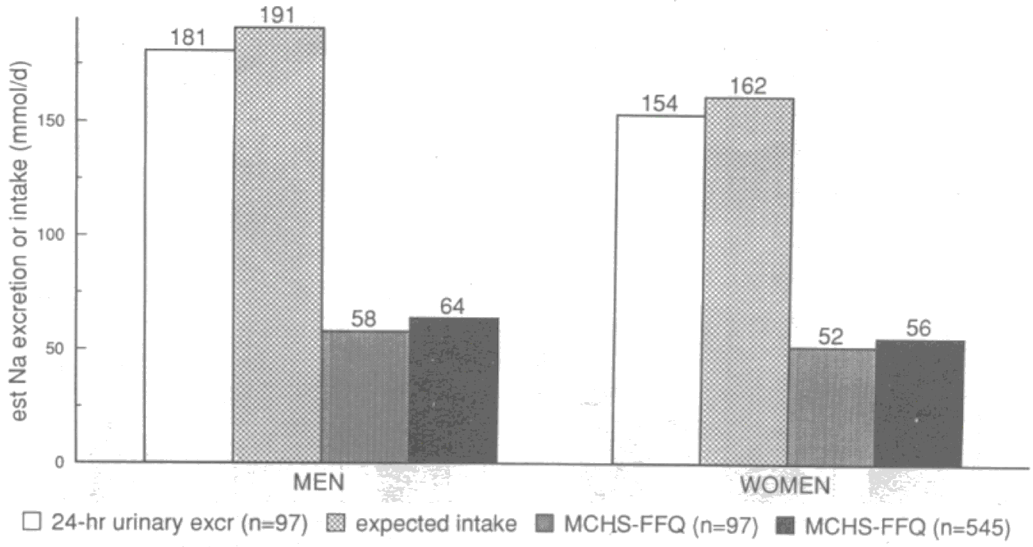

Fig. 5. Average single 24-h urinary sodium excretion, expected daily sodium intake estimated by 24-h urinary excretion, average daily sodium intake estimated by MCHS-FFQ for those who collected a 24-h urine sample (n = 97) and the total population (n = 545).

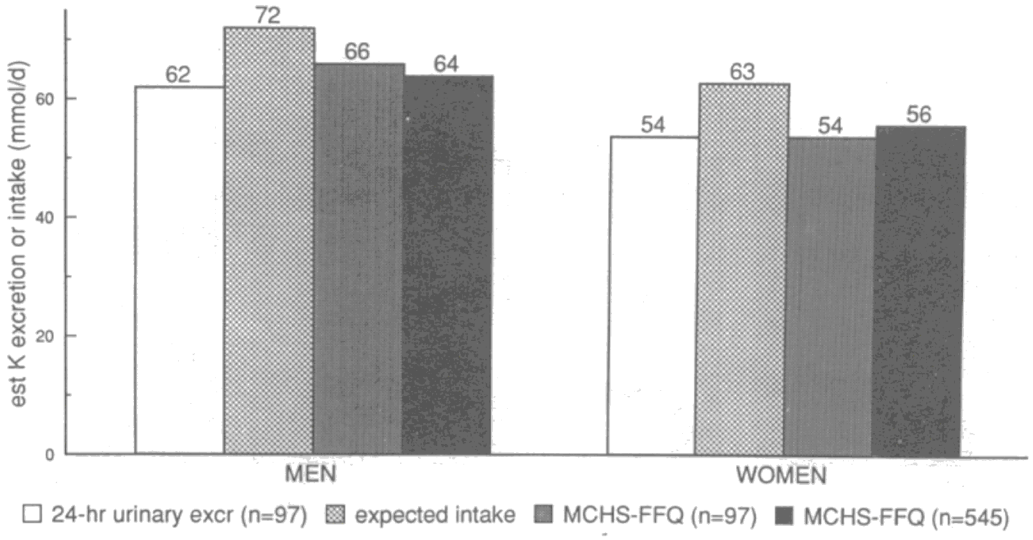

Fig. 6. Average single 24-h urinary potassium excretion, the expected potassium intake estimated by 24-h urinary excretion, the average daily potassium intake estimated by MCHS-FFQ for those who collected a 24-h urine sample (n = 97) and the total population (n = 545).

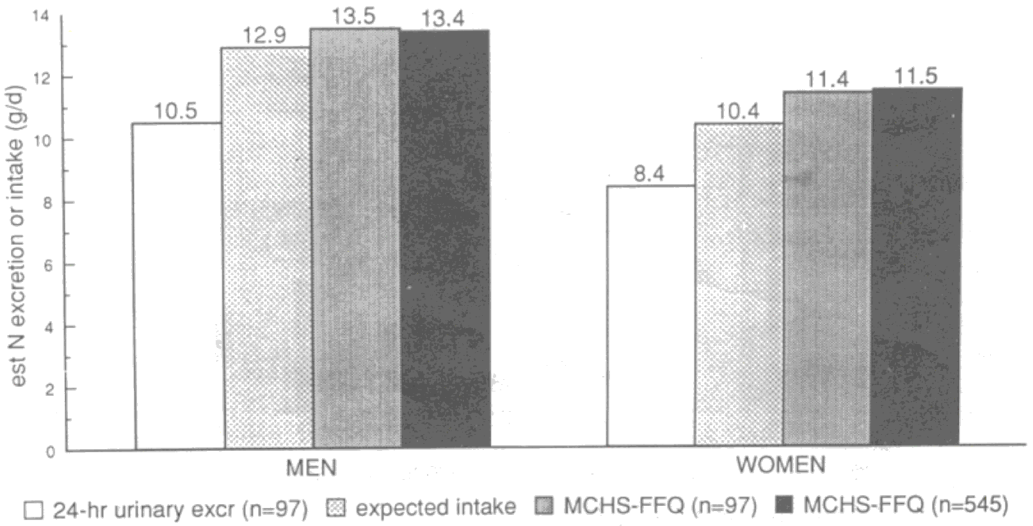

Fig. 7. Average single 24-h urinary nitrogen output, the expected daily nitrogen intake estimated by 24-h urinary excretion, the average daily nitrogen intake estimated by MCHS-FFQ for those who collected a 24-h urine sample (n = 97) and the total population (n = 545).

Urinary potassium excretion. Figure 6 shows mean urinary potassium excretion [62 (±24) mmol/d for men and 54 (±32) mmol/d for women], the expected potassium intake (72 (±28) mmol/d for men and 63 (±38) mmol/d for women] and the potassium intake estimate from MCHS-FFQ [66 (±23) mmol/d for men and 54 (±23) mmol/d for women]. No differences were found between the potassium intake calculated from the urinary excretion and that estimated from the MCHS-FFQ, for those who collected the urine sample and for the entire population.

Total nitrogen output and protein intake. The expected mean nitrogen intake level was 12.9 (±6.2) g/d for men and 10.4 (±4.6) g/d for women. Figure 7 shows that there was no difference between the expected nitrogen intake and the estimates derived from the MCHS-FFQ [13.5 (±4.1) g/d for men and 11.4 (±4.1) g/d for women].

There was no linear relationship between the log-transformed urinary total nitrogen output and log-transformed nitrogen intake estimated from the MCHS-FFQ for the entire study population. However, positive associations were found when separate analyses were performed in those who had a nitrogen intake derived from the MCHS-FFQ below or above the expected intake derived from the urinary excretion. The log-transformed urinary nitrogen output was positively and significantly related to the log-transformed nitrogen intake from MCHS-FFQ in three of the four separate analyses. No linear relationship was found in women whose MCHS-FFQ estimated nitrogen intake was greater than the expected intake (Figure 8).

Figure 9 shows that individuals who had an MCHS-FFQ nitrogen intake estimate above the expected value had a lower total energy and nitrogen intake estimate compared to their counterparts. These comparisons were statistically significant for women only.

Ability to predict plasma cholesterol levels. Table 3 shows Pearson's correlation coefficients for univariate relationships between plasma cholesterol levels and nutrient intakes derived from the MCHS-FFQ. Positive relationships were found between total fat intake or the percentage energy intake from total fat, as derived from the MCHS-FFQ, and plasma total or LDL cholesterol levels in men, but not women. Total energy intake, for women, and total carbohydrate or the percentage energy intake from total carbohydrate for men and women predicted plasma total and LDL cholesterol levels in a favourable fashion.

Table 3. Significant univariate associations between nutrient intakes and plasma cholesterol variables.

Nutrients	*r*	*P*-value
Total Cholesterol (mmol/l)		
MEN		
Fat (%kJ)	0.14	0.0178
Carbohydrate (%kJ)	−0.16	0.0087
WOMEN		
Total energy (kJ/d)	−0.14	0.0227
Total carbohydrate (g/d)	−0.16	0.0080
HDL-C (mmol/l)		
MEN		
Alcohol (g/d)	0.20	0.0010
Alcohol (%kJ)	0.23	0.0002
WOMEN		
Total energy (kJ/d)	0.13	0.0321
Total fat (g/d)	0.16	0.0067
SFAs (g/d)	0.18	0.0028
MUFAs (g/d)	0.14	0.0209
PUFAs (g/d)	0.14	0.0203
Dietary cholesterol (g/d)	0.13	0.0375
Sodium (mg/d)	0.14	0.0191
Calcium (mg/d)	0.16	0.0065
Phosphorus (mg/d)	0.13	0.0310
Iron (mg/d)	0.14	0.0191
Riboflavin (mg/d)	0.14	0.0195
SFAs (%kJ)	0.18	0.0033
Fat (%kJ)	0.15	0.0156
M/S ratio	−0.13	0.0321
LDL-C (mmol/l)		
MEN		
Total fat (g/d)	0.14	0.0209
SAFs (g/d)	0.16	0.0087
MUFAs (g/d)	0.13	0.0316
Fat (%kJ)	0.20	0.0010
Carbohydrate (%kJ)	−0.17	0.0057
WOMEN		
Total energy (kJ/d)	−0.15	0.0116
Total carbohydrate (g/d)	−0.18	0.0031
Calcium (mg/d)	−0.13	0.0277
Retinol (mg/d)	−0.13	0.0285
Retinol equivalents (mg/d)	−1.13	0.0298

%kJ, percentage energy intake of; SFAs, saturated fatty acids; MUFAs, mono-unsaturated fatty acids; PUFAs, poly-unsaturated fatty acids; M/S ratio, MUFA to SFA intake ratio.

Discussion

Characteristics of the MCHS-FFQ

In the course of developing a dietary method for use in a Melbourne Chinese population, we considered several dietary methods[4,17-21] and attempted to adopt and improve an existing method that would measure individual usual intakes in Chinese Australians living in Melbourne. Additionally, we were interested in a less expensive method which would take advantage of newer computer technology.

The CSIRO FREQPAN[6] had been used in a large dietary survey in the state of Victoria, Australia, from which our study population was drawn. The questionnaire had been tested and developed for computerized processes. It was suitable for estimation of the assessment of individual usual intakes. For these reasons, the food frequency questionnaire, rather than any other dietary intake method, was used.

We have also considered the need to develop a reference portion so that food intake can be quantified in a manner that was culturally relevant. The way in which a Chinese family conducts its meal setting was considered and the traditional Chinese rice bowl was used as a reference portion for most foods. Because different type of foods are usually served in accordance with meal setting we have used the 'usual time of the day eaten' for internal validity at the interview.

Approaches in validation

Various approaches have been used to evaluate the performance of food frequency questionnaires. One common approach is to compare nutrient intake estimates of individuals in the study, using correlation coefficients to evaluate the agreement, with those

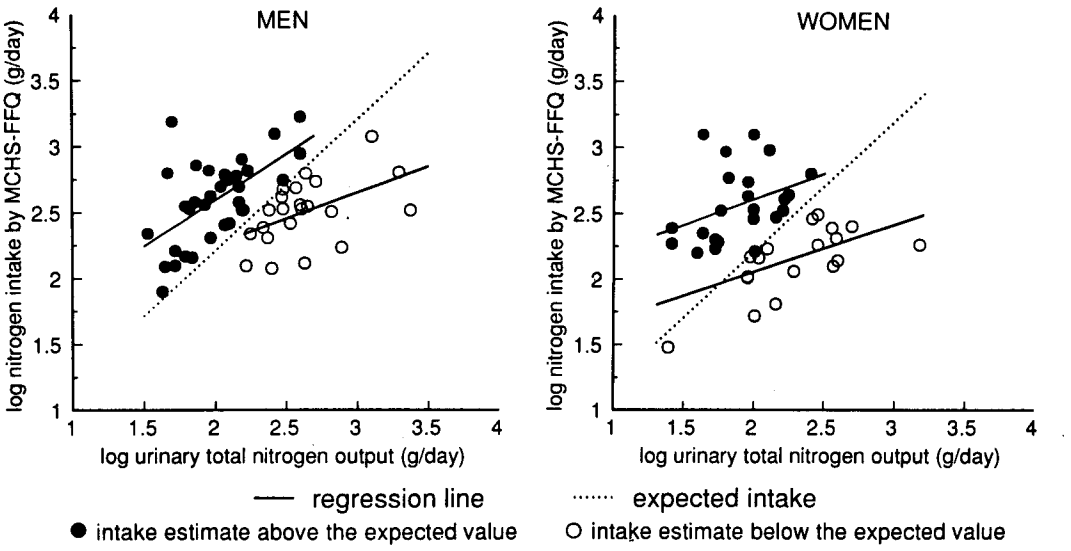

Fig. 8. Relationships between nitrogen intake estimates (log-transformed) and single 24-h urinary total nitrogen output (log-transformed) for individuals with an MCHS-FFQ estimate above or below the expected intake estimate being derived from urinary excretion.

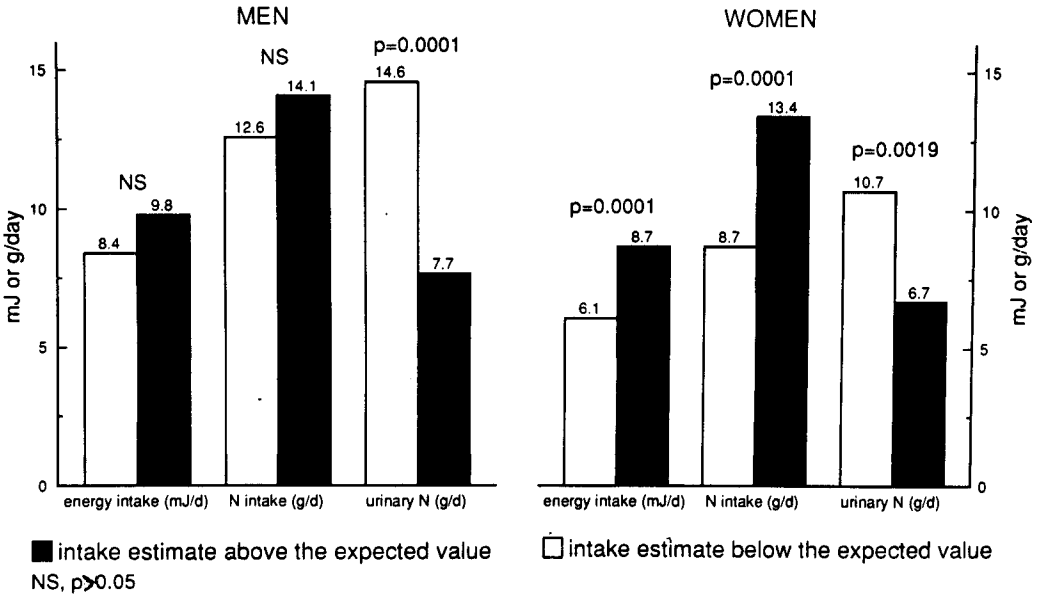

Fig. 9. Total energy and nitrogen intake estimates by MCHS-FFQ and 24-h urinary total nitrogen for individuals with an MCHS-FFQ estimate above or below the expected intake estimate being derived from urinary excretion.

derived from an independent standard[4,21–26]. Because there is no gold standard method for dietary assessment, and the nature and/or major sources of error produced by an alternative dietary method are often fairly similar to the one to be validated [2,4,27], the choice of an independent standard for the validation of a dietary assessment methodology may therefore introduce a validity problem in itself. Comparisons of group means of intake estimates are also questionable as a validity exercise. A serious concern is that such comparisons disregard possible differences in nutrient intake among individuals and the same amount of food, or the same nutrient intakes, across population groups[4].

The reproducibility of individual nutrient intakes has also been widely used to validate a dietary method[28]. This approach differs from previous approaches, in that research investigators use the same dietary method repeatedly over a range of time intervals and assess the agreement in individual nutrient intakes. There is, however, a fundamental problem in the interpretation of reproducibility and validity of a dietary method.[4] As individual dietary intake is highly variable, a low agreement in estimates between time intervals may simply reflect changing eating practices of individuals. This is particularly important in the study of migrant health, as in our study. Individual dietary change is often considered a major determinant of changing disease patterns. We used internal validation so that various nutrient 'intake indices' derived from the 220-item food frequency questionnaire could be assessed.

The need for a comprehensive food and beverage list

Foods and beverages frequently consumed by the population were mostly traditional Chinese foods or foods in abundant supply. On the other hand, traditional Chinese foods that are less accessible in general food supply, snacks and non-traditional Chinese foods were rarely consumed by the Melbourne Chinese (Table 2).

This implied that the food consumption pattern of Melbourne Chinese remains traditionally Chinese and limited to accessible foods. It is equally appropriate to consider food intake patterns associated with food acculturation with a shift toward the Australian way of eating and its related health outcomes. Thus the inclusion of foods and beverages rarely consumed by the study population should not be seen as being redundant in this particular study.

Macro-nutrient intakes

Where a complete food list is provided, one would expect to observe a positive relationship between 'intake index' and either total energy intake or the expected basal metabolic rate, and positive relationships between intake index and some macro-nutrients. We observed increases in major macro-nutrient intake as intake index increased, except for total carbohydrate intake in men (Figure 2). Additionally, increases in total energy intake with intake index were accounted for by intakes in excess of the expected BMR (Figure 3). In other words, individuals responding to a higher percentage of foods in the questionnaire had a higher energy intake which was independent of BMR. Our result also suggests that the total energy intake was adequately estimated using the MCHS-FFQ (Figure 4), so that the minimal energy requirement is met[29].

Sodium and potassium intake estimates

The food frequency questionnaire depends upon portion-size estimation of quantitative intake. As a result of this, foods which are not served in standard portion are likely to be under-estimated[8]. In this study, a 1 day sodium intake was estimated from a 24-h urinary sodium excretion. Urinary sodium excretion over 1 day may not be representative of a year-long Chinese diet probed by the food frequency questionnaire. Nevertheless, if the assumption is made that urinary sodium intake is correct, it is clear that the food frequency questionnaire would have under-estimated true sodium intake (Figure 5). The agreement between potassium intake estimated from a urinary excretion and the MCHS-FFQ (Figure 6) suggests that the MCHS-FFQ has the ability to estimate daily potassium intake similar to that of single 24-h urine sample. This implied that potassium balance may fluctuate less than sodium balance across a year and/or there is less problem with unmeasured potassium additions in a Chinese diet than sodium additions. Sources of added sodium intake in a Chinese diet are soysauce, salt, mono-sodium glutamate (MSG) and stock[8].

Urinary nitrogen output and protein intake

There was no difference in population mean nitrogen level estimated from the 24-h urinary nitrogen output and the MCHS-FFQ (Figure 7). Our results did not support an intra-individual relationship between estimates derived from the two independent methods for the entire population (Figure 8). This is probably due to daily variation in dietary intake and marked daily fluctuations in daily nitrogen balance. Bingham and Cummings[14] showed that single 24-h urine collection can be substantially in error. In healthy individuals with normal western diets, an 8-day 24-h urine nitrogen collection would verify its completeness and a dietary assessment from 18 days of records or 24-h recalls would minimize reporting errors from such methods.

When considered separately for those who had a nitrogen intake estimate by MCHS-FFQ higher or lower than the expected nitrogen intake, as derived from the single 24-h urinary nitrogen output, our data confirmed intra-individual relationships between urinary total nitrogen output and nitrogen intake estimated by MCHS-FFQ. In all cases, slopes were attenuated for both men and women and the linear relationships were less pronounced in women (Figure 8). This indicates that the lack of one-to-one relationships between the 24-h urinary nitrogen output and the MCHS-FFQ estimated nitrogen intake may depend upon the level of true protein intake. Individuals with a higher protein intake have been shown to have a lower urinary nitrogen output than expected[14,30]. This is confirmed in our study, particularly in women (Figure 9). The gender differences in the significance levels further suggest that a higher total energy intake in men, as estimated by MCHS-FFQ, have resulted in a lower urinary nitrogen output.

In summary, single 24-h urinary nitrogen output is not appropriate for the individual validation of protein intake because the steady state condition is rarely achieved in free-living individuals and large day-to-day fluctuations in protein intake exist. The single 24-h urinary nitrogen output, however, provides a good ball-park figure for the validation of population mean protein intake in the case where urinary nitrogen does not exceed the estimate of dietary intake over a short period of time[14]. The MCHS-FFQ thus gives a reasonable estimate of the population mean protein intake.

Predictive power of the MCHS-FFQ

One of the most important expectations for a dietary method is that it should predict outcome variables. A method cannot be claimed as valid or reliable if it fails to demonstrate the ability to predict what it is supposed to. The emphasis in tackling problems associated with various dietary methods has been on external validation against an independent method or on internal reliability tests over a time[2,3,31]. Neither approach has taken into account the possibility of errors associated either with the methods themselves or the use of alternative methods to validate them. The predictive power of a dietary method has rarely featured, however, in the considerations.

Nutrient estimates derived from the MCHS-FFQ are capable of predicting health outcomes (Table 3). Although Table 3 shows univariate associations, similar results were found in the multivariate models[8]. Positive relationships between fat intake and plasma cholesterol and coronary heart disease are well established. To mention a few, the same predicitve power of dietary fat intake, particularly saturated fatty acids and the percentage energy of fat intake, for 4-year coronary incidence has been reported in the young Framingham cohort[32] and in the 10-year coronary mortality in Japanese men living in Hawaii[33]. Less evidence is avilable in the cross-sectional studies. A cross-sectional relationship between fat intake, particularly saturated fatty acid intake, and plasma cholesterol has however been reported in a coloured population in South Africa[34]. As cross-sectional relationships are likely to be attenuated due to cohort effect, such relationships when

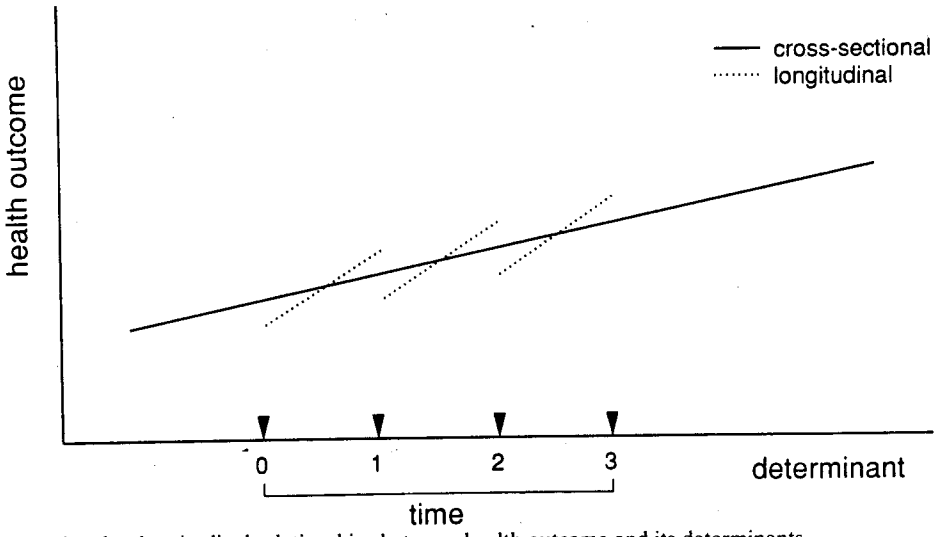

Fig. 10. Cross-sectional *vs* longitudinal relationships between health outcome and its determinants.

identified would be better appreciated in a longitudinal study (Figure 10). Thus, the validity of MCHS-FFQ is appropriate insofar as the predictive power of plasma cholesterol and other health outcomes is concerned.

In conclusion, the MCHS-FFQ is a simple and valid method in the assessment of usual food intake in a representative adult Chinese living in Melbourne. Australia. The method, when carefully applied, provides a reasonable estimate of all macro-nutrients and has the ability to predict the major health outcomes we explored. The method, however, is not appropriate for estimation of foods not served in a standard portion or as quantifiable additions. Where such foods or food sources of nutrient are of importance to the study outcomes, an alternative or supplementary method will be required to remove these sources of error.

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A food frequency questionnaire for us in Chinese populations and its validation

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摘要

爲中式膳食習慣所設計的問卷：

個人膳食之評估沒有一定基準。其選擇原則通常以研究方案之目標爲準。爲要瞭解在澳洲墨爾本華人的膳食習慣與心血管病之關係，我們採用現存之膳食習慣問卷加以改善。這個問卷屬"類似量"的分析方法，其設計強調過去膳食習慣．本問卷有 220 項食品和飲料，每一項目有一攝食量，作爲過去進食計量參考之用。本問卷採膳食習慣評估方法，因此無法有效地評估某些營養成分，尤其是添加物之類食品，如食鹽，醬油等所含之鈉質。和24小時尿液磷和氮質分析結果作比較，本問卷可準確地評估此兩項營養素。本問卷並可預測營養攝取值和血液膽固醇之關係。

因此，本問卷適合用於過去膳食計量之評估，尤其是住在澳洲墨爾本之華人。雖然，本問卷無法準確地評估營養素取自食品添加物，就華人膳食之瞭解而言，確有相當價值。