Evaluating The Photomethod: A Validity Study

by

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ABSTRACT

Traditional methods of food intake measurements are subject to several errors, one of which is the quantification of individual food consumption. A photographic technique has been shown to provide good estimates of food volume, and nutrient content.

An investigation was undertaken to determine the validity of this photographic technique, by comparing its estimates of food quantities and nutrient content with those obtained by physical measures of weight, and the 24-hour recall.

The study comprised of two parts: Part 1 proposed to investigate intra-individual variability in differences between estimates of weighed and photomethod records of food intake. Differences were measured in one male individual over a 21 day period. Differences in mean daily intake of nutrients, and differences in the variability of daily nutrient intakes were determined. Part 2 proposed to investigate differences between estimates of weighed and photomethod food intake, and differences between weighed and recalled food intake from a group of 13 university students. This study was unique since photomethod measurements were made when several food items were held on a plate.

Results from part 1 of the study showed that for the 197 food items analyzed, photographic estimates of weight were not significantly different from the actual weights of the food items. Mean daily intake, and variability of nutrients showed no significant differences between the two methods. Results from part 2 showed that for the 44 food items analyzed, the photographic record quantifies food intake with a smaller bias than the recall method. No significant differences were found between weight estimates of the photographic record and the weighed record. However, significant differences between recall weight estimates and the weighed record estimates were found.

This photomethod technique has been shown to provide more precise estimates of food quantities than estimates taken from 24-hour recalls. It appears to be a valid measure of food intake, and could thus be a promising alternative to existing dietary methodologies.

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Chapter I

INTRODUCTION

Since the late 1800's attempts have been made to obtain accurate measurements of food and nutrient intake, so as to be able to investigate the relationship between diet and disease. Food intake data are used as part of the health assessment of individuals, as well as in the decision making procedures involved in food and nutrition policies that are set up by government and other agencies. The precision of these data is important in that results generated will influence decisions as to the requirement of nutrition programs necessary to promote the health of individuals and population groups.

Food intake measurements include quantitative methods such as the weighed record, and qualitative methods such as the dietary history, none of which is free of errors and limitations (Beal,1967). Depending on the purpose of a dietary study, some methods of food intake evaluation are more suitable than others (Gibson,1987). The most commonly used methods by researchers are the weighed food record, the recall interview, the estimated food record, and the diet history.

Errors and limitations are recognized in each of these conventional methods by researchers concerned with valid measures of food intake. The weighed food record and estimated food record are designed such that quantities of food eaten are noted at the time of eating. This poses problems, in that these methods are time consuming for the subject, and are likely to change habitual food consumption patterns (Marr, 1971). The recall interview and diet history depend on the ability of the respondent to remember precise quantities of food eaten. As such, these methods can give only conservative estimates of food amounts eaten, especially if respondents are asked to recall foods consumed over a period of time. In an effort to control these sources of error, an objective, computerized method of estimating individual food consumption was developed by Sevenhuysen (1985). The purpose of this research was to determine the validity of this computerized, photographic method for research that aims to obtain precise food intake data from free-living individuals, by comparing with the weighed food record and the 24-hour recall methods of assessing food intake.

Chapter II

LITERATURE REVIEW

Dietary methodologies that have been developed by researchers interested in determining the role of diet in the health of individuals, include measures of either current or past food intake (Marr, 1971).

The recording of current food intake is achieved by use of either the weighed food record or the estimated food record. The weighed record necessitates the weighing and recording of food items as they are consumed (Burk and Pao, 1976). The estimated food record involves the recording of food intakes in terms of household measures (Burk and Pao, 1976; Marr, 1971).

Recording of past food intake can comprise recent or longterm assessments. In the 24-hour recall method, food intake in the 24 hours previous to an interview is determined, by asking individuals to remember the quantity of food and drink consumed in that period (Burk and Pao, 1976). The interview method is a modified version of the technique described by Burke and Stuart (1938). Food intakes up to seven days before the interview have also been investigated (Block, 1982).

The most common technique used to estimate the usual food intake of individuals is a dietary history (Block, 1982; Marr, 1971). A nutritionist conducts an intensive interview which is structured to obtain a detailed record of food consumption during a specified period of time.

One month (Beal, 1967), to one year (Karvetti and Knuts, 1981) dietary histories have been attempted.

Major sources of systematic error or bias that have been recognized in the literature include problems with quantifying food items, omission of food items, respondent and interviewer bias, and recording burden. These errors affect the precision of the estimated nutrient intakes of individuals and groups.

2.1 FOOD INTAKE QUANTIFICATION

The ability of an individual to accurately estimate food quantities will affect the validity of data obtained from methods such as the dietary history, estimated food record, and the recall interview.

Madden et al.(1976), examined the validity of the 24 hour recall as compared to the 'actual' intake obtained by trained individuals. Subjects were 76 elderly persons participating in a meal program. Subjects were interviewed within the 24 hour period following the surreptitious observation of their intake. Since facilities did not permit the weighing of individual items, several extra meals were weighed by the researchers to determine whether there were differences between meals in terms of the quantity served. Madden et al.(1976), found little variation in portion sizes of food served, which led them to conclude that the 'actual' intake observed was 'reasonably accurate', and reflected the 'true' weight of the food items served.

For each subject, intakes of energy, protein, calcium, iron, vitamin A, thiamin, riboflavin, and ascorbic acid were calculated for both actual and recalled dietary intake data.

Results indicated that for group means, the recall and actual intake values were not significantly different($p<.05$), except in the case of energy, which was underestimated. Regression analyses of the data demonstrated the 'flat slope syndrome', which has also been noted by other researchers (Carter et al,1981; Gersovitz et al,1978).

Figure 1 illustrates the 'flat slope syndrome', which occurs when a one-unit increase in actual intake corresponds to a smaller than one unit increase in recalled intake, the overall tendency being that the subject overestimates low intakes, and underestimates large intakes. Madden et al.(1976), observed the 'flat slope syndrome' for kilocalories, protein, and vitamin A intake of the elderly subjects, but not for any of the other nutrients that were investigated.

Gersovitz et al.(1978), investigated the validity of the 24-hour recall, as compared to the actual intake, which was obtained by investigators weighing the food items served. Subjects were 31 elderly persons participating in a meal program. The subjects were interviewed in a 24-hour period after their food intake had been observed. Food models of varying portion sizes were used to assist the individuals in recalling food quantities. For each subject, intakes of energy, protein, calcium, phosphorus, iron, riboflavin, thiamin, vitamin C, vitamin A, and cholesterol were determined for actual and recalled dietary intake.

For the sample as a whole, the difference between mean actual and mean recalled intakes was significant ($p<0.05$) only for protein. The 'flat slope syndrome' was observed for all nutrients, except cholesterol and phosphorus, where a one unit increase in actual intake was shown to

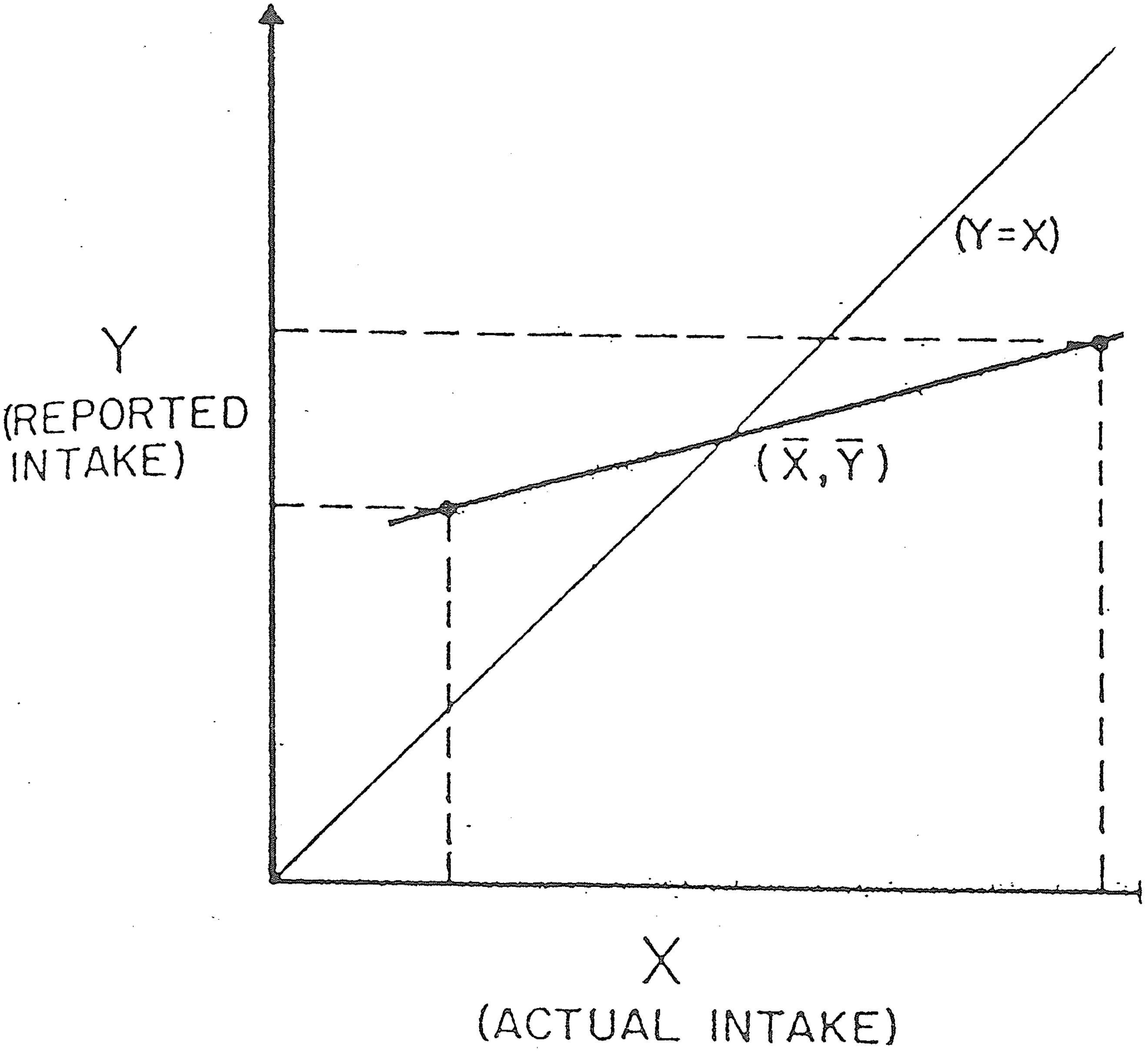


Figure 1: Illustration of flat slope syndrome.

Gersovitz et al. (1978)

correspond to a one unit increase in recalled intake. The differences in results observed between this study and that of Madden et al.(1976), could be attributed to the fact that in this work, the investigators carried out the weighing of food items consumed by the elderly persons.

The validity of the 24-hour recall for measuring food intake from a group of 28 children at a summer camp was examined by Carter et al.(1981). Standardized portions of food were served, which allowed dietitians to make unobtrusive observations of the 'actual' intakes of these children during the meals. The children were interviewed on the day following observation of their food intake, and 24-hour recalls were obtained. For each child, only intakes of energy and protein were calculated for the actual and recalled dietary intake data.

Results indicated that for group means, the recalled and observed intake values for energy ($p< 0.002$) and protein ($p< 0.004$) were significantly different. Regression analyses revealed that children with low intakes tended to overestimate their intake, while children with high intakes underestimated their food consumption.

Acheson et al.(1980) undertook a dietary survey involving twelve individuals ranging in age from 21 to 29 years stationed at an Antartic base. Their food intake was studied for an average of one week each month, for a period of one year. Subjects weighed and recorded all food consumed, and once during each week of study they were asked to write down everything they could remember eating during the previous 24 hours. A printed questionnaire was used for this purpose, however on some occasions a blank sheet of paper was provided, and no attempt was made to interview the individuals. Data obtained from the recall questionnaire were compared to the weighed record for the same day.

Results showed that in terms of energy, subjects underestimated their intake by a mean of 21% using the printed questionnaire, and by a mean of 33.6% when a blank sheet of paper was provided. This difference was statistically significant($p<0.05$). The discrepancy between recall and weighed records was due to problems encountered in quantifying food intake. Of 86 dietary recalls, 79 underestimated food intake.

In general, studies of the validity of the 24-hour recall show that in paediatric groups, the elderly, and young adults, the data from 24-hour recalls underestimate energy consumption of these groups. For most other nutrients reported, the 24-hour recall appears to provide acceptable (Block, 1982) estimates of the mean intakes of a group. Studies indicate that individuals tend to overestimate their food intake if it is low, and underestimate their intake if it is high, when recalling their food intake. A structured questionnaire appears to provide better estimates of food energy intakes than a blank sheet of paper, however, even with the use of memory aids, such as structured questionnaires and food models, to assist subjects in recalling food quantities, an underestimation of food amounts is observed with the 24-hour recall.

2.2 RESPONDENT MEMORY

The success of retrospective dietary methodologies, such as the recall interview and dietary history, is dependent on the ability of individuals to remember accurately all food and drink consumed.

Adelson (1960) reported a study which attempted to obtain seven day recalls from a group of 59 men. It was observed that sometimes a man telephoned a business associate to assist with the recall of the menu of a meal eaten together. Interviewers were instructed for a long period, and were skilled in assisting the men to remember quantities of food eaten. It was necessary to use food models and household measures, to obtain more precise estimates of food quantities eaten.

Omission of food items in the study reported by Acheson et al.(1980) contributed to the overall underestimation of energy intake. It was found that subjects usually left out one complete food item. Subjects had weighed and recorded all items eaten, and therefore, should have been able to report more accurately than individuals participating in a recall interview alone.

Campbell and Dodds (1967) compared the dietary recall data from older persons and younger persons using the 24 hour recall method. The subjects, hospitalized patients having lung ailments, were 100 persons between the ages of 20 and 40 years. It was assumed that the lung disorders had no effect on memory. The menus served to these individuals within the past 24 hours were known. The subjects recalled what she or he could, and the answers were read back to the individuals by the interviewers. Food items were occasionally added at this point by the subject. The individual was then given the menu, and food items added at this point were recorded as items 'probed'. These items were forgotten by the subject.

Table 1 shows the percentage contribution of the probe to energy and protein intakes. These results point to the loss of nutrient intake information that is possible in a 24 hour recall interview.

TABLE 1

Percentage contribution of probe to nutrients.

Group	Energy	Protein
Younger men	20.6	15.6
Young women	12.5	8.4
Older men	35.2	27.7
Older women	27.9	24.8

Adapted from: Campbell and Dodds,(1967)

Campbell and Dodds(1967) found a difference in recall between the older and younger persons. A mean of 537 kilocalories was forgotten by the younger subjects, whereas a mean of 675 kilocalories was forgotten by the older persons. This difference was significant at the $p<0.05$ level of significance. A significant difference in energy recalled was also found between men and women, a mean of 785 kilocalories was forgotten by men, compared to 427 kilocalories by women($p<0.01$). This difference was attributed to the fact that women are more familiar with food preparation than are men and would be more likely to remember details regarding meals.

Beaudoin and Mayer (1953), compared the data obtained from obese and non-obese women. One day estimated food records from 58 control women of normal weight, and 59 overweight women were compared. Completed dietary histories were also obtained from 20 women of normal weight, and 30 obese women.

From Table 2, it can be seen that obese women reported eating more than normal weight women when a dietary history was used. This difference was significant ($p < 0.01$). With the one day food record, obese women recorded significantly less food intake than normal weight women ($p < 0.05$).

TABLE 2

Mean energy intake of overweight and normal weight women

Dietary method	Mean daily energy (kcal)		Probability
	Overweight women	Normal weight women	
One day record	1964±594	2198±587	0.05
Dietary history	2829±674	2201±475	0.01

Adapted from: Beaudoin and Mayer, (1953)

The authors concluded that with the obese women, the detailed attention given the women by skilled interviewers resulted in the greater reported energy intake, however, it could be possible that some of the difference was due to the fact that the two groups of obese women were not identical.

The dietary recall can range from interviews to determine food intakes during the previous day, to a detailed history which aims to assess an individual's habitual food pattern. The precision of food intake data obtained from these methods depends on the subject's ability to recall such information as accurately as possible. It can be seen, that to obtain the maximum information from the individual, well trained interviewers are required, who must spend much time and effort to elicit precise food intake information from the subject.

2.3 RESPONDENT AND INTERVIEWER BIASES

Another potential source of error recognized in retrospective methods is that of respondent and interviewer biases.

Beal(1967) has noted that techniques of questioning the individual should be such that a rapport is established between the interviewer and the subject. Interviewers should be persistent, and prepared to depart from a rigid interview pattern so as to allow the individual more opportunity to give complete responses, with regards to her/his food consumption. Questions should be asked of food practices that do not necessarily correspond to those of the interviewer; as well, they should be phrased in such a way that the subject does not feel obligated to answer in a positive manner. The tone of voice of the interviewer is also important, in that an expression of approval or disapproval may influence responses, and thereby the precision of information obtained.

Worsley et al.(1984) have also noted that because of a need for social approval, respondents may tend to give desirable answers, such as reporting consumption of fruits and vegetables, and neglecting to report foods that may be considered as 'bad'. Biases in the food intake data are also possible if interviewers record responses incorrectly, or assume an average serving size for food items reported (Beal, 1967; Gibson, 1987).

The problems associated with interviewer and respondent biases may be minimized by intensive training of individuals conducting dietary interviews. Beal (1967), noted that training of personnel required to conduct dietary histories usually demands a six month apprenticeship, while for the 24-hour recall interview, Adelson (1960) stated that the interviewers 'had long schooling'. Although the training period may vary depending on the type of dietary recall required, it is evident that interviewers must be judicious, and skilled in techniques that would provide precise estimates of the individuals' food consumption.

2.4 RECORDING BURDEN

While recall methods have the disadvantage of relying on memory, the recording burden caused to the respondent is small, and the co-operation required is minimal compared to the prospective recording of food intake, which demands co-operation and motivation on the part of the subjects.

In a study of the validity of the 24 hour recall and seven day written dietary record, Gersovitz et al.(1978) attempted to obtain complete seven day food records from 65 elderly subjects. Although 85% returned atleast two days usable records, and 78% returned five day records; by day seven the number of usable records was reduced to 60 percent. Similar rates of complete records have been reported by Sprauve and Dodds(1965), who received 45% complete seven day records from 150 adolescents.

Gersovitz et al.(1978) note that for group comparisons, the nutrient data from seven day written records must not be used, since the nature of the sample may be altered by those not completing usable records, or by those failing to remain in the study. In the study reported, by day seven, the predominant number of people returning complete records were from a more educated group of individuals.

The weighed record requires measures of each item of food and drink, and is considered to be the most demanding and time consuming for individuals (Burk and Pao,1976; Pekarrinen et al.,1967). In the Adelson (1960) study, 59 men weighed and recorded their food intakes for a period of seven days. The men were all highly educated individuals, such as physicians and businessmen, and were 'aware of their contribution to science' (Adelson,1960). However, in order to carry out the obligations required of a weighed record, the men chose a week free of social obligations that may have interfered with the precise measurement of all food consumed.

To ease the recording obligation, subjects may alter their usual pattern of food intake, however, it has been observed (Burk and Pao,1976;Marr,1971) that the extent to which this occurs is difficult if not impossible to determine.

Estimated food records and weighed food records place responsibility on the respondent to provide precise estimates of food consumption. Requirements of these methods are such that estimates of food intakes outside the home are made difficult, limiting food intake measurements to food consumption in the home. Since the actual recording is made by the respondent, these methods can only be used with literate persons who are highly motivated. The validity of food intake data also appears to decline as the number of days of recording required increases. Gersovitz et al.(1978) noted that records of nutrients obtained on days one and two were more valid than records of nutrients obtained for the remaining five days, as compared to the actual nutrient intakes observed for those days.

2.5 ALTERNATE METHODS OF MEASURING FOOD INTAKE

Traditional methods of food intake assessment have errors and limitations. An approach that may reduce these errors is a photographic method of estimating food intake. Such a method has been shown to be acceptable to individuals (Bird and Elwood, 1983), and is likely to minimize alterations in habitual food intake because of the decreased respondent burden.

Bird and Elwood(1983), compared a photographic method of evaluating individuals diets with weighed records. Sixteen subjects were given a camera, weighing scales, and a record book, and asked to photograph and weigh their food for a four day period.

The slides for each subject were then projected on a screen, and subjective estimates made by the researchers as to the weight of each food item. To assist in the estimations, the authors prepared a number of standard slides, each of which displayed different portion sizes of a food item together with a card which showed the weight of each food item shown in the slide. A total of 1431 items were recorded, however, for 9% of this total, the authors gave an assumed weight to both the weighed and photographic records. Bird and Elwood (1983), do not clarify what is meant by the use of the term 'assumed weight', however, it is presumed that the same weight was accorded the weighed and photographic records of 9% of the food items recorded. These items were inadequately recorded; that is the items were either photographed but not weighed, or they were photographed such that the items recorded were obscured and the weight difficult to judge.

Table 3 shows the differences in mean daily intakes of the nutrients estimated by the weighed record and this photographic method. Differences were small, and none approached statistical significance.

Table 4 shows the correlation coefficients observed between daily intakes of nutrient estimates by the weighed record and the photographic method. Although the photographic technique provided a good estimate of weights, a disadvantage with this particular method is the need for prepared standard slides to be made before the study. The preparation was noted to be time consuming and tedious (Bird and Elwood,1983). Moreover, correlation coefficients presented, and the conclusions based on them might be more valid had the authors excluded items that were difficult to compare, rather than giving an assumed weight for both methods.

TABLE 3

Mean daily intake and (s.d) for nutrients.

Nutrients	Weighed record	Photographic record	Difference
Energy(kcal)	1743.3(340.7)	1706.3(326.0)	37.0
Protein(g)	65.4(14.4)	64.2(11.1)	1.2
Fat(g)	78.6(19.0)	77.7(19.9)	0.9
Carbohydrate(g)	205.6(50.9)	198.8(46.4)	6.8
Saturated fat(g)	34.0(8.8)	34.0(9.6)	0.0
PUFA(g)	9.6(3.2)	9.4(2.8)	0.2
Fibre(g)	19.0(6.9)	17.8(5.1)	1.2
Vitamin C(mg)	52.0(29.1)	49.6(27.0)	2.4

(s.d)=standard deviation Bird and Elwood (1983)

TABLE 4

Correlation coefficients between weight estimates of nutrients by weighed and photograhic methods.

Nutrients	Correlation coefficient
Energy	0.86
Protein	0.91
Fat	0.90
Carbohydrate	0.84
Saturated fat	0.93
PUFA	0.87
Fibre	0.89
Vitamin C	0.97

Bird and Elwood (1983)

Sevenhuysen (1985), presented a different photographic method which involved an objective, computerized process for estimating food quantities. Sevenhuysen and Wadsworth (1988) presented research findings to validate the method. The research was divided into two sections; the first section addressed the standardization procedures involved in the production and analysis of 35mm slides; the second section described the direct validation of this method with a weighed measure, using standard objects and individual food items.

Sources of error have been investigated by Wadsworth (1986). It was expected that this photographic method would improve accuracy of food intake estimates, by reducing the subjective decisions by either the individual or the investigator during the data collection and analysis of slides.

Development and standardization of this technique involved the investigation of nine variables, each of which was expected to influence the image characteristics of standard objects. Direct validation of this method, tested by comparing the photographic weight estimates with the absolute weights of individual food items was determined using image characteristics found to give the least error for the standard objects.

A photographic record was made of twenty individual food items. Prior to taking the photographs, investigators recorded the weights and physical volumes of the items. Volumes of liquid and semi-solid foods such as yoghurt and soup, were measured using liquid and dry household measures. The volumes of most solid foods, such as fruits and meat, were obtained by water displacement. Those food items not appropriate for this process were measured using a ruler, and volume formulae used for their particular shapes. The weights and volumes measured were used to calculate density factors for each food item. The photographic records were analysed to give volume estimates of the food items. The volume estimates were converted to weight estimates using the calculated density factors. These weight estimates were converted to nutrient content estimates using computer based food composition calculations. Three relationships examined and tested were;

1. Photographic volume estimate compared to the physical volume measure.
2. Photographic weight estimate compared to the gravimetric weights.
3. Photographic nutrient content estimate compared to the gravimetric nutrient content estimate.

The variability of photographic estimates was shown to be greater with food items than with the standard objects. However, as shown in Table 5, the high and significant correlation obtained indicated a close relationship between the photographic volume estimates of food items and the physical volume measures of the same items. Differences between the two estimates were not significant.

TABLE 5

Relationship between photomethod volume estimate and physical volume.

Pearson's correlation		Paired t-test	
r value	probability	t value	probability
0.90412	0.0001	- 0.51	0.6125

Wadsworth (1986)

Table 6 shows results of the Pearson's correlation coefficient and paired t-test. The association between the photographic weight estimates and gravimetric weights was high and significant. Differences were not significant.

TABLE 6

Relationship between photomethod weight estimate and gravimetric weights.

Pearson'correlation		Paired t-test	
r value	probability	t value	probability
0.9279	0.0001	- 1.37	0.1738

Wadsworth (1986)

Investigation of the relationships between the photographic nutrient content estimates and the gravimetric nutrient content showed that for the four nutrients studied, the photographic record provided a good estimate of nutrient content(Table 7).

Using published density figures(Health and Welfare, Canada, 1984) to convert volumes of food items to weight estimates, Wadsworth(1986) examined the relationship between photomethod nutrient content estimates and gravimetric nutrient content estimates. As shown in Table 8, results obtained indicated that published density figures rather than measured density figures may be used to calculate weight estimates without affecting nutrient content estimates. Survey methods commonly require

TABLE 7

Relationship between photomethod nutrient content and gravimetric nutrient content.

Nutrient	Pearson's Correlation		Paired t-test	
	r-value	probability	t-value	probability
Energy	0.9477	0.0001	- 0.17	0.8669
Protein	0.9848	0.0001	0.27	0.7854
Carbohydrate	0.9362	0.0001	0.09	0.9263
Fat	0.9834	0.0001	-1.22	0.2256

Wadsworth (1986)

the use of published density figures to obtain weight estimates, on which the nutrient contents of food items are based.

TABLE 8

Relationship between gravimetric and photomethod nutrient content estimates using published density figures.

Nutrient	Pearson's Correlation		Paired t-test	
	r-value	probability	t-value	probability
Energy	0.9509	0.0001	0.55	0.5851
Protein	0.9681	0.0001	- 0.73	0.4709
Carbohydrate	0.9746	0.0001	1.20	0.2380
Fat	0.9820	0.0001	0.57	0.5695

Wadsworth (1986)

2.6 CONCLUSION

Due to the interest of researchers and clinicians in the impact of diet on health and disease, several dietary methodologies have been developed to obtain food consumption information from individuals for research purposes. There appears to be no generally accepted method of measuring the food consumption of individuals (Marr,1971), but depending on the purpose of the dietary study, some methods are more suitable than others (Gibson, 1987). Available methods of food intake measures are quantitative or qualitative in nature. Systematic errors and limitations are inherent in each of these methods. Table 9 shows a list of available dietary methods and the associated limitations.

Recognizing these limitations in existing dietary methods, Sevenhuysen (1985) presented a photographic method which would minimize the errors due to the subjective estimations of food quantities by either the investigator or respondent. This prospective recording procedure would eliminate the need to rely on respondent memory for precise quantities of food consumed, and as well, should reduce the recording obligation of the respondent, thereby curtailing changes that may be made to habitual food patterns. Research findings (Sevenhuysen and Wadsworth, 1988), have shown that for individual food items recorded, this photographic method provided good estimates of food volumes, weights, and nutrient content.

Further work on the validity of food intake measurements of individuals from the photographic method described by Sevenhuysen and Wadsworth (1988), is required. The usefulness of this method as an alternative to

TABLE 9

Dietary methods and their limitations

Dietary Method	Limitation
Weighed record	Recording burden Detailed written record Habitual food pattern altered
Estimated food record	Low response rate Detailed written record Subjective estimation of food
24-Hour recall	Dependent on memory Subjective estimation of food Low intake over-reported High intake under-reported Group comparison only
7-Day recall	Dependent on memory Subjective estimation of food Time consuming
Dietary history	Requires trained interviewers Time consuming
Photographic method (Bird and Elwood, 1983)	Subjective estimation of food Preparation of standard slides of items recorded

existing dietary methodologies would depend on the precision of food intake data obtained by this technique, from free living individuals, compared to data observed from traditional methods such as the 24 hour recall and the weighed record of individual food consumption. The 24 hour recall is the method of choice especially in field surveys where the nutrient intake of a large number of individuals is studied (Rasanen, 1982). The recording burden caused to the respondent is small and co-operation demanded minimal, however, data obtained are subject to the limitations outlined in Table 9. The weighed record, on the other hand, gives the most precise measure of individual food intake (Block, 1982; Rasanen, 1982), but the procedure requires a high degree of motivation from subjects. A method that may reduce the errors observed with traditional methods is the photographic technique of assessing food quantities, put forward by Sevenhuysen and Wadsworth (1988). Single food items were analyzed and the estimates obtained compared to the actual volume and weight for each food item. It can be expected that the photographic method may perform differently when plates holding several food items on a plate are analyzed to give food quantities.

The present study was undertaken to determine the extent to which the photomethod estimates of food amounts reflected the actual food quantities. This required that the photomethod estimates be compared to those of an external 'gold standard'. The most precise assessment of food quantities is obtained by weighing each food item (Marr, 1971). Using these weights the direct validity of a measure can be studied since it is possible to observe and record the actual food consumption. The present study used data from a weighed record of food consumption to evaluate the direct validity of food quantity estimates from the photomethod and the recall interview. Variations in the food quantity estimates obtained from the photomethod and the recall were compared to the variation observed in data from the weighed record.

Chapter III

RESEARCH DESIGN

Given the importance of addressing the limitations and errors of existing dietary methods, and the proposed improvements to these traditional methods described by Sevenhuysen and Wadsworth (1988), this study examined the following objectives:

1. To determine the direct validity of nutrient intake measurements estimated using the photomethod by comparison with nutrient intake estimated from weighed food records.
2. To determine the direct validity of nutrient intake measurements estimated from recall interviews by comparison with nutrient intake estimated from weighed food records.

The present research comprised two parts, each having a set of related hypotheses which were tested.

3.1 PART 1: 21 DAY WEIGHED RECORD AND PHOTOMETHOD RECORD OF ONE INDIVIDUAL

Part 1 of this study proposed to investigate the intra-individual variability in differences between estimates of weighed or photomethod records of food intake. Differences were measured in one male individual over a 21 day period. Absolute differences indicated the precision with which the photomethod approximated the weights of foods consumed.

Differences in the mean daily intake of nutrients between estimates of weighed or photomethod records of food intake, and differences in the variability of daily nutrient intakes were determined. Variability in differences indicated the relative precision achieved for individual food items and for daily intakes as a whole.

3.1.1 Design

The individually weighed food record of an adult male was recorded for 21 days. One dietitian weighed all food items. In this study 'physical weight' will refer to the items of food as weighed by the dietitian. Another dietitian chose food codes for all weighed items to reflect the nutrient content. The subject photographed all food consumed during the 21 days. This investigator, was blind as to the weights of the food items, and analyzed the photographic record for amounts of food items. Food codes chosen coincided with those for the weighed record. Density factors of food were determined from the Canadian Nutrient File (CNF, Health and Welfare, Canada,1986). Nutrient content was determined using computer based food composition calculations.

The following hypotheses were put forward, and tested:

1. Photomethod weight estimates of individual food items will not differ from the physical weight of the same food items.

   Variable A: Physical weight of an individual food item
   Variable B: Photomethod weight of an individual food item

2. Photomethod volume estimate of individual food items will not differ from the physical volume of the same food items.

   Variable A: Physical volume estimate of an individual food item
   Variable B: Photomethod volume estimate of an individual food item

3. The mean daily intake of nutrients based on gravimetric estimates will not differ from the mean daily intake of nutrients based on photomethod volume estimates, and the volume to weight determinations.

   Variable A: Mean daily intake of nutrients based on gravimetric estimates
   Variable B: Mean daily intake of nutrients based on photomethod volume estimates, and the volume to weight determinations

   The mean daily intake of the following nutrients will be estimated;
   Energy, carbohydrate, protein, fat, calcium, iron, vitamin A, vitamin C

4. The variability of daily nutrient intakes based on gravimetric estimates will not differ from the variability of daily nutrient intakes based on the photomethod estimates.

   Variable A: Variability of daily nutrient intakes based on gravimetric estimates
   Variable B: Variability of daily nutrient intakes based on the photomethod estimates

The variability of the following nutrients will be estimated; Energy, Protein, carbohydrate, fat, calcium, iron, vitamin A vitamin C

3.2 PART 2: 24-HOUR RECALLS, WEIGHED RECORDS, AND PHOTOMETHOD RECORDS OF A GROUP OF SUBJECTS

Part 2 of this study proposed to investigate differences between estimates of weighed and photomethod food intake, and differences between estimates of weighed and recalled food intake from a group of university students. Possible bias in estimates from recalls were compared to that associated with photomethod estimates.

3.2.1 Design

Thirteen University students were asked to participate. Selection criteria related to the subjects ability to complete tasks required of them in this study. The subjects were given an explanation regarding the requirements of this study. A choice of 15 lunches were provided during one lunch time period. Prior to this, two nutritionists weighed and recorded the volume of each food item on a plate. In this study 'physical weight' will refer to food items weighed in the laboratory, and 'physical volume' will refer to the volume of food items as measured in the laboratory. Volumes were estimated using household measures. Each plate was numbered, and then photographed by this investigator, who was unaware of the weights and volumes of the food items recorded. Each subject chose one plate of food to eat, and was interviewed the following day by a dietitian. The interviewer was blind to the lunches, and the weights and volume served. The recall records were coded by the interviewer. Food codes chosen coincided with those for the weighed and photomethod records. Density factors of foods were determined from the CNF. For comparison purposes, density factors were determined from the weight and volume measured by the nutritionists in the laboratory. For all three dietary methods evaluated, nutrient content was determined using computer based food composition values.

The following hypotheses were put forward, and were tested:

1. Photomethod weight estimate of individual food items will not differ from the physical weight estimate of the same food items.

   Variable A: Physical weight estimate of an individual food item
   Variable B: Photomethod weight estimate of an individual food item

2. Photomethod volume estimate of an individual food item will not differ from the physical volume of the same food item.

   Variable A: Physical volume estimate of an individual food item
   Variable B: Photomethod volume estimate of an individual food item

3. Photomethod weight estimate of individual food items will not differ from the weight estimate of the same food items given in recall interviews.

   Variable A: Photomethod weight estimate of an individual food item

Variable B: Recall weight estimate of an individual food item

4. Volume estimate of food items given in a recall interview will not differ from the photomethod volume estimate of the same food item.

   Variable A: Photomethod volume estimate of an individual food item

   Variable B: Recall volume estimate of an individual food item

5. Weight estimate of individual food items given in a recall interview will not differ from the physical weight estimate of the same food item.

   Variable A: Physical weight estimate of an individual food item

   Variable B: Recall weight estimate of an individual food item

6. Volume estimate of food items given in the recall interview will not differ from the physical volume of the same food items.

   Variable A: Physical volume estimate of an individual food item

   Variable B: Recall volume estimate of an individual food item

7. Photomethod nutrient content estimates of individual food items will not differ from the nutrient content of the same food items based on gravimetric estimates.

   Variable A: Nutrient content estimates of individual food items based on gravimetric estimates

Variable B: Nutrient content estimates of individual food items based on photomethod volume estimates, and the volume to weight conversions

The following nutrients will be estimated;

Energy, protein, carbohydrate, fat, calcium, iron, vitamin A, vitamin C

8. Photomethod nutrient content estimates of individual food items will not differ from the nutrient content estimates of the same food items based on recall interviews.

Variable A: Nutrient content estimates of individual food items based on photomethod volume estimates, and the volume to weight conversions

Variable B: Nutrient content estimates of individual food items based on recall interviews

The following nutrients will be estimated;

Energy, protein, carbohydrate, fat, calcium, iron, vitamin A, vitamin C

9. Nutrient content estimates of individual food items based on recall interviews will not differ from the nutrient content estimates of the same food items based on gravimetric estimates.

Variable A: Nutrient content estimates of individual food items based on gravimetric estimates

Variable B: Nutrient content estimates of individual food items based on recall interviews

The following nutrients will be estimated;

Energy, protein, carbohydrate, fat, calcium, iron, vitamin A, vitamin C

3.3 DATA ANALYSIS

As noted previously, Sevenhuysen and Wadsworth (1988) evaluated the photomethod technique of volume estimations by comparing the photomethod measurement of a single food item on a plate with a weighed record of the same item. This study was unique in that photomethod measurements were made when several food items were held on a plate. It was of interest to this investigator to determine results of photomethod volume and weight estimations that could be obtained with minimal random error. Thus, the photomethod and weighed records were examined to check for any random error that may have occurred during the study. The 'Results' section show statistical analyses on two sets of data: Data A represents the 'cleaned' dataset,for example, this dataset did not include values obtained when random errors were observed in any of the dietary records. Data B represents the complete dataset, for example, no observations were excluded in the analyses. Since the focus was to validate the photomethod estimates of food, data A, with some of the random error eliminated, was used to report results observed in this study. Tables at the end of the results' section of each part of the study will compare results obtained with data A and data B. There were no significant differences in the results observed between the two datasets, however, results obtained with data A were consistently better than those obtained with data B.

3.3.1 Part 1

Hypotheses 1 and 2 were tested using a paired t-test, which indicated if differences between pairs of results from the photomethod and weighed method were significantly different from zero.

Simple linear regression analyses was used to test for relationships between volumes, or, weights obtained using the photomethod and weighed method. The extent to which photomethod volume or weight estimates changed with unit change in the corresponding physical measurement was determined.

Pearson's correlation(r) and the coefficient of determination (r^2) was applied to describe the degree of relationship between pairs of variables. The coefficient of determination represents the proportion of variation found that is explained by the regression model.

To determine if the calculated mean daily intake of nutrients differs between the photomethod and weighed method (Hypothesis 3), a two-way ANOVA(method x day) was used. This test allowed possible interaction effects to be detected, which indicated if the relative effectiveness of the methods varied from day to day.

To determine the equality of variances obtained for nutrients by the weighed method and the photomethod, Bartlett's test (Neter et.al, 1985), for the equality of variances was used.

3.3.2 Part 2

Hypotheses 1 through 9 was tested using a paired t-test, which allowed for investigation of the differences between pairs of variables. Hotelling's T^2 (Freund et al. 1986), was also used to test for equality of means between pairs of variables. Unlike the paired t-test, Hotelling's test allowed for comparison of all variable pairs to be made within one test, thus controlling the chance of making a Type 1 error. With repeated statistical analyses, the confidence level of finding a significant difference other than what would occur by chance, is decreased from 95% confidence, depending on the number of tests undertaken.

Simple linear regression analyses was used to test for relationships between each pair of variables under study.

Pearson's correlation, and the coefficient of determination tested the degree of relationship between the pairs of variables.

Chapter IV

METHODOLOGY

Both Part 1 and Part 2 of this research involved the volume estimation of individual food items using the photomethod described by Sevenhuysen and Wadsworth (1988). The first part of this chapter addresses the theoretical and technical aspects underlying this photomethod. Methodological details specific to Part 1 and Part 2 of the study will be discussed separately.

4.1 PHOTOMETHOD: THEORETICAL CONCEPTS

The photomethod involves the production of photographic records, which are 35 mm slides of food items. These slides are projected onto a digitizer which is an electronic device that allows the investigator to put data information regarding the food items into an IBM computer to which it is connected. The computer is programmed to estimate the volume of the food item.

The procedure for making a photographic dietary record under survey conditions requires that subjects place a reference object next to their plate of food, lean back in their chair, and ensure that the plate is in the centre of the photograph before a picture is taken by the subject. The subject must then make simple written notes to describe items of food consumed. So that the method is convenient enough for the subject, only one photograph is required for each plate of food consumed. To quantify food intake in terms of volumes a minimum of three images taken from predefined angles is required to calculate the volume of a food item. Since a single photograph will not have enough data points to allow the calculation of volume estimates for food items vertical contour lines are used to recognize points on a photographic record that are spatially related. These lines are produced by projecting a 35mm transparency which contains vertical dark and white bands, on the food items at the time the image is recorded. The contour line allows the investigator to identify a sequence of points that share the same vertical plane or 'slice' through the food items. Successive parallel lines show slices through the food item. Pierson(1963) has described the use of vertical contour lines as part of an anthropometric tool used in the estimation of body surface area and volume.

Contour lines must be seen on the horizontal surface both in front of and behind the food items recorded (see Figure 2), such that a line can be identified which represents the bottom of a slice of the food item. This line assists the investigator in identifying hidden points at the back of the slice, all of which must lie in the same vertical plane as the visible points. The points describing one or more slices through a food item are measured in two dimensions by recording X and Y co-ordinates. These measurements are recorded by projecting the slides onto a vertically held Hipad digitizer with a cursor, which allows co-ordinate data input. The surface of the digitizer is covered with a white piece of paper that is marked with horizontal and vertical lines. These lines facilitate the measurement of co-ordinates and other parameters required in this method. The digitizer is connected to an IBM

Figure 2: Photographic record showing comparison object and contour lines

Personal computer, which is programmed to store the data measurements, and to calculate the final food volume.

To determine the actual size and shape of a slice of the food item, the points outlining slices through the food item must be transformed to make allowance for the image characteristics due to;

1. the angle between the camera and the source of the contour lines
2. the angle of elevation of the camera
3. the deviation of contour lines from the vertical plane of the camera
4. the distance between the camera and the food item, ie: the magnification

To take these characteristics into account, a cylindrical comparison object of known height and diameter must be present in each photographic record. A measurement is also made of the angle (Q) formed by the contour lines and the horizontal, as defined by the comparison object (see figure 3). This angle gives an estimation of the true angle between the camera and the source of the contour lines. With knowledge of these three angles and the magnification, the slice can be transformed into the dimensions of the same slice through the actual food item using standard trigonometric formulae. The area of one slice is then determined using a formula to calculate the area of a polygon (Kemper, 1982). Since all the contour lines are the same distance apart from each other the slices through a food item are also equidistant. The distance between slices is obtained from the magnification of the photograph. Using trigonometric formulae, this distance between one slice and the next is transformed into the distance across the actual food item. A volume estimate is calculated by combining slice areas and widths. Since the two-dimensional areas of successive slices are of differing proportions, Simpson's integration formula of slice areas is used (Smith, 1969). This integration allows the inclusion of the third dimension of the slice with the two dimensions in each slice area. Perspective, or the apparent relation between visible points as to distance and position, is not taken into account in these measurements of volume.

4.1.1 Volume calculation

The transformation of a slice into dimensions of the same slice through the actual food item is based on the manipulation of the X and Y co-ordinates measured. The slice is rotated in space such that the slice plane is brought perpendicular to the line of sight (Wadsworth, 1986). An area and corresponding volume is then calculated. The co-ordinate manipulations and formulae applied in this method are as follows:

The first transfiguration consists of decreasing all Y co-ordinate values except those that are flagged (1st and last values). This brings the slice in the same horizontal as the line of sight. To achieve this, the formula below is applied:

$$Y_2 i = Y_1 i + (X_1 i - X_{f1}) d/f$$

where $Y_2 i$=decreased Y co-ordinate value

$Y_1 i$=initial Y co-ordinate value

X_{f1}=first flagged value

$X_1 i$=X co-ordinate corresponding to Y_1

d=absolute difference between two flagged

Y_1i values

f=absolute difference between two flagged

X_1 values

The length of the hypotenuse of the horizontal angle (Q), formed between the contour line and a horizontal line defined by the comparison object, is calculated as follows:

$$a_2=a_1(W_H/W_V)$$

$$c^2=a^2+b^2$$

where W_H=projected horizontal width of comparison object

W_V=projected vertical width of comparison object

a_1=length of side opposite angle A

a_2=altered a_1 value

c=length of hypotenuse

b=length of side adjacent to horizontal angle

The second alteration consists of dropping all X co-ordinate values, except the first flagged X_1 value and those equal to it. This turns the slice to 90° on the line of sight in the horizontal plane. The formulae used are:

For co-ordinates with X_1 values greater than the first flagged X_1 value:

$$X_2i=Xf_1+(Xf_1-X_1i)(c/b)$$

For co-ordinates with X_1 values less than the first flagged X_1 value:

$$X_2i=Xf_1+(X_1i-Xf_1)(c/b)$$

where X_2i=altered X_1i value

A constant K for each slide is determined using:

$$K=\text{Cos } Z\ (W_H/W_A)(H_A)/H_P$$

where Z=angle between projected contour line and the side of the comparison object

W_A=absolute width of comparison object, in cm

H_A=absolute height of comparison object, in cm

H_P=projected height of comparison object, in cm

In this study, the projected contour lines were parallel to the side of the comparison object ($Z=0^\circ$) and thus, Cos Z=1.

The final co-ordinate transformation consists of increasing all Y_2 values, except the flagged Y values. This brings the slice perpendicular to the line of sight. The formula applied is as below:

$$Y_3i=Y_2 + K(Y_2i - Y_2)$$

where Y_3=altered Y_2value

Y_2=second flagged Y value

The area of a slice is calculated using the formula:

$$A_1=X_{2a}Y_{3b}+X_{2b}Y_{3c}+X_{2c}Y_{3d}+X_{2d}Y_{3a} - X_{2b}Y_{3a}-X_{2c}Y_{3b}-X_{2d}Y_{3c}-X_{2a}Y_{3d}$$

where X_2i and Y_3i are transformed X and Y co-ordinates.

i denotes the co-ordinate pair,

i=a, b, c ...etc..

A=slice area in square units

The area in square units is transformed into square centimetres by:

$$A_2=A_1(W_A/W_H)$$

where A_2 is the absolute slice area

The slice width in centimetres is determined:

$$W_S=(W_H/S)(W_A/W_H)=W_A/S$$

where W_S=width of slice
S=number of bands across the top of the comparison object

Simpson's integration formula and the slice width calculated are used with the area estimates to determine a volume estimate in millilitres.

Simpson's formula - for odd number of slices-

$$V_1=W_S/3(A_1 + 4A_2 + 2A_3 + \ldots + 2A + 4A_{n-1} + A_n$$

for even number of slices-

$$V_1=3/8(W_S)(A_1 + 3A_2 + 3A_3 + A_4) + (W_S/3)$$
$$(A_4 + 4A_5 + 2A_6 + \ldots + 2A_{n-2} + 4A_{n-1} + A_n)$$

where V_1=volume estimates, in ml
A_n=slice area
n=slice number, n=1, 2, 3...n

The volume estimates of the portions on the left and right edges are then calculated and added to the previous volume estimates (Simpson's) to give a final volume estimate of an item:

$$V_2=[L(A_1)]/2 + [R(A_n)]/2$$

where L=proportion of slice width between left- most
and left edge of item
R=proportion of slice width between right-most
and right edge of item
A_1=area of left-most slice, in cm^2
A_n=area of right-most slice, in cm^2

Final volume, $V=V_1 + V_2$

The volume estimates can be converted to weight estimates using standard density values (Health and Welfare Canada, 1984). These weight estimates are then converted to nutrient content estimates using computer based food composition calculations.

4.2 PHOTOMETHOD: TECHNIQUE

For study purposes, the photographic records were taken by the investigator, except in Part 1 of the research undertaken. Photographic records were made in the laboratory, using a 35 mm single lens reflex camera(Pentax SP II). The film used was 100 ASA Fujichrome colour slide film made by Fujifilm.

The camera, provided with a cable release, was mounted on a Reditilt Mini tripod(Davis and Sanford Company,New Rochell, New York). The elevation angle of the camera was set at 30^0 by tilting the camera lens downward and reading the angle on the tripod dial.

The camera and tripod were then set on a low table surface that was also used to place the plates of food to be recorded. The table surface was covered with brown paper which was marked to indicate the two angles used to position the camera(0°), and the light source (projector, 30°). The camera was positioned in such a way that the line of sight of the lens followed the 0° line on the paper, and was focused on the central point from which the angle lines radiated. The lens was approximately 72 cm from the central point.

A Kodak Ektagraphic Slide projector was used to cast contour lines. These contour lines were produced by projecting a slide with dark and light vertical bands 1 mm apart. In Part 2 of this study, each dark band had a specific design, which was expected to aid the investigator in terms of identifying separate slices.

The projector was set on an elevating device designed specifically for the photomethod, and was then placed on a horizontal surface to the left of and higher than that on which the camera and tripod rested. The angle of elevation of the projector was measured using a protracter, and was recorded to be 30°. In order to increase the depth of field, a cardboard disc having an aperture of 1.1 mm was attached to the front of the projector lens. The 35mm transparency which contained the contour lines was projected onto the lower table surface, and an edge of the middle contour line was lined up with the 30° angle drawn on this surface. This was the angle between the camera and light source. The f/stop and shutter speed of the camera was adjusted to obtain the greatest depth of field.

The plate of food to be recorded was placed over the central point on the table surface. A metal comparison object, 6.0 cm in height and 6.0

cm in width, was placed to the left of the plate of food. Before photographing each plate, it was ensured that the picture was in focus, and that the contour lines could be seen clearly on the surface in front of and behind the plate. A photograph of the plate of food was taken, and the film then developed. Measurement of co-ordinates and parameters necessary to give final volume estimates were undertaken as follows.

The Hipad digitizer(Houston Instrument Division of Bausch and Lomb, Austin, Texas, 1983), having an 11 inch by 11 inch surface, was held vertically in a device designed for this purpose. It was then placed beside an IBM Personal Computer, to which it was connected. The slide projector with carousel was set up so that the lens was at the same height as the digitizer screen. It was ensured that the projection struck the screen at a 90^0 angle.

The photographic records were projected onto the digitizer surface. In each case, the right edge of the comparison object was lined up with a vertical line on the digitizer screen. It was necessary to tilt one side of the slide projector in order to achieve such an alignment. This placed the photographic record in the same vertical and horizontal plane as the digitizer screen.

The projected height, projected horizontal width, and projected vertical width of the comparison object were first measured (see Figure 3). The cursor was used to enter the top and bottom points of these measures. The computer was programmed to calculate the absolute differences between these points, and store the values in created files. The projected vertical and horizontal width were measured ensuring that these measurements were taken through the marked mid-point across the top of the comparison object.

The number of contour bands across the top of the comparison object were then estimated. One light band and one dark band was taken to represent one slice. Partial bands on both edges of the comparison object were estimated to one decimal place of a slice. The above values were manually entered into the computer.

To estimate the angle between the camera and light source, measurements of the lines 'A' and 'B' (Figure 3) were taken from the projected photographic record. These measurements give the size of the angle formed by the contour lines and horizontal line on the digitizer screen. The measure 'A' was the vertical distance between the point that met the left edge of a shadow line and a point that met a horizontal line on the digitizer surface. The distance 'B' was measured as the horizontal distance between the lower point of 'A' and a point that met the same shadow line (left edge) used to measure 'A'. All these points were entered into the computer using the cursor. 'A' and 'B', and the shadow line form a right angle triangle, which allows for the calculation of the angle between the camera and light source.

Each food item was measured once. The partial slice on the left and right edge of the food item was first estimated in a similar manner as for the comparison object. The item was measured from the left to right, and each slice was measured along the left edge of the dark band of the slice. Several X and Y co-ordinates were chosen, and marked with a pencil along the left edge of each slice. Each point was then entered

HT = Projected height
PHW = Projected horizontal width
PVW = Projected vertical width

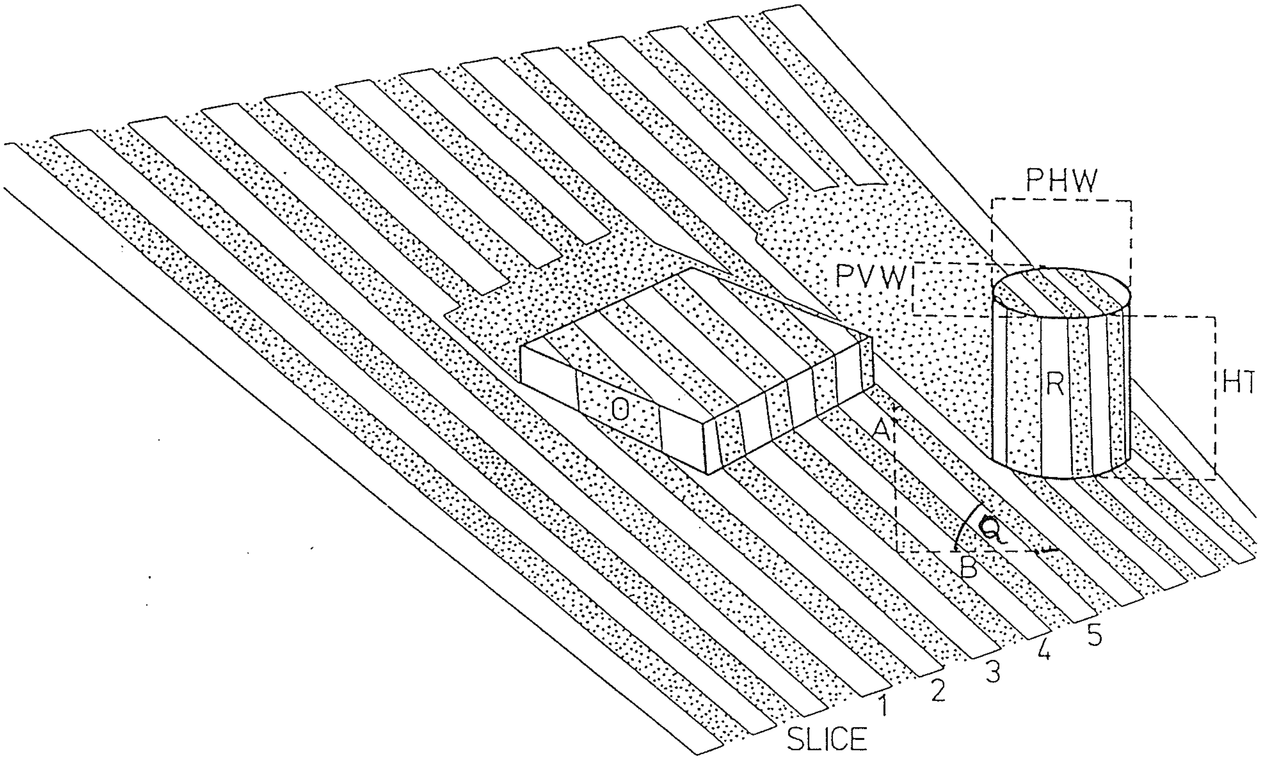


Figure 3: Schematic diagram of measurements on cylindrical object, A, and B

into the computer by using the cursor. The first and last point measured for each slice fell on the same horizontal plane, and were flagged so that the computer program recognized these values for use in calculations. The last point for each slice was hidden, and had to be subjectively estimated by the investigator, using the bottom of the slice as a guide. When each slice of a food item was measured in this manner, the data input was terminated. A computer program was then used to give a volume estimation for each food item recorded. A weight estimate for each food was obtained by applying a density factor to the volume estimate. These density values were found in different published material that is available. Appendix A contains a list of density factors and the published material from which they were taken in order to obtain a weight estimate. Each food item was then coded, and the Nutrient Analysis Program (Department of Food and Nutrition, 1986), submitted to give nutrient compositions of the individual foods.

4.3 PART 1: 21 DAY WEIGHED RECORD AND PHOTOMETHOD RECORD OF ONE INDIVIDUAL

The 21 day food intake of the adult male was recorded as described below. The total number of food items analyzed was 207. The food record included several items that could not be included since published density factors were not available.

Prior to food consumption, each item in a meal was weighed by one dietician using a beam balance (12kg x 5g) which had previously been verified with 100 gm and 500 gm weights. One dietitian coded all weighed food items. The plate, or, item of food was then photographed by the subject. The camera was placed on the same horizontal surface, at a distance of 1.0 to 1.5 m, and at angles between 20° and 30° from the plate of food. The Ektagraphic Slide projector was on a higher platform, at a distance of 2.0 to 2.5 m, and at angles between 20° and 30° from the plate of food. The investigator analysed and coded each photographic record as previously described, such that a volume, weight, and nutrient content estimate was obtained for each food item.

4.4 PART 2: 24-HOUR RECALL, WEIGHED RECORD, AND PHOTOGRAPHIC RECORD FROM A GROUP OF SUBJECTS

Thirteen University of Manitoba undergraduate students volunteered to take part. Subjects were given a verbal explanation regarding the requirements of the study, and asked to sign a consent form (Verbal explanation given, and consent form are in Appendix B).

Fifteen lunches, none of which had identical foods or portion sizes, were chosen for lunch from a Country Kitchen outlet. The total number of food items on the thirteen plates selected by the subjects was 54. Before plates were prepared and served to the subjects, two nutritionists weighed and manually determined the volume of each food item on the plate. Weighing was done using a Soehnle Electronic Dietary Scale. Volumes were determined using dry and liquid household measures which were previously checked using a graduated cylinder. A ruler and appropriate mathematical formulae for volume were used for such items as hotdog buns and chicken fingers. Each plate was numbered, and photographed by the investigator in the manner previously described for the photomethod. Each subject chose a specific meal, which was heated and served. The number of the plate chosen was noted in terms of the respective subject. Any waste on the plate was weighed, and photographically recorded by the author. The photomethod was then used to estimate the volume of each food item, and a weight estimate calculated.

Food items in this study included hotdog buns and baked potatoes. Manual measurements of these items were those that gave a volume estimate of a rectangular shaped object (ie:length x breadth x height). Since these items are not rectangular objects, a factor (bun, 0.7; potato, 0.5) was applied to the measured volume, which was expected to give a volume estimate closer to that of the actual volume of the food items. Appendix C contains an explanation regarding the derivation of these factors.

After a 24 hour period, each subject was interviewed by a dietitian, who had no knowledge of the meals served the previous day. The interview followed the procedure required in a 24 hour recall (Burk and Pao, 1976), and was preceeded by questions regarding food preferences. For the purpose of this study, only information pertaining to the lunch eaten the previous afternoon was required for data analysis. Subjects recalled food eaten in terms of household measures, dimensions of food items, 'pieces' of food items, and weight. Coding of the recall records was done by the interviewer. Items recalled as 'pieces' were given weights by the interviewer. These weights were based on average servings of similar food items listed in published sources, such as the Canadian Nutrient File (Health and Welfare, Canada, 1986), and nutrient information on fast foods (Timesaver, 1986). Nutrient composition was determined by transposing the amount of each food item in grams, and then using the Nutrient Analysis Program (Department of Food and Nutrition, 1986) for compositional calculations. Food items recorded in volume measures were converted to weights by using the same density factors used in the conversion of photomethod volume estimates to weights of the same food items.

To test the hypotheses put forward, statistical analyses for Part 1 and Part 2 of this study were performed using the Statistical Analysis System (SAS) (SAS Institute, Inc., 1986).

Chapter V

RESULTS

5.1 PART 1: 21 DAY WEIGHED RECORD AND PHOTOMETHOD RECORD OF ONE INDIVIDUAL

5.1.1 Hypothesis 1: Weight estimates

A total of 207 weight and volume estimates of individual food items were obtained from the physical measures and photomethod record. Examination of the photomethod records showed that for 10 food items, the number of slices estimated by the investigator were incorrect. The shape of these food items were such that identifying contour lines that corresponded to particular slices was difficult and therefore, inaccurate estimations of the number of slices were made during analyses of these photographic records. This would affect the final volume estimate observed, and hence, the corresponding weight estimate of those 10 items. Statistical analyses were performed on Data A and Data B. Results observed with Data A will be presented below.

A paired t-test was performed to test if differences between weight estimates from the photomethod and physical measure of weight were statistically significant.

The means and standard deviations are shown in Table 10. Results show that on average, the physical weight estimates were 5% larger, however, this difference was small, and not significant (t=0.98, p=0.3276). Hypothesis 1 was accepted.

TABLE 10

Data A: Means for weight estimates of food items in 21 day gravimetric and photomethod record.

Variable	N	Mean(g)	S.D	C.V
Gravimetric measure	197	104.9	103.5	0.98
Photomethod	197	99.9	105.7	1.06

C.V = coefficient of variation (S.D/Mean)

TABLE 11

Data A: Pearson's correlation results for weight estimates of food items in 21 day gravimetric and photomethod record

Variables	r-value	probability	r^2
Gravimetric wt. and photomethod wt.	0.76	0.0001	0.58

Pearson's correlation(r) and the coefficient of determination(r^2) values are shown (table 11).

Thus, approximately 58% of the variation in both the physical weight estimate and the photomethod weight estimate is common. Figure 4 shows the regression line obtained with results from these two variables.

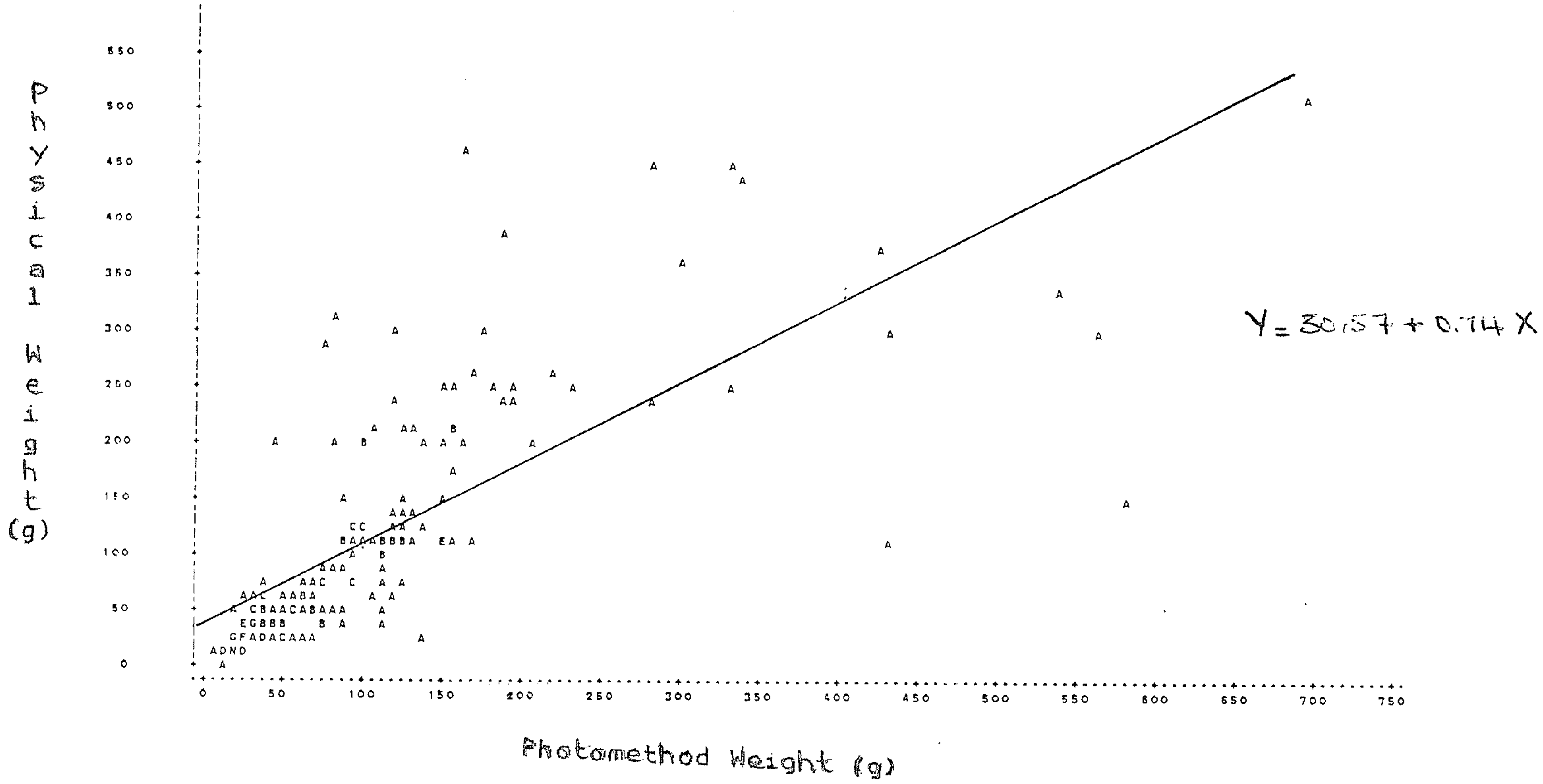


Figure 4: Part 1: Regression line and plot of weight estimates from the weighed and photomethod

5.1.2 Hypothesis 2: Volume estimates

Differences between the photomethod volume estimates and the physical volume estimates were tested using the paired t-test.

The means and standard deviation values are shown(Table 12). As with weight estimates, the 8% difference between the means was not statistically significant (t=1.60, p=0.1120). Hypothesis 2 was accepted. Pearson's correlation and the coefficient of determination are listed in Table 13. Figure 5 shows regression line and plot observed with this dataset.

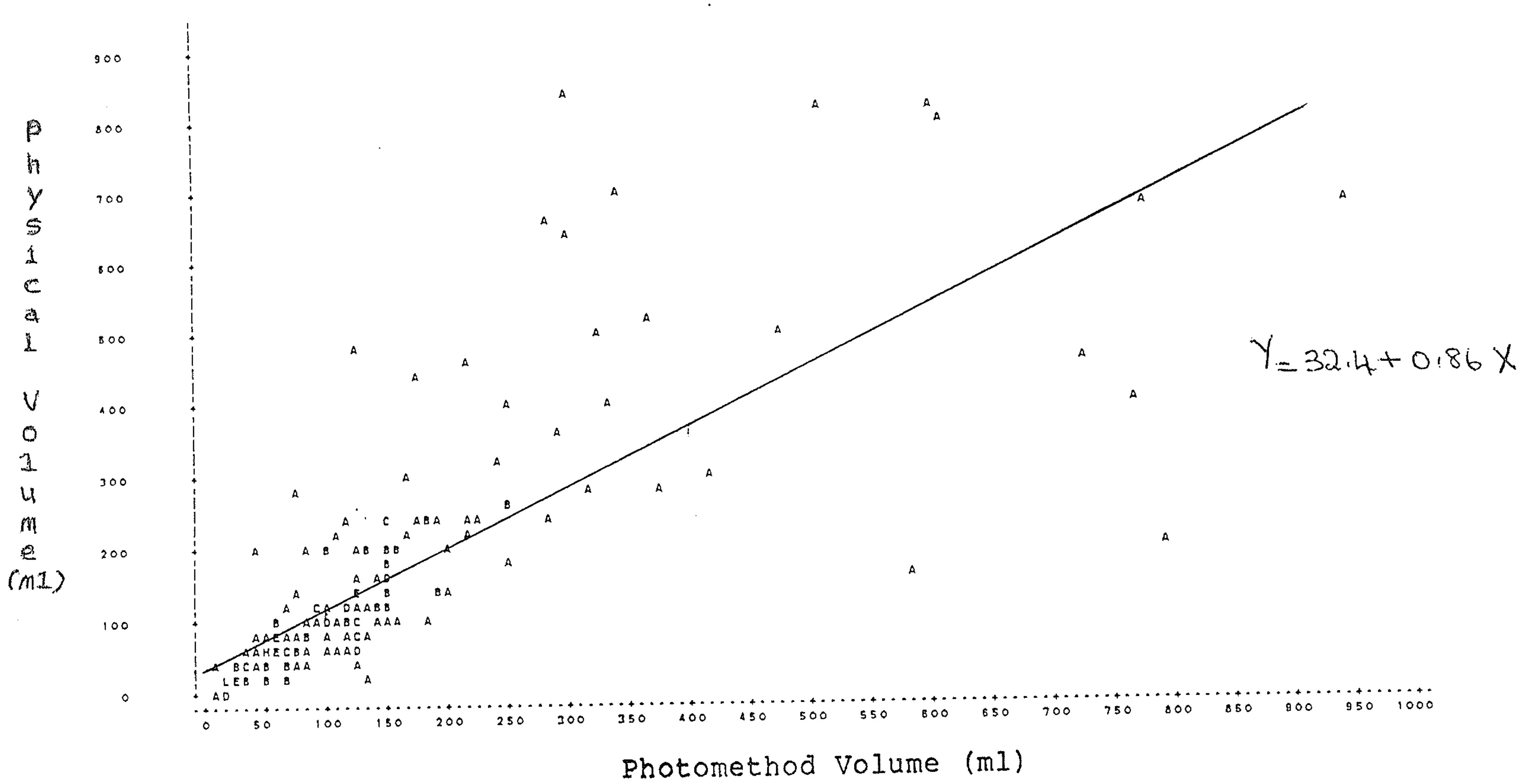


Figure 5: Part 1: Regression line for volume estimates from physical measure and photomethod

TABLE 12

Data A: Means for volume estimates of food items in physical and photomethod records.

Variable	N	Mean(ml)	S.D	C.V
Physical measure	197	154.4	167.6	1.09
Photomethod	197	142.0	150.3	1.06

C.V=Coefficient of variation

TABLE 13

Data A: Pearson's correlation for volume estimates of food items in physical and photomethod records.

r-value	probability	r^2
0.77	0.0001	0.59

5.1.3 Hypothesis 3: Mean daily intake of nutrients

Results from a 2-way ANOVA indicates that for all nutrients considered, the mean daily intakes of nutrients based on weighed estimates do not differ from the mean daily intakes of nutrients obtained by the photomethod over the 21 days recorded. Hypothesis 3 was accepted. Table 14 shows the F-values and associated probabilities from the analysis. Table 15 shows the mean daily intake of energy estimated, using the gravimetric record and photomethod record.

TABLE 14

Data A: Results of Two-way ANOVA: Method.

Nutrient	F-value	Probability
Energy	0.00	0.9475
Protein	0.05	0.8245
Fat	0.10	0.7550
Carbohydrate	0.00	0.9978
Calcium	0.04	0.8462
Iron	0.08	0.7812
Vitamin A	0.00	0.9528
Vitamin C	0.12	0.7336

The method x day interaction analysis showed that the mean day-to-day variation of nutrient intake in the weighed record was also found in the photomethod record (see Table 16)

TABLE 15

Data A: Mean daily energy intake estimated using the gravimetric and photomethod record.

Day	Gravimetric record (kcal)	Photomethod record (kcal)	Difference (kcal)
1	125.0	125.0	0.0
2	122.0	96.0	26.0
3	47.0	43.0	4.0
4	114.0	97.0	17.0
5	85.0	135.0	- 50.0
6	126.0	144.0	- 18.0
7	37.0	52.0	- 15.0
8	77.0	102.0	- 25.0
9	86.0	126.0	- 40.0
10	115.0	72.0	43.0
11	128.0	90.0	38.0
12	84.0	70.0	14.0
13	158.0	215.0	- 57.0
14	114.0	111.0	3.0
15	112.0	89.0	23.0
16	96.0	114.0	- 18.0
17	127.0	96.0	31.0
18	130.0	111.0	19.0
19	105.0	100.0	5.0
20	133.0	111.0	22.0
21	218.0	259.0	- 41.0

TABLE 16

Data A: F-value and probability: Method x day.

Nutrient	F-value	Probability
Energy	0.22	0.9999
Protein	0.07	1.0000
Fat	0.13	1.0000
Carbohydrate	0.22	0.9990
Calcium	0.09	1.0000
Iron	0.18	1.0000
Vitamin A	0.07	1.0000
Vitamin C	0.05	1.0000

5.1.4 Hypothesis 4: Variability of nutrient estimates

Bartlett's test for equality of variances (Neter et al, 1985), showed that the variability of daily nutrient intakes based on the photomethod estimates was not significantly different from the variability of daily nutrient intakes based on weighed estimates(Table 17). Hypothesis 4 was accepted. Results observed are variable, and appear to depend on the nutrient concerned.

Tables 18, 19, and 20 show a summary of results with data A, and data B.

TABLE 17

Data A: Results for equality of variances: Nutrients.

Nutrient	χ^2-value	Probability
Energy	0.904	0.342
Protein	0.148	0.700
Fat	0.941	0.332
Carbohydrate	0.621	0.431
Calcium	0.038	0.845
Iron	2.610	0.106
Vitamin A	0.596	0.440
Vitamin C	0.005	0.941

TABLE 18

Part 1 summary of means, s.d, and r^2 obtained with data A, and data B.

Variables	Data A N=197	Data B N=207
Gravimetric mean wt. (S.D)(g)	104.9 (103.5)	107.7 (104.9)
Photomethod mean wt. (S.D)(g)	99.9 (105.7)	97.9 (103.7)
r^2	0.58	0.53
Gravimetric mean vol.(S.D)(ml.)	154.4 (167.6)	160.7 (174.5)
Photomethod mean vol.(S.D)(ml,)	142.0 (150.3)	139.6 (147.4)
r^2	0.59	0.53

TABLE 19

Part 1 summary of two-way ANOVA obtained with data A, and data B.

Nutrient	Data A F-value	Data B F-value
Energy	0.00	0.73
Protein	0.05	0.29
Fat	0.10	0.01
Carbohydrate	0.00	0.78
Calcium	0.04	0.29
Iron	0.08	1.26
Vitamin A	0.00	0.04
Vitamin C	0.12	0.05

None of the F-values were significant at the 0.05 level of significance.

TABLE 20

Part 1 summary of results for Bartlett's test with data A, and data B.

Nutrient	Data A χ^2-value	Data B χ^2-value
Energy	0.90	1.26
Protein	0.15	0.14
Fat	0.94	0.29
Carbohydrate	0.62	0.67
Calcium	0.04	0.03
Iron	2.61	3.47
Vitamin A	0.60	0.58
Vitamin C	0.01	0.15

None of the values were significant at the 0.05 level of significance.

5.2 PART 2: 24-HOUR RECALL, WEIGHED RECORD, AND PHOTOMETHOD RECORD OF A GROUP OF SUBJECTS

5.2.1 Hypotheses 1, 3, and 5: Weight estimates

A total of 54 individual food items were obtained for the physical measure, recall method, and photomethod record. For two food items recorded, laboratory measurements did not give enough data so as to be able to calculate the physical volume of those items. For five food items, the density factors calculated in the laboratory were not comparable to the range of factors published, suggesting that errors were made in the laboratory measures. For three food items, examination of the photomethod records showed that the number of slices estimated were incorrect, which would result in errors in the final volume and weight estimate. Statistical analyses were performed with these 10 items excluded (Data A). Since no physical volume estimates were available for two of those items, they could not be included in the analyses. Thus, when errors were included in the analyses (Data B), 52 food items were in the dataset. Results observed with Data A will be presented below. Hotelling's T^2 analyses gave the same results as were observed with the paired t-tests.

The paired t-test analysis was performed on the set of results to test differences between pairs of variables in each hypothesis. Means and standard deviations for each method are listed in Table 21.

Differences between weights of individual food items obtained by the physical measure and estimates obtained by the photomethod were not significant (t= -1.57, p=0.1236). Hypothesis 1 was accepted.

Differences between weight estimates of individual food items obtained by the physical measure and recall interview were significant (t=2.65, p=0.0109). Weight estimates given in recall interviews were on average, less than gravimetric measures. Hypothesis 2 was rejected.

Differences between weight estimates of food items obtained by the photomethod and recall interviews were significant (t=3.21, p=0.0024). On average, weight estimates from the photomethod were greater than those weights given in recall interviews. Hypothesis 3 was rejected.

TABLE 21

Data A: Means for weight estimates of food items in gravimetric measure, photomethod, and recall method.

Variable	N	Mean(g)	S.D	C.V
Gravimetric wt.	44	94.0	58.4	0.62
Photomethod wt.	44	103.0	79.8	0.77
Recall wt.	44	74.0	62.5	0.84

C.V=Coefficient of variation (S.D/Mean)

Pearson's correlation and coefficient of determination found for weight estimates between variable pairs are shown (Table 22). Coefficient of determination values indicates that there is a stronger relationship between physical and photomethod weight estimates, than with either of the other two variable pairs, with 62% of the variation found being common to both methods. Figures 6,and 7 show the plot and regression line for each relationship.

TABLE 22

Data A: Pearson's correlation results for weight estimates between methods.

Variables	r-value	probability	r^2
Gravimetric wt. and Photomethod wt.	0.78	0.0001	0.62
Gravimetric wt. and Recall wt.	0.69	0.0001	0.48
Photomethod wt. and Recall wt.	0.62	0.0001	0.39

For comparison purposes, statistical analyses were undertaken using photomethod weight estimates obtained by converting the volume estimates to weight using density factors calculated from laboratory measures of weight and volume.

Means and standard deviations for these weight estimates from gravimetric, photomethod and the recall method are in Table 23. Pearson's correlation and coefficient of determination values are also shown(Table 24).

Figures 8 and 9 show the plot and regression line obtained for the relationship between physical weight and photomethod weight estimates, and the relationship between physical weight and recall weight estimates. It can be seen that there is a much stronger relationship between physical weight and photomethod weight estimates, when laboratory

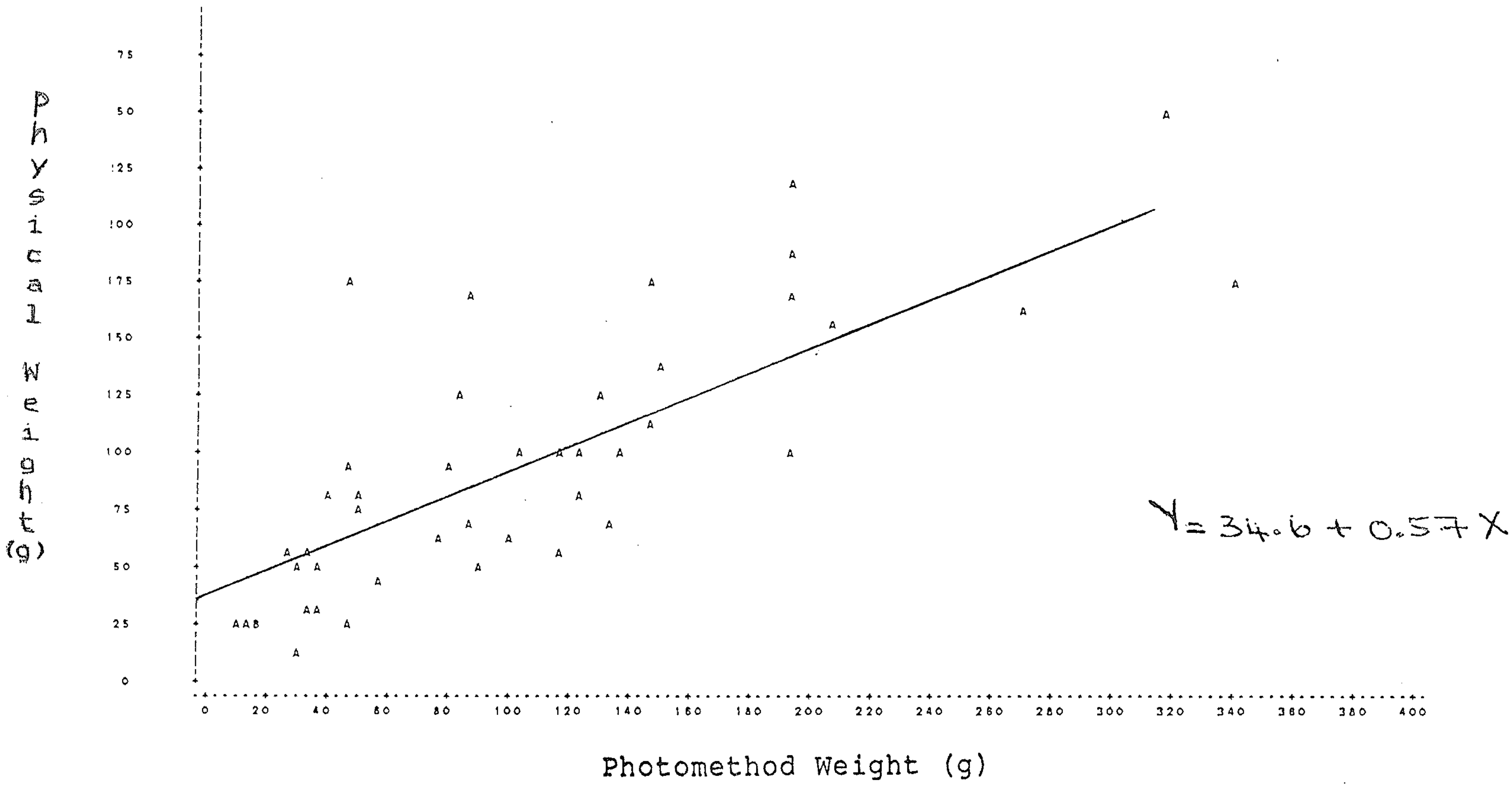


Figure 6: Part 2: Regression and plot: Gravimetric and photomethod weight estimates

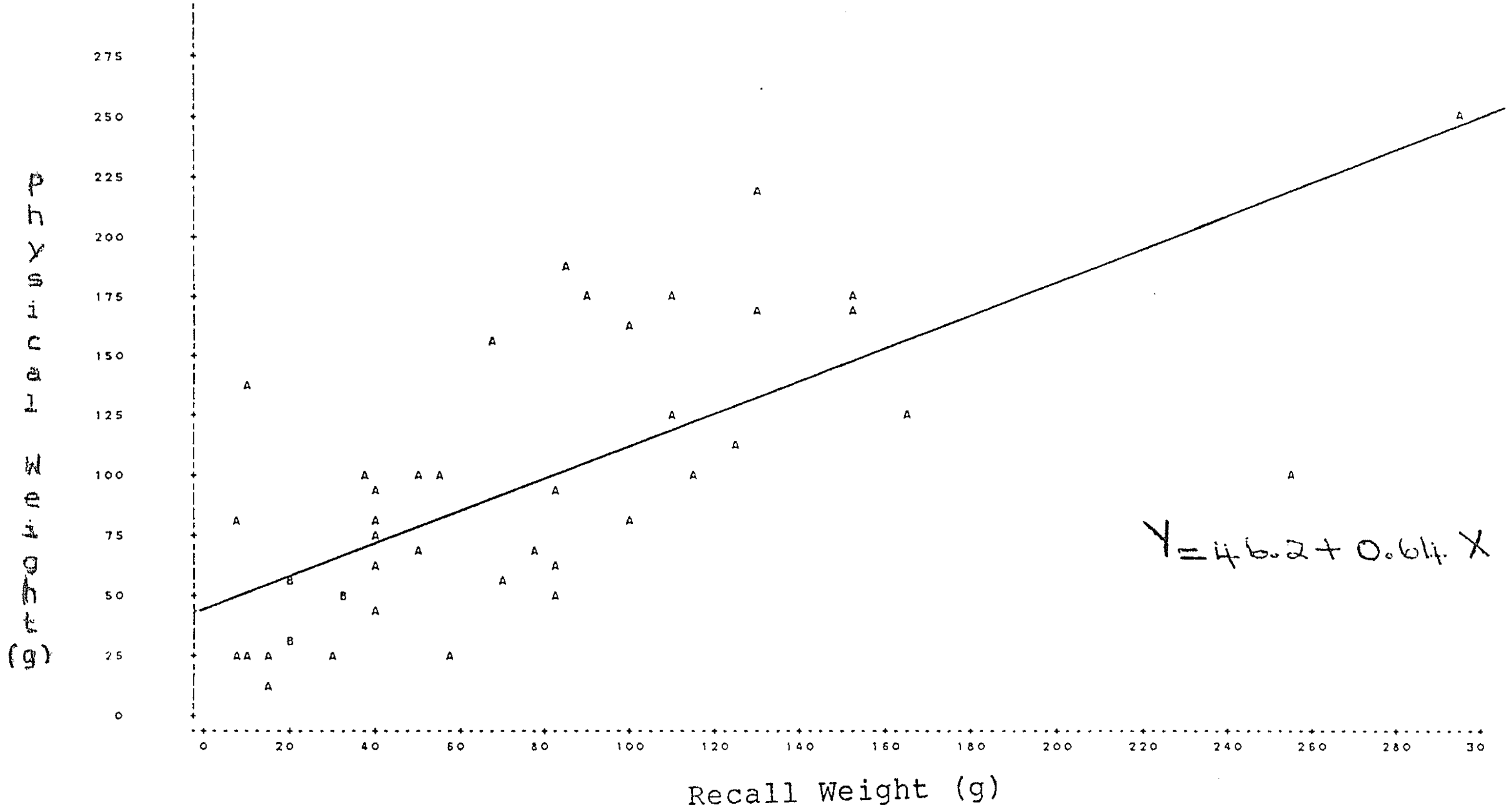


Figure 7: Part 2: Regression and plot: Gravimetric and recall weight estimates

TABLE 23

Data A: Means for weight estimates of food items in weighed, photomethod, and recall method: Manual density factors

Variable	N	Mean(g)	S.D	C.V
Gravimetric wt.	44	94.0	58.40	0.62
Photomethod wt.	44	96.0	66.83	0.70
Recall wt.	44	71.0	61.92	0.87

C.V = Coefficient of variation (S.D/Mean)

TABLE 24

Data A: Pearson's correlation results for weight estimates between methods: Manual density factors.

Variables	r-value	Probability	r^2
Gravimetric wt. and Photomethod wt.	0.93	0.0001	0.87
Gravimetric wt. and Recall wt.	0.76	0.0001	0.57
Photomethod wt. and Recall wt.	0.73	0.0001	0.54

determined rather than published density figures are used to convert the photomethod volume estimates to weights. The regression line obtained for the relationship between photomethod and recall weight estimates is not shown since in this validity study we are concerned with the precision of data obtained from the photomethod and recall method as compared to data from the physical measures of weight.

Tables 25 and 26 show a summary of means, s.d, and r^2 for data A, and data B.

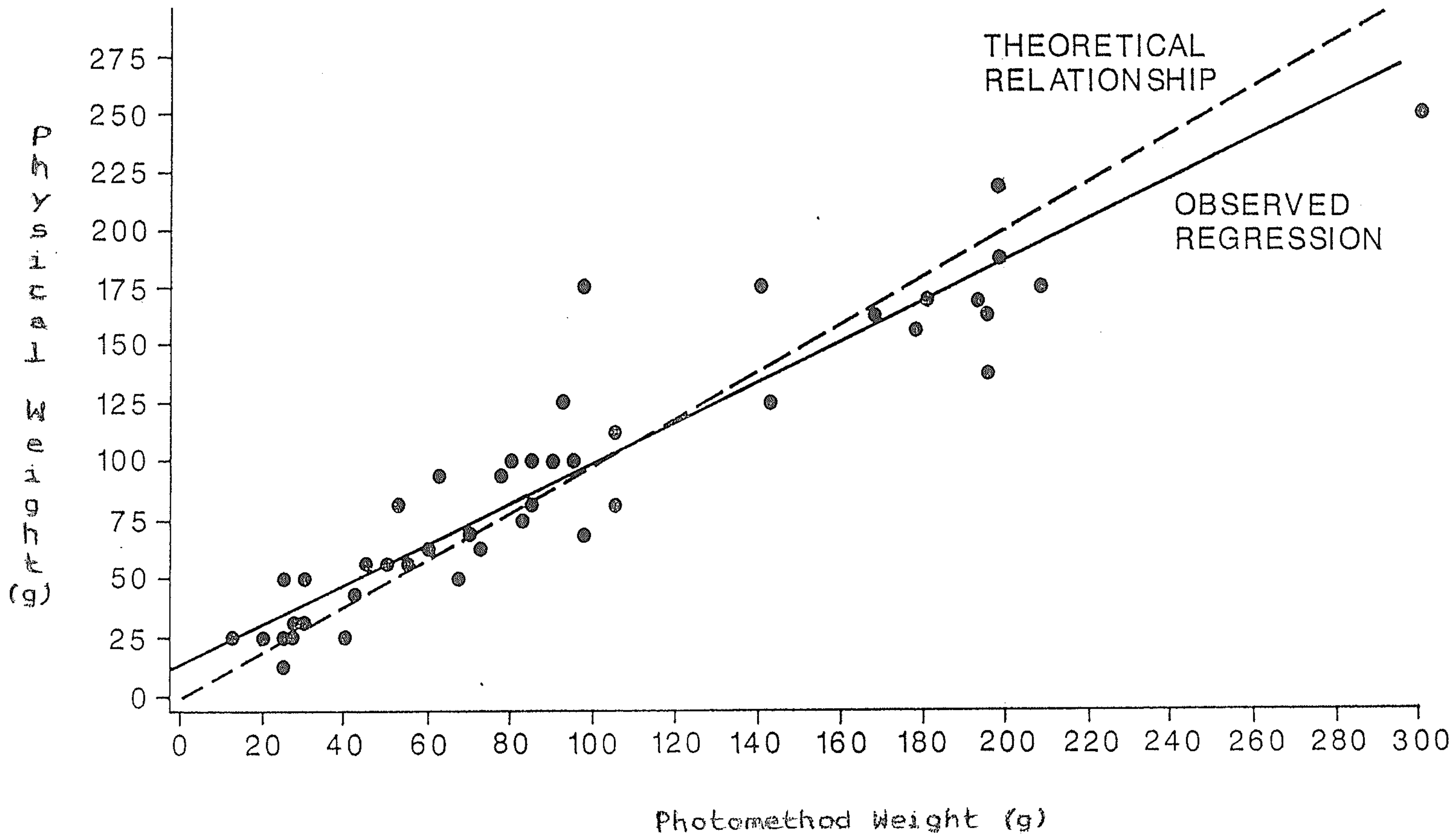


Figure 8: Regression and plot: Weighed estimates, and Photomethod weights using manual density factors

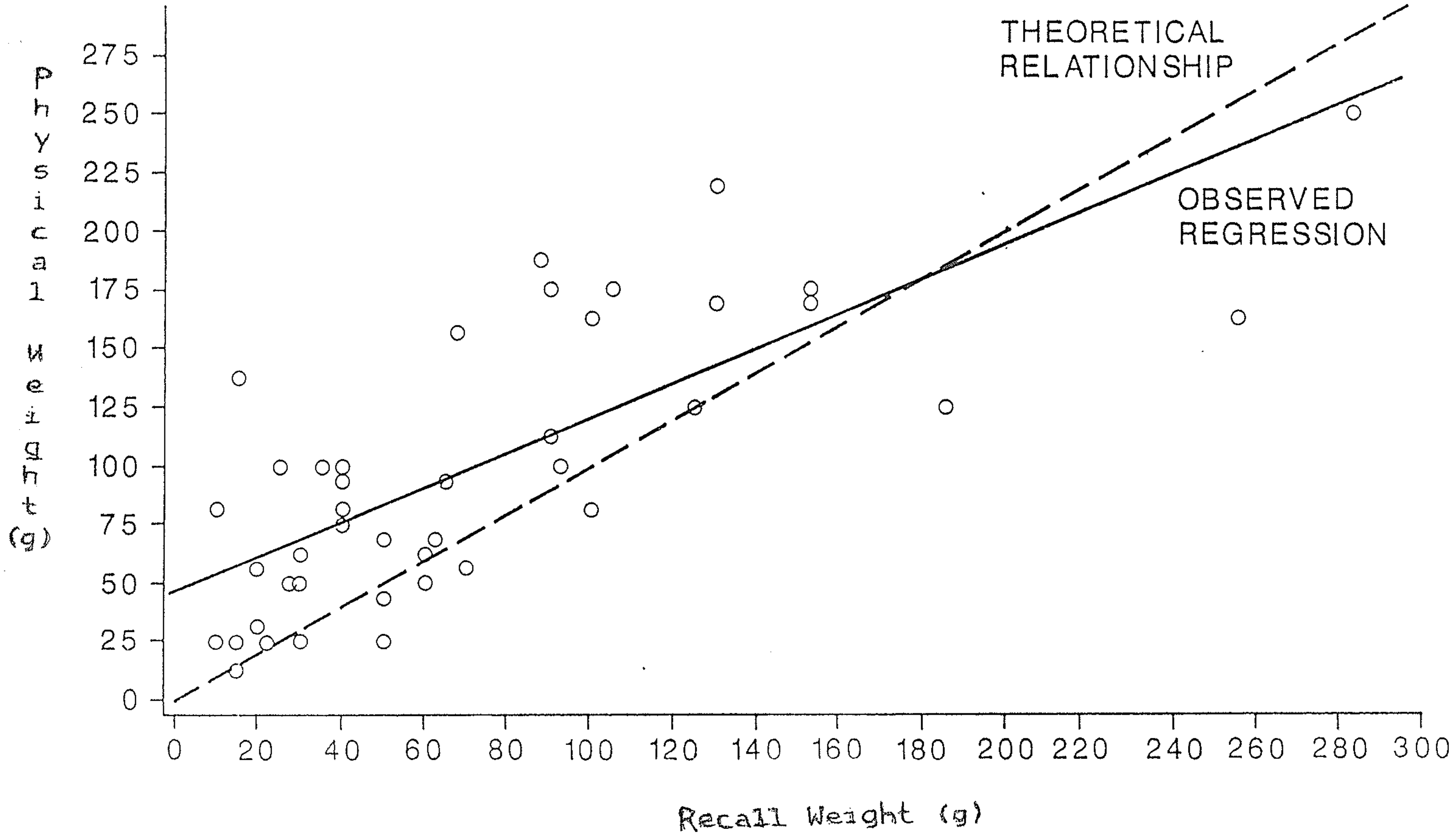


Figure 9: Regression and plot: Weighed estimates and Recall weights using manual density factors

TABLE 25

Part 2 summary of means, and S.D obtained with data A, and data B.

Variables	Data A N=44	Data B N=52
Gravimetric mean wt.(S.D)(g)	94.0 (58.4)	89.6 (55.9)
Photomethod mean wt.(S.D)(g)	103.0 (79.8)	102.0 (77.6)
Recall mean wt.(S.D)(g)	74.0 (62.5)	72.0 (58.4)

TABLE 26

Part 2 summary of r^2 obtained with data A, and data B.

Variables	Data A	Data B
Gravimetric and photomethod wt.	0.62	0.61
Gravimetric and recall wt.	0.48	0.47
Photomethod and recall wt.	0.39	0.39

5.2.2 Hypotheses 2, 4, and 6: Volume estimates

Differences between volume estimates of individual food items obtained by the physical measure and the photomethod were not significant (t= -1.42, p=0.1634). Hypothesis 2 was accepted.

Differences between volume estimates of individual food items obtained by the physical measure and the recall interview were significant (t=2.36, p=0.0226). Volume estimates given in a recall interview were, on average, less than physical measures of the same items. Hypothesis 4 was rejected.

Differences between volume estimates of individual food items obtained by the photomethod and recall interview were significant (t=3.56, p=0.0008). As was found for weight estimates, volumes from photomethod estimations were greater on average than volumes reported in the recall interviews. Hypothesis 6 was rejected.

The means and standard deviations for the 44 items analysed are listed in Table 27. Pearson's correlation and coefficient of determination found for volume estimates between pairs of variables are listed (Table 28). A comparison of the coefficient of determination for each relationship shows that, as with the weight estimates, there exists a stronger relationship between volume estimates of the photomethod and those physically measured in the laboratory, than with the other two variable pairs, with 81% of the variation common to both variables. Figures 10 and 11 show regression lines and plots for each variable pair. Regression line for volume esimates between recall and the photomethod is not included for the reason previously stated.

Table 29 and 30 show a summary of means, S.D,and r with data A, and data B.

TABLE 27

Data A: Means for volume estimates of food items from physical measure, photomethod, and recall method.

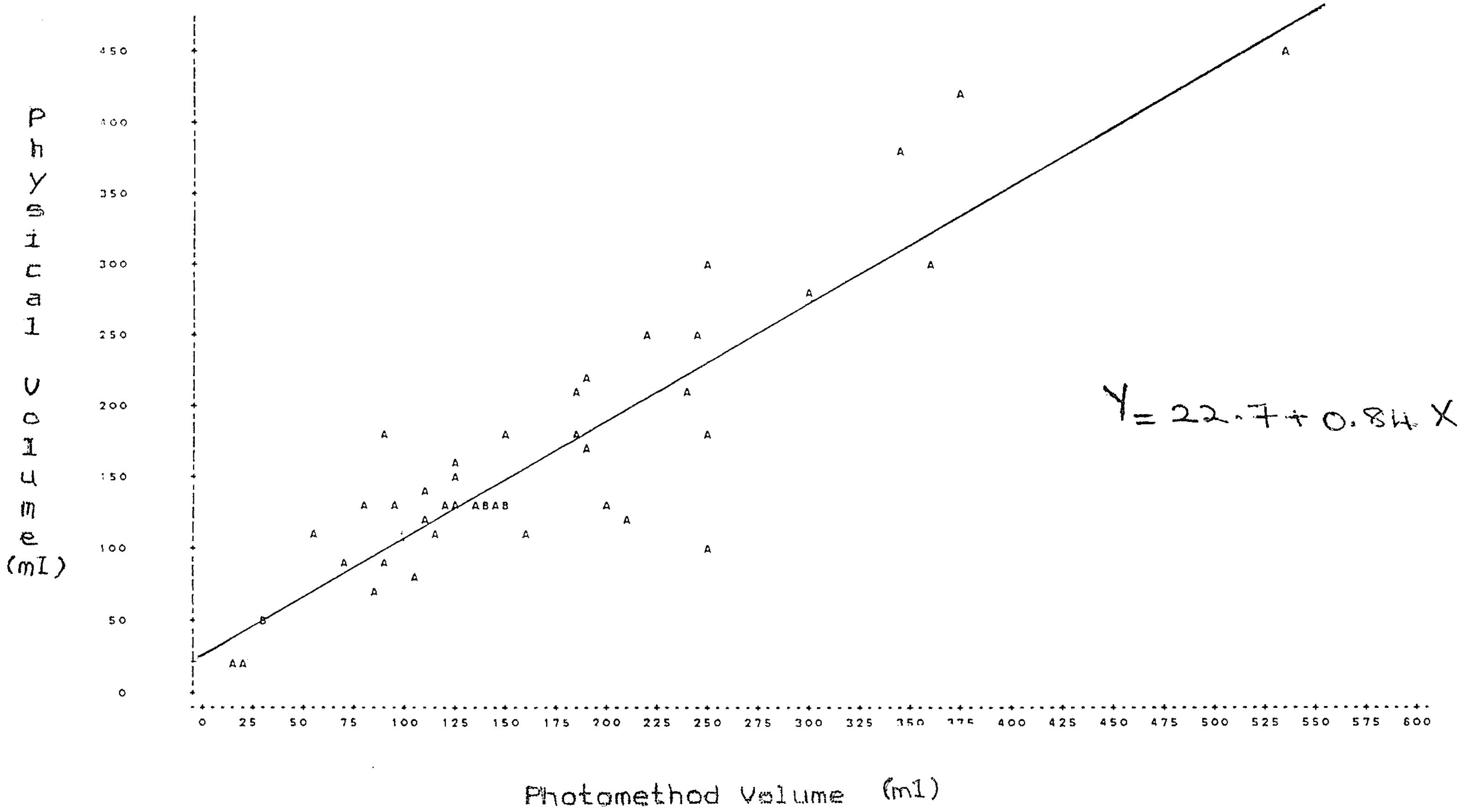
Variable	N	Mean(ml)	S.D	C.V
Physical vol.	44	162.0	96.4	0.60
Photomethod vol.	44	166.0	103.8	0.63
Recall vol.	44	124.0	99.5	0.80

C.V=Coefficient of variation (S.D./Mean)

TABLE 28

Data A: Pearson's correlation results for volume estimates between methods.

Variables	r-value	probability	r^2
Physical vol. and Photomethod vol.	0.90	0.0001	0.81
Physical vol. and Recall vol.	0.68	0.0001	0.46
Photomethod vol. and Recall vol.	0.73	0.0001	0.54



$Y = 22.7 + 0.84 X$

Figure 10: Part 2: Regression and plot: Physical and photomethod volume estimates

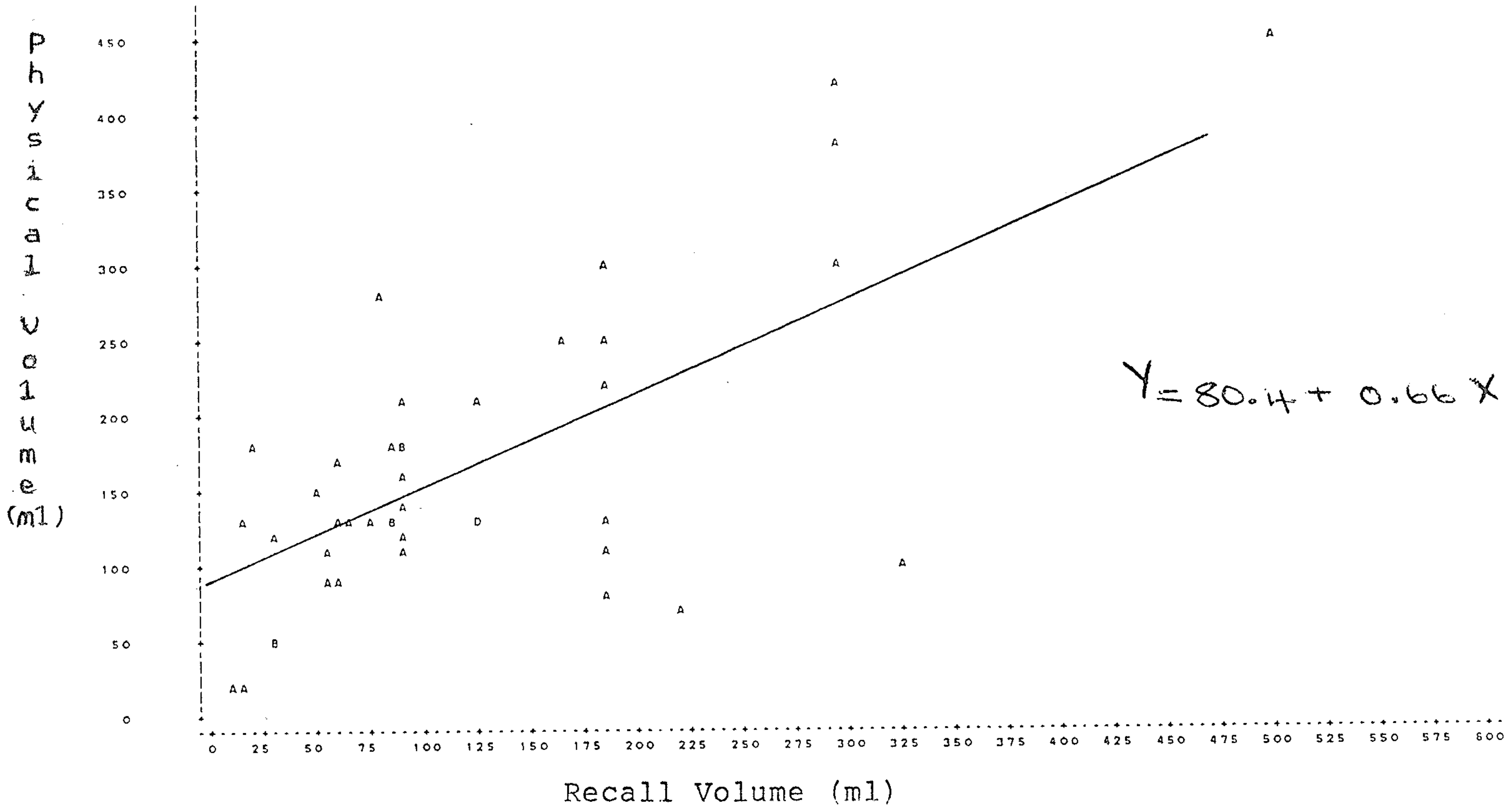


Figure 11: Part 2: Regression and plot: Physical and recall volume estimates

TABLE 29

Part 2 summary of mean volume, S.D, with data A, and data B.

Variables	Data A N=44	Data B N=52
Physical mean vol.(S.D)(ml.)	162.0 (96.4)	145.9 (97.1)
Photomethod mean vol.(S.D)(ml.)	166.0 (103.8)	157.7 (99.9)
Recall mean vol.(S.D)(ml.)	124.0 (99.5)	119.1 (95.2)

TABLE 30

Part 2 summary of r^2 with data A, and data B.

Variables	Data A r^2	Data B r^2
Gravimetric and photomethod vol.	0.81	0.75
Gravimetric and Recall vol.	0.46	0.43
Photomethod and Recall vol.	0.54	0.54

5.3 HYPOTHESES 7, 8, AND 9: NUTRIENT ESTIMATES

Paired t-test analyses were conducted to test hypotheses 7, 8, and 9. Hotelling's T^2 analysis gave the same results as were observed with the paired t-test.

Differences between energy (t=1.22, p=0.2304), calcium (t=-0.61, p=0.5442), iron (t=0.96, p=0.3427), vitamin A (t=1.65, p=0.1054), and vitamin C (t=-0.20, p=0.8404) estimates of individual food items were not significant for weighed and photomethod assessments of nutrient intake. Significant differences were found for protein, carbohydrate, and fat.

Differences between protein (t=-1.93, p=0.0603), fat (t=- 0.74, p=0.4638), iron (t=-1.55, p=0.1286), vitamin A (t=-0.40, p=0.6924), and vitamin C (t=-1.59, p=0.1186) estimates of individual food items were not significant for weighed and recall interview assessments of nutrient intake. Significant differences were found for energy, calcium and carbohydrate.

Differences between carbohydrate (t=0.71, p=0.4785), vitamin A (t=1.55, p=0.1285), and vitamin C (t=1.29, p=0.2028) estimates of individual items were not significant for photomethod and recall interview measures of nutrient intake. Significant differences were found for energy, protein, fat, calcium, and iron.

Means and standard deviations observed for each method are listed(Table 31). Pearson's correlation and coefficient of determination values are also shown (Table 32).

TABLE 31

Data A: Comparison of means of nutrient estimates of food items: Weighed, photomethod and recall method (N=44)

Nutrient	Source	Mean	S.D	C.V.
Energy(kcal)	Gravimetric	146.0^{a}	117.6	0.81
	Photomethod	163.0^{a}	171.0	1.05
	Recall	114.0^{b}	131.0	1.15
Protein(g)	Gravimetric	10.0^{a}	15.3	1.53
	Photomethod	14.0^{b}	25.1	1.79
	Recall	7.0^{a}	12.3	1.76
Fat(g)	Gravimetric	6.0^{a}	7.7	1.28
	Photomethod	8.0^{b}	10.5	1.31
	Recall	5.0^{a}	9.4	1.88
Carbohydrate(g)	Gravimetric	13.0^{a}	15.8	1.22
	Photomethod	10.0^{bc}	13.0	1.30
	Recall	9.0^{c}	13.0	1.44
Calcium(mg)	Gravimetric	20.0^{a}	18.3	0.92
	Photomethod	19.0^{a}	16.2	0.85
	Recall	15.0^{b}	16.5	1.10
Iron(mg)	Gravimetric	1.4^{ab}	1.4	1.02
	Photomethod	1.5^{a}	1.7	1.15
	Recall	1.0^{b}	1.7	1.70
Vitamin A(R.E)	Gravimetric	123.0^{a}	357.3	2.90
	Photomethod	141.0^{a}	425.0	3.01
	Recall	117.0^{a}	377.0	3.22
Vitamin C(mg)	Gravimetric	4.0^{a}	8.3	2.07
	Photomethod	4.0^{a}	8.8	2.20
	Recall	3.0^{a}	6.3	2.10

C.V.= coefficient of variation (S.D./Mean)
a,b,c means with same superscript are not significantly different from each other.

TABLE 32

Data A: Pearson's correlation results for nutrients between dietary methods

Nutrient	Gravimetric and Photomethod		Gravimetric and Recall		Photomethod and Recall	
	r	r^2	r	r^2	r	r^2
Energy	0.87	0.76	0.67	0.45	0.73	0.53
Protein	0.97	0.94	0.74	0.55	0.77	0.60
Fat	0.94	0.88	0.77	0.60	0.86	0.74
Carbohydrate	0.86	0.74	0.86	0.74	0.90	0.81
Calcium	0.78	0.61	0.77	0.60	0.74	0.55
Iron	0.89	0.80	0.78	0.61	0.79	0.62
Vitamin A	0.99	0.98	0.97	0.94	0.97	0.94
Vitamin C	0.81	0.66	0.84	0.71	0.85	0.72

Chapter VI

DISCUSSION

Rasanen (1982), defines the validity of a measure as the extent to which the measure accurately reflects some underlying truth. The weighed record, accepted as the most precise measure of food consumption (Marr,1971; Pekkarinen et.al, 1967), is used in this study to evaluate the direct validity of the photomethod and 24-hour recall. The results in Part 1 and Part 2 of this study will be discussed separately.

6.1 PART 1: 21 DAY WEIGHED AND PHOTOMETHOD RECORD FOR ONE INDIVIDUAL

Since differences between weight estimates from the photomethod and physical measure of weight were not significant, it appears that the photomethod technique of quantifying food intake provides good estimates of weight. Wadsworth (1986), also found no significant differences between weight estimates from these two methods, however, the percentage of variation common to these methods was higher than those found in this study. Some of the variation that is unexplained by the relationship between the physical and photomethod estimates of weight, could be due to the fact that photomethod volume estimates of food items were converted to weight estimates using published density factors. Wadsworth (1986), obtained weight estimates for 20 individual food items, calculated from density figures determined in the laboratory. In Part 1, foods were not physically manipulated, hence only published density figures could be utilized in the conversions of volume estimates to weight estimates of the food items.

The better correlation values observed might be due to the fact that with published density figures, values are available for food items which are likely to have a range of shapes and moisture contents. This would influence the density value obtained for any particular food item, and would thus not correspond to values cited in published materials. However, as noted by Wadsworth (1986), such a source of variation would present a bias in any of the dietary methodologies that attempt to quantify food intake. Volume estimates of food items in Part 1 of the study were undertaken with the researcher having minimal training experience with the photomethod technique, which could also account for some of the variation that is unexplained by the relationship between the physical and photomethod estimates of weight. However, the 42% variation left unexplained by the regression model indicates that improvements are necessary in the photomethod technique, such that volume estimates provided will give unit changes in weight estimates that corresponded to the unit changes in weights of food consumed. It is possible that to obtain less variation in the photomethod estimates of volumes and weights of food items, volume calculations presently undertaken will have to take into account the role of visual and stereo perspective.

Mean daily intakes and the variability of nutrients were not significantly different between the weighed record and the photomethod estimates. Results obtained with the two-way ANOVA indicate that there is no weakening of accuracy with the photomethod estimates of food intake over a period of 21 days. The photomethod appears to perform consistently for the 21 day period. Although high variability is observed in the volume and weight estimates of the photomethod, there appears to be no bias in the estimations that lead to inappropriate conclusions on nutrient intakes of food consumed. It would appear that the photomethod technique is estimating nutrients with a precision similar to that found with a weighed record. Estimating the 'usual' intake of individuals requires that more than one day of food intake be assessed in order to obtain a reliable estimate (Beaton et.al, 1979; Todd et.al, 1983), of nutrient consumption. If the most precise method of assessing this intake is a daily weighed record, one can expect at best, a conservative estimate of nutrient intake. Subjects have found a photographic method (Bird and Elwood, 1983), to be easy and less demanding. Perhaps this photographic method would give more reliable estimates of individuals 'usual' nutrient consumption since habitual food habits are less likely to be altered. Future studies should investigate if food behaviour, particularly snacking, is altered, when individuals are required to photograph their entire food intake for several days.

6.2 PART 2: 24-HOUR RECALL, WEIGHED RECORD, AND PHOTOMETHOD RECORD FOR A GROUP OF SUBJECTS

As was observed in Part 1 of the study, the photomethod technique of quantifying food intakes provides good estimates of weight. The association between the photomethod and physical estimates of weight are better than that found in Part 1. It is possible that the use of a 35mm transparency containing contour lines having dark bands of specific designs enabled more precise estimations of food volume than those obtained in Part 1 of the study. Identification of the bottom of food 'slices' was facilitated, as well as the measurements of obscured portions of food. Such factors would provide better estimates of food volume, which would give good estimates of food weight such that they are comparable to the weight of those items. Photomethod weight estimates were closer to the gravimetric measure than weight estimates recalled in the 24-hour recall method (see Table 21).

Testing the direct validity of the 24-hour recall indicated that significant differences were found between weight estimates measured in the laboratory and those recalled in the 24-hour recall interview. Estimates of food quantities were underestimated, especially those food items of smaller portion size. Such a finding was not surprising, given that individuals have been documented to have difficulty estimating quantities of food as served (Acheson et.al, 1980; Burk and Pao, 1976). Studies on the validity of the recall method are usually undertaken by examining the mean daily intakes obtained, compared to that from the weighed record (Gersovitz et al., 1978; Madden et al., 1976). Such studies show that for most nutrients, mean weighed and recalled intakes observed are not significantly different. However, in this study, the validation of the recall method and photomethod were done on an item by item comparison of food intakes, which could account for the difference observed between the results of this study, and that of Gersovitz et al. (1978) and Madden et al. (1976). Inspection of the recall questionnaire showed that in some instances, subjects omitted certain food items, whereas in one instance, food items were added that were not served in the lunch that day. Food items such as condiments, were omitted in the recall of the lunch eaten. Although this was observed, statistical testing of the extent of food item omission present was not possible due to the small sample size in terms of subjects.

With the photomethod record, measurement was difficult of such items as the cheese sauce on broccoli pieces, however, since it was visible on the slide, an investigator could make a subjective estimate in terms of volume amounts. Thus, nutrient information from such food sources would not be omitted when nutrient intake assessments are obtained from individuals.

It is of interest to note the similarity in standard deviation values observed for the weighed method and recall method (see Table 21). Closer inspection of the dataset revealed that investigators preparing the plates of food tended to have common servings, such as half a cup, which was the amount frequently recalled by the subjects. It has been noted (Gibson, 1987), that the interviewer may suggest or assume average serving sizes which would result in incorrect estimation of food quantity. It is speculated that in this case, because the investigators and interviewer considered food servings in terms of average portions, variation observed was similar in both the weighed method and recall method. However, this dependent relationship requires empirical investigation which could not be attempted in this study because of experimental design restrictions.

When density figures calculated in the laboratory were used in the volume to weight conversions of photomethod estimates, the high correlation coefficient observed between gravimetric estimates and photomethod estimates of weight is consistent with the findings of Wadsworth (1986).

The variation around the mean value shows greater similarity to the pattern observed with the weighed estimates (see Table 23), than when published density figures are used in the volume to weight conversions (see Table 21). The precision of measurements with the photomethod appears to improve when density figures calculated in the laboratory are used. A comparison of figures 8 and 9 shows that although the regression lines in both graphs demonstrate the flat slope syndrome (Madden et al., 1976), this bias is smaller for photomethod estimates of food weights than for recall estimates.

When the weighed record, photomethod, and recall method were compared in terms of energy estimates obtained, significant differences were observed between the weighed and recall estimates, and photomethod and recall estimates. On average, recall estimates of energy were less than estimates obtained with the two other methods. This finding is consistent with results observed in other studies (Acheson et.al, 1980; Campbell and Dodds, 1967; Carter et.al, 1981), which report that mean recalled kilocalories are underestimated, because of omission of food items, and inaccuracies in portion size estimates.

Inspection of the coefficient of variation values (Table 31) indicates that with the exception of protein and vitamin C, the variations about the mean for nutrient estimates from the photomethod show greater similarity to the pattern observed with estimates from the weighed measure, than are variations seen with the recall method. The photomethod estimates of energy and nutrient content of the food items showed some variation. Such differences could be due to the fact that certain food items, having a higher proportion of a particular nutrient, for example calcium, were more difficult to analyze because of the particular shape.

The results presented indicate that compared to the recall method the photomethod provides better estimates of food quantity. It must be noted, however, that the analyses of each photographic record requires much effort and time on the part of the investigator. However, greater automation would reduce the time required to complete analyses of a number of photographic records, as well, it should reduce the random errors that may occur during analyses.

Researchers (Beaton et.al, 1983; Gibson et.al, 1987), note that the choice of a dietary methodology may vary depending on the nutrient under study (because of variability of nutrients found in foods), and the purpose for which this information is required. Since one day intake data are not considered to be a good indicator of an individual's 'usual' intake, replications are necessary to give a reliable estimate of 'usual' intake. Beaton et al.(1983), has stated that the precision with which an individual's 'usual' intake can be estimated is predicted by the equation;

$$\text{S.D.}_{\varepsilon} = \frac{\text{Mean} \times \text{C.V.(intraindividual)}}{\sqrt{n} \times 100}$$

where $\text{S.D.}_{\varepsilon}$ = S.D. of estimate of usual intake

C.V. = intraindividual coefficient of variation

n = number of replicated days of observation

Future studies with this photomethod technique should compare reliability estimates for specific nutrients with those observed with the 24-hour recall. Balogh et.al, (1971), have found that with 24-hour recalls repeated on randomly chosen days, to obtain a ±20% precision of individual mean for 90% of the population, the number of replicated recalls ranged from 9 for energy, to 45 for cholesterol.

Although measurement errors noted contributed little change in final results of weight observed, changes were evident in the correlation coefficient results obtained for volume estimates from the gravimetric record and photomethod, which showed an improvement in statistical values obtained (see Table 30) This suggests that errors were made in the manually determined volumes of some food items. If such errors remain unchecked, nutrient composition data obtained will not reflect the 'true' composition of the food item. These sources of error are true of any dietary methodology, however, they must be recognized, since results generated will preclude accurate inferences made about the food intake of an individual, or, population group.

Chapter VII

CONCLUSION

This study attempted to determine the validity of the photomethod technique of volume estimation by comparing with the gravimetric record, and, recall interview.

Paired comparisons of individual food items showed no significant differences between weight and volume estimates from physical measures, and the corresponding weight and volume estimates from the photomethod. It was concluded that the photomethod provides good estimates of food weights, when several food items are placed on a plate.

Differences were observed between weight and volume estimates from physical measures, and the corresponding weight and volume estimates from a 24-hour recall interview. The 24-hour recall interview does not appear to give food weights comparable to the weighed food items when an item by item comparison is undertaken. However, it must be noted that the recall method has been shown to give acceptable results when group mean values are compared with the weighed record (Madden et al, 1976).

A test for equality of variances showed no differences between nutrients estimated by the gravimetric estimates and those estimated by the photomethod. The photomethod appears to estimate nutrients with a precision similar to that found with the weighed estimates. No differences were found with mean daily intakes obtained by these two methods for a 21 day period.

Significant differences were found between energy estimates of individual food items from the weighed record, and recall interview. The recall interview appears to underestimate energy intake. Photomethod energy intakes were higher, on average, however, this difference was not significant.

Coefficient of variation values for nutrients showed that with the exception of protein, the photomethod appears to have a similar pattern around the mean value as compared to the weighed record for those nutrients. It is speculated that the photomethod estimates nutrient intake with a precision similar to the gravimetric record.

Further research is required to compare the precision with which the photomethod and 24-hour recall can estimate nutrients for the 'usual' intake of individuals. Such research will demand a need for larger nutrient databases with the appropriate density factors. Also, although nutrient information in databases is much improved, there is a lack of information on composite food items. Furthermore, such a study will determine whether or not the recording procedure for this photomethod presents significant respondent burden.

The photomethod appears to be a promising instrument for the assessment of food intake. It seems to be able to quantify food items even when several food items are on the plate, which causes portions of food to be obscured. Even though certain items, such as sauces, are difficult to quantify because of the nature of the item, it is possible to subjectively estimate a volume amount for such foods, and thus, nutrient information is not lost for such secondary foods.

REFERENCES

Acheson, K.J., Campbell, I.T., Edholm, O.G., Miller, D.S. and Stock, M.J. 1980. The measurement of food and energy intake in man - an evaluation of some techniques. *Am. J. Clin. Nut*, *33*, 1147-1154.

Adelson, S.F. 1960. Some problems in collecting dietary data from individuals. *J. Am. Dietet. Assoc*, *36*, 453-461.

Balogh, M., Kahn, A., and Medalie, J.H. 1971. Random repeat 24-hour dietary recalls. *Am. J. Clin. Nut*, *24*, 304-310.

Beal, V.A. 1967. The nutritional history in longitudinal research. *J. Am. Dietet. Assoc*, *51*, 426-432.

Beaton, G.H., Milner, J., Corey, P., McGuire, V., Cousins, M., Stewart, E., de Ramos, M., Hewitt, D., Grambsch, P.V., Kassim, N., and Little, J.A. 1979. Sources of variance in 24-hour dietary recall data: implications for nutrition study design and interpretation. *Am. J. Clin. Nut*, *32*, 2546-2559.

Beaton, G.H., Milner, J., McGuire, V., Feather, T.E., and Little, J.A. 1983. Source of variance in 24-hour dietary recall data: implications for nutrition study design and interpretation. Carbohydrate sources, vitamins, and minerals. *Am. J. Clin. Nut*, *37*, 986-995.

Beaudoin, R., and Mayer, J. 1953. Food intakes of obese and non-obese women. *J. Am. Dietet. Assoc*, *29*, 29-33.

Bird,G., and Elwood, P.C. 1983. The dietary intakes of subjects estimated from photographs compared with a weighed record. *Human Nutrition: Applied Nutrition*, *37A*, 470-473.

Block, G. 1982. A review of validations of dietary assessment methods. *Am. J. Epidemiology*, *115*, 492-505.

Burk, M.C. and Pao, E.M. 1976. Methodology for large-scale surveys of household and individual diets. *Home Economics Research Report No. 40*, Agriculture Research Service, United States Department of Agriculture (Washington, D.C.).

Burke B.S. and Stuart H.C. 1938. A method of diet analysis: Application in research and pediatric practice. *J. Pediatrics*, *12*, 493-503.

Campbell, V.A. and Dodds, M.L. 1967. Collecting dietary information from groups of older people. *J. Am. Dietet. Assoc*, *51*, 29-33.

Carter, R.L., Sharbaugh, C.O., and Stapell, C.A. 1981. Reliability and validity of the 24 hour recall. J. Am. Dietet. Assoc, 79, 542-547.

Department of Foods and Nutrition 1986. Nutrient analysis program. Department of Foods and Nutrition, University of Manitoba.

Freund, R.J., Littell, R.C., and Spector, P.C. 1986. SAS system for linear models. SAS Institute Incorporated (Cary, N.C.).

Gersovitz, M., Madden, J.P., and Smicklas-Wright, H. 1978. Validity of the 24 hour recall and seven day record for group comparisons. J. Am. Dietet. Assoc, 73, 48-55.

Gibson, R.S. 1987. Sources of error and variability in dietary assessment methods: A review. J. Can. Dietet. Assoc, 48, 150-155.

Health and Welfare Canada. 1984. Canadian nutrient file. Bureau of Nutritional Sciences, Department of National Health and Welfare (Ottawa).

Health and Welfare Canada. 1986. Canadian nutrient file. Bureau of Nutritional Sciences, Department of National Health and Welfare (Ottawa).

Karvetti, R., and Knuts, L. 1981. Agreement between dietary interviews. J. Am. Dietet. Assoc, 79, 654-660.

Kemper, G. 1982. Application of analytical geometry and computing used to determine spacing of electrical power transmission lines. Seminar presented to Department of Statistics, University of Manitoba: Cited in, Wadsworth, L. 1986. A photographic record method for estimation of individual food consumption: Developement and validation. Master's thesis, University of Manitoba, 1-117.

Madden, J.P., Goodman, S.J., and Guthrie, H. 1976. Validity of the 24 hour recall. J. Am. Dietet. Assoc, 68, 143-147.

Marr, J.W. 1971. Individual dietary surveys: purposes and methods. World Rev. Nut. and Dietet, 13, 105-164.

Neter, J., Wasserman, W., and Kutner, M. H. 1985. Applied linear statistical models. Regression, ANOVA, and experimental designs. Richard D. Irwin, Inc., Illinois.

Pekkarinen, M., Kivioja, S., and Jortikka, L. 1967. A comparison of the food intake of rural families estimated by one-day recall and precise weighing methods. Voeding, 28, 470-476.

Pekkarinen, M. 1970. Methodology in the collection of food consumption data. World Rev. Nut. and Dietet, 12, 145-171.

Pierson, W.R. 1963. A photogrammetric technique for the estimation of surface area and volume. Annals of the New York Academy of Sciences, 110, 109-112.

SAS Institute Inc. 1986. SAS User's Guide 1986 Edition. SAS Institute Incorporated (Cary, N.C.).

Rasanen, L. 1982. Validity and reliability of recall methods. Working paper prepared for workshop on the Methodology of evaluating nutritional status, 92-99. Department of Nutrition, University of Helsinki, Finland.

Sevenhuysen, G.P. 1985. Food image processing to measure individual food consumption. (original communication at the X111 International Congress of Nutrition, Brighton, U.K.).

Sevenhuysen, G.P., and Wadsworth, L. 1988. Food image processing: A potential method for epidemiological surveys.1-20. (paper accepted for publication by Nutrition Reports International).

Smith, C.A.B. 1969. Biomathematics. Volume 1. Algebra, Geometry, Calculus. Hafner publishing company (New York). Cited in, Wadsworth, L. 1986. A photographic record method for estimation of individual food consumption: Development and validation. Master's thesis, University of Manitoba, 1-117.

Sprauve, M.E., and Dodds, M.L. 1965. Dietary survey of adolescents in the Virgin Islands. J. Am. Dietet. Assoc, 47, 287-291.

Timesaver. 1986. Fast foods 1986: Nutrient analysis. Dietetic currents, 13. Ross laboratories, 625 Cleveland Ave, Columbus, Ohio 43216, Division of Abbott Laboratories, USA.

Todd, K.S., Hudes, M., and Calloway, D.H. 1983. Food intake measurement: problems and approaches. Am. J. Clin. Nut, 37, 139-146.

Wadsworth, L. 1986. A photographic record method for estimation of individual food consumption: Development and validation. Masters thesis, University of Manitoba, 1-117.

Worsley, A., Baghurst, K.I., and Leitch, D.R. 1884. Social desirability response bias and dietary inventory responses. Human Nutrition: Applied Nutrition, 38A, 29-35.

Appendix A

DENSITY FACTORS AND SOURCE

Food item	Source	Density factor
Cornflakes	CNF	0.09586
Milk (2%)	CNF	1.03550
Orange juice	CNF	1.05241
Yoghurt	CNF	1.03550
Soup	CNF	1.01437
Whiskey	CNF	0.95455
Mashed potato	CNF	0.88757
Peanuts	CNF	0.61285
Strawberry	CNF	0.62975
Peas	CNF	0.67625
Asparagus	CNF	0.76078
Broccoli	CNF	0.62975
Broccoli(frozen)	CNF	0.77770
Spinach(boiled)	CNF	0.80304
Corn(canned)	CNF	0.88757
B.Sprouts(boiled)	CNF	0.65511
Carrot(frozen	CNF	0.61708
Macaroni	CNF	0.54945
Tomato sauce	CNF	1.03550

Spaghetti	CNF	0.54950
Rice(white)	CNF	0.73964
Raisins(unpacked)	CNF	0.61285
Hashed brown	CNF	0.65930
Lettuce	CNF	0.23250
BBQ sauce	CNF	1.05660
Sour cream	CNF	1.01010
Ham	CNF	0.59172
Coleslaw	CNF	0.50720
Marmalade	CNF	1.35135
Apple butter	CNF	1.19189
Honey	CNF	1.43280
Blueberries	CNF	0.61285
Grapes	CNF	0.67625
Cheddar cheese	CNF	1.04961
Whipping cream	CNF	1.01014
Shrimp	CNF	0.54100
Roast lamb	CNF	0.59172
Red pepper	CNF	0.42265
Beans	CNF	0.57481
Cauliflower	CNF	0.52832
Potato(boiled)	CNF	0.65934
Icecream	CNF	0.55368
Cabbage(raw)	CNF	0.63398
Cucumber(raw)	CNF	0.44379
Celery(raw)	CNF	0.63398
Butter	CNF	0.95943
Tomato(raw)	Handbook 41	0.72400

Wine(white)	Handbook 41	0.89200
Pineapple slice	Handbook 41	0.79000
Banana	Handbook 41	0.58000
Rutabaga	Handbook 41	0.97200
Carrot(raw)	Handbook 41	0.48800
Hotdog bun	Handbook 456	0.13560

CNF: Canadian nutrient file (1986) Health and Welfare Canada, Ottawa.

Handbook 41: Average weight of a measured cup of various foods. U.S. Department of Agriculture Maryland, U.S.

Handbook 456: Nutritive value of some common foods, In common units. U.S. Department of Agriculture Washington, D.C. 1975.

Appendix B

VERBAL EXPLANATION AND CONSENT FORM

Verbal Explanation

Food Study

"The Department of Foods and Nutrition is studying methods to record food choice. We ask you to participate in two ways. Firstly, to allow us to record your choice of meals from a small number of ready to eat lunches. You can eat as much as much as you wish of the lunch that you choose. Secondly, to complete an interview the next day. Questions about the meal you choose and other foods you ate during the day will be asked. Both sessions should last about 30 min. each. All information will be kept strictly confidential and reports will not identify your answers in any way. You can withdraw at any time, without penalty. None of the study is associated with any course assignment. If you agree to participate and are available, please sign the consent form."

Consent Form

The study has been explained to me and I agree to participate. I understand that two periods of approximately 30 minutes each are involved. A first period to select a lunch of which I can eat any amount. A second period the following day to complete an interview on any food preferences and food consumption.

I understand this study is not associated with any coursework or student assignments and I can choose to withdraw at any time without penalty. All information I give will be kept strictly confidential and will not be identifiable in reports on this study.

SIGNED: ---------------------
DATE: ---------------------

Appendix C

DERIVATION OF FACTORS APPLIED TO LABORATORY MEASURED VOLUME

Hotdog Bun

Consider a cylinder contained within a symmetrical rectangular object, where the end faces of the cylinder coincide with the end planes of the rectangular object, and the curved face of the cylinder touches the sides of the rectangular object in four lines.

a) The volume of the rectangular object = l x b x h
where l= lenght, b=breadth, h=height of the object

b) The volume of the cylindrical object = $\pi r^2 \times h$
where r= radius, h= height of the object

Using unit values for all dimensions, it can be shown that:
Volume (b) is approx. 0.78 of (a)

Since the hotdog bun is not a true cylindrical object, an approx. value of 0.70 was chosen to estimate the flatter volume of a hotdog bun.

Baked Potato

Consider the two interfacing shapes described above. If the cylinder were replaced by a spherical object (c) and the rectangular object shortened(d) , the sphere would touch the rectangular object only in six points, instead of two planes and four lines. This will reduce the volume that the sphere occupies in the rectangular object from that occupied by the cylinder.

Using unit values for all dimensions, it can be shown that
Volume (c) is approx 0.7 x 0.7= 0.49 of (d)