Record Report from the Women's Health Trial, page 7. This page has two graphs, one showing the amount of fat exceeding the Fat Gram Goal, and the other showing percentages of the RDA for key nutrients.

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FIG 1

FIRST LEVEL MENU:

MAJOR FOOD GROUPS

1. MILK/MILK PRODUCTS
2. MEAT/POULTRY/FISH AND MIXTURES
3. EGGS/MIXTURES/SUBSTITUTES
4. LEGUMES/NUTS/SEEDS
5. GRAIN PRODUCTS
6. FRUITS/JUICES
7. VEGETABLES
8. FATS/OILS/DRESSINGS/SAUCES
9. SWEETS/BEVERAGES
10. MISCELLANEOUS

SECOND LEVEL MENU:

MILK/MILK PRODUCTS

1. MILK/MILK DRINKS
2. CREAM/CREAM SUBSTITUTES
3. MILK/CREAM DESSERTS
4. CHEESE/IMITATIONS
5. CHEESE PRODUCTS/DESSERTS
6. YOGURT
7. MEAL SUBSTITUTES

THIRD LEVEL MENU:

MILK; MILK/MILK DRINKS

1. BUTTERMILK
2. CHOCOLATE/MALTED
3. COCONUT MILK
4. SOYMILK
5. WHITE; FLUID
6. WHITE; DRY
7. WHITE; CONDENSED/EVAPORATED
8. MISCELLANEOUS

FOURTH LEVEL MENU:

SELECTION SCREEN:

MILK; DRINKS; WHITE, FLUID

WHOLE, FLUID		
3.7% FAT	1	E=1 CUP
LOWFAT, FLUID		F=1 QT
2.0% FAT	2	
2.0% FAT, PROT FORT	3	
2.0% FAT, W/NFMS	4	
1.0% FAT	5	
1.0% FAT, PROT FORT	6	
1.0% FAT, W/NFMS	7	
SKIM, FLUID		
SKIM	8	
PROT FORTIFIED	9	
W/NFMS	10	
....		
WEIGHT WATCHERS	11	A=FL OZ B=CUP

CODING RULE:

Milk, as beverage, amount unknown

Code 8 oz. appropriate milk.
USDA-HNIS-HERR 44, 1982, P 296, 1985

FIG 2

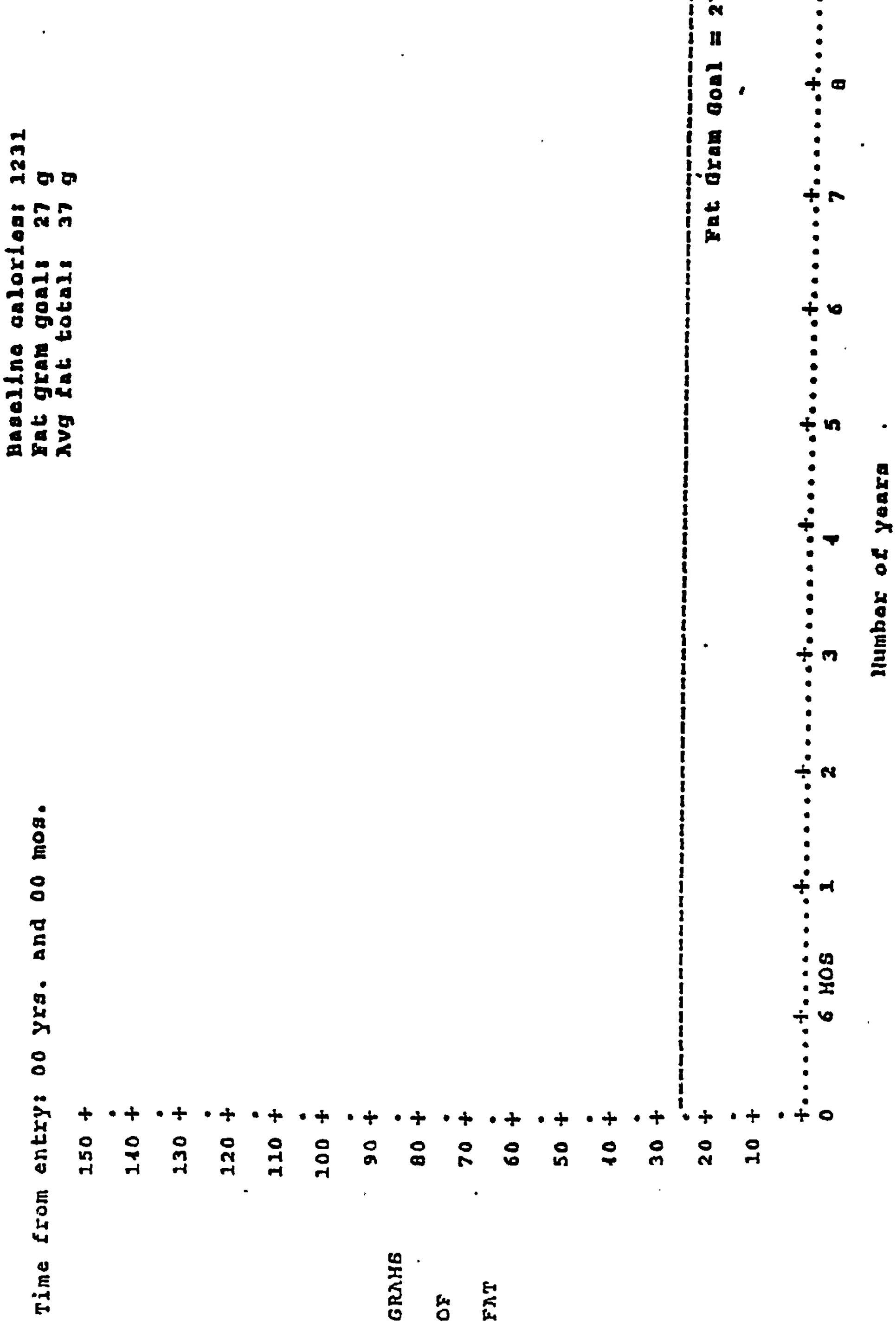
Time from entry: 00 yrs. and 00 mos.
Baseline calories: 1231
Fat gram goal: 27 g
Avg fat total: 37 g
GRAMS
OF
FAT
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
Fat Gram Goal = 27 g
0
6 MOS
1
2
3
4
5
6
7
8
9
Number of years

FIG 3

FOOD FOR DAY 1

FOOD	PORTION SIZE	GRAMS OF FAT
HERBAL TEA, BREWED	16.00 FL OZ	0.0
POACHED EGG	0.90 1 LRG EGG	5.0
OIL,VEG,CORN	0.01 100 GRAMS	1.0
BREAD,RYE,AMERICAN	0.99 1 REG SLICE/LB LOAF	0.3
VITAMIN E	4.00 100 IU	0.0
VITAMIN B1	15.00 1 MG RDA	0.0
RIBOFLAVIN	10.00 1 MCG	0.0
VITAMIN B6	1.00 5 MG	0.0
NIACIN (NICOTINIC)	5.00 10 MG	0.0
VITAMIN B-12	10.00 1 MCG	0.0
VITAMIN C	3.00 100 MG	0.0
YOGURTSKIM13GPRO/8OZ	1.00 1 CNTR,8 OZ,NT WT	0.4
GRAPEFT,RD/WH/PK,ALL	0.74 1/2 FRT,3-9/16 DIAM	0.1
CHERRY,SWEET,RAW	0.50 10 FRUITS,WO/PF	0.3
BEV,GIN,ETC.80-PROOF	2.00 1 FL OZ	0.0
BEV. SPECIAL DIETARY	6.00 1 FL OZ	0.0
BEEF,ROUND CKD	0.28 100 GRAMS	1.7
BEEF,ROUND CKD	0.28 100 GRAMS	4.3
SQSH,WNTR,ALL,BK,W/S	0.28 100 GRAMS	0.2
SUGARS,BROWN	0.01 1 CUP NOT PACKED	0.0
LETTUCE,ICEBERG,RAW	0.56 100 GRAMS	0.1
LETTUCE,COS OR ROMAI	1.50 1/2 CUP SHREDDED	0.1
SAL DRES,THOUSI,LOWC	1.00 1 TBSP	1.6
DAILY TOTAL FAT		15.2 gm
DAILY TOTAL CALORIES		768

FOUR DAY NUTRIENT SUMMARY

NUTRIENT	A AVG. DAILY INTAKE-FOOD ONLY	B % OF RDA FOOD ONLY	C AVG. DAILY INTAKE-FOOD AND SUPP.	D % OF RDA FOOD AND SUPP.	E RDA
Calories	1231		1231		
Carbohydrate, gm	109		109		
Protein, gm	57	130	57	130	44
Total fat, gm	37		37		
% Cal. due to fat	27		27		
Polyunsat. fat, gm	8		8		
Sat'd fat, gm	13		13		
P:S ratio	0.6		0.6		
Cholesterol, mg	247		247		
Vitamin A, IU	5645	141	5645	141	4000
Vitamin C, mg	77	128	377	628	60
Thiamin, mg	1	100	16	1600	1
Riboflavin	1	83	11	917	1
Niacin equiv, mg	15	115	65	500	13
Folacin, mcg	143	36	143	36	400
Vitamin B-6, mg	0	0	5	250	2
Vitamin B-12, mcg	2	67	12	400	3
Calcium, mg	563	70	563	70	800
Phosphorus, mg	832	104	832	104	800
Ca:P ratio	0.7		0.7		
Magnesium, mg	104	35	104	35	300
Iron, mg	8	80	8	80	10
Zinc, mg	5	33	5	33	15
Sodium, mg	2355		2355		
Potassium, mg	1808		1808		

FIG 4

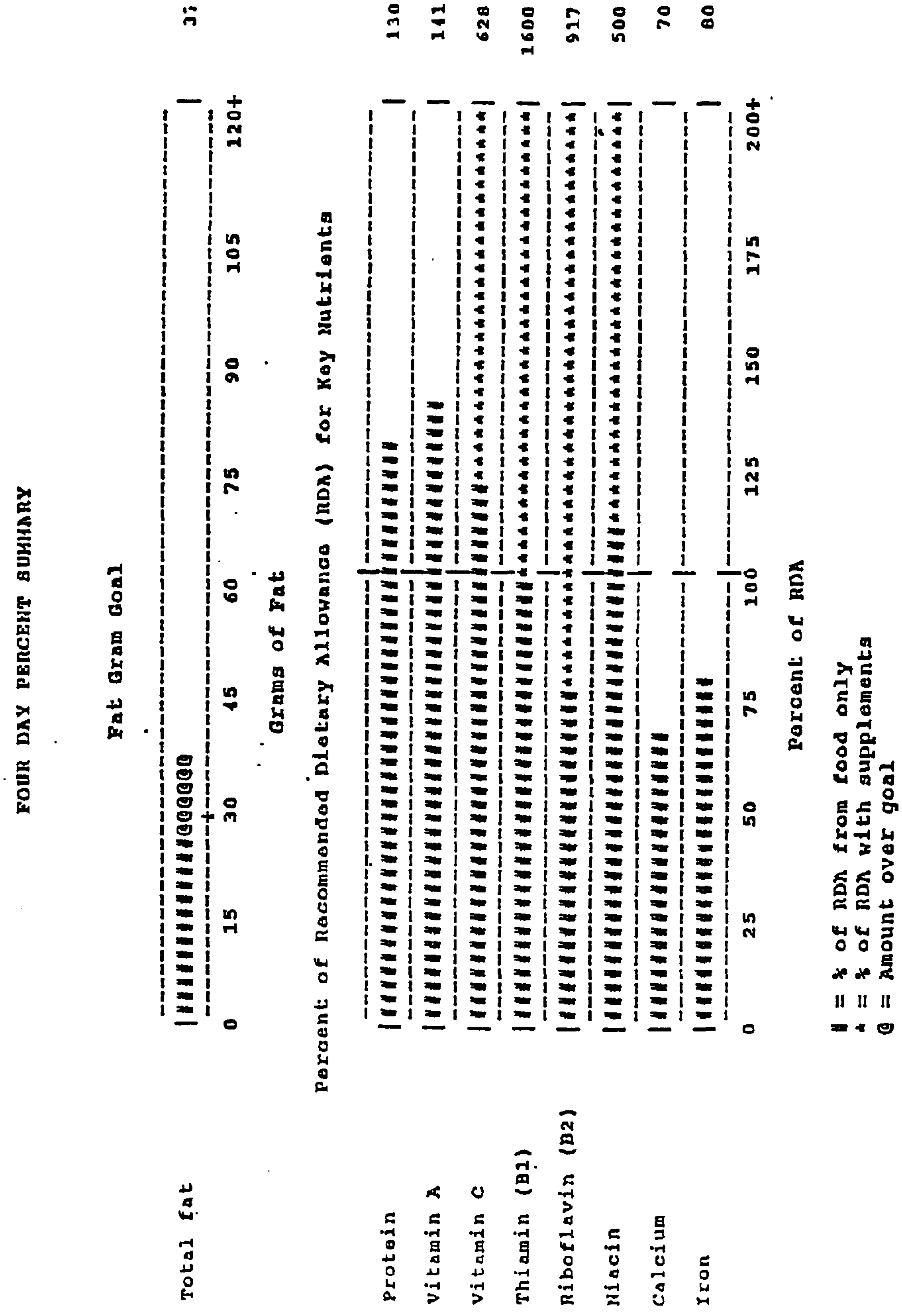
FOUR DAY PERCENT SUMMARY
Fat Gram Goal
Total fat
37
0
15
30
45
60
75
90
105
120+
Grams of Fat
Percent of Recommended Dietary Allowance (RDA) for Key Nutrients
Protein
Vitamin A
Vitamin C
Thiamin (B1)
Riboflavin (B2)
Niacin
Calcium
Iron
130
141
628
1600
917
500
70
80
0
25
50
75
100
125
150
175
200+
Percent of RDA
= % of RDA from food only
+ = % of RDA with supplements
@ = Amount over goal

FIG 5