# The Linoleic Acid Content of Subcutaneous Adipose Tissue as a Valid Index of the Intake of Linoleic Acid by Individuals*

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We have developed a rapid method for sampling subcutaneous buttock adipose tissue, and describe its application and validation for the assessment of linoleic acid intake. In 324 free-living individuals a correlation of 0.52 was found between dietary intake according to the 2-day record method and adipose tissue linoleic acid (both expressed as g/100 g fatty acids). In view of the large random errors associated with short-term survey methods used to determine intake, the true correlation with long-term intake is probably higher. In another study the error in the assessment of the habitual diet of the subjects was reduced by increasing the number of measurements per individual. Fat biopsies were taken from 59 young Dutch women after a 2½-year period over which their food intake had been estimated 19 times by a 24-h recall method. Using the mean of the 19 food intake measurements, a correlation of 0.62 (n = 59) was computed between dietary and adipose tissue linoleic acid. For women with body weight changes of less than 3 kg/2½ year the correlation was 0.82 (n = 32). Thus, the linoleic acid content of fat tissue biopsies is a valid indicator of the long-term intake of linoleic acid of individuals, especially for subjects with a stable body weight. Applications of the fat biopsy method are discussed.

**Der Linolsäure-Gehalt des subkutanen Fettgewebes als ein sicheres Kriterium für die Aufnahme von Linolsäure bei einzelnen Menschen**

Wir haben eine Schnellmethode zur Probenahme von subkutanem Fettgewebe des Gesäßes entwickelt und beschreiben seine Anwendung und Gültigkeit für die Ermittlung der Linolsäureaufnahme. Bei 324 unter normalen Bedingungen lebenden Personen fand man eine Korrelation von 0.52 zwischen diätetischer Aufnahme, entsprechend der zweitätigen Aufzeichnungsmethode, und dem Linolsäuregehalt im subkutanen Fettgewebe (beides ausgedrückt als g/100 g Fettsäuren). Angesichts der großen Zufallsfehler, die Kurzzeitüberwachungsmethoden zur Bestimmung der Aufnahme begleiten, ist die wirkliche Korrelation bei Langzeitaufnahme vermutlich höher. In einer anderen Studie wurde der Fehler bei der Beurteilung normaler Ernährung der Personen reduziert, indem man die Zahl der Messungen pro Individuum erhöhte. Von 59 jungen holländischen Frauen wurden Fettbiopsien entnommen, nachdem während einer Zeitspanne von 2½ Jahren ihre Nahrungsaufnahme mittels der 24-Stunden-Rückschaumethode 19mal geschätzt wurde. Wenn man den Durchschnitt der Messungen der 19 Nahrungsaufnahmen verwendet, wurde eine Korrelation von 0.62 (n = 59) zwischen diätetischer Linolsäure und dem Linolsäuregehalt im Fettgewebe berechnet. Für Frauen mit einer Körpergewichtsveränderung von weniger als 3 kg in 2½ Jahren betrug die Korrelation 0.82 (n = 32). Insofern ist der Linolsäuregehalt der Fettgewebebiopsien ein sicheres Kriterium für die Langzeitaufnahme von Linolsäure bei einzelnen Menschen, besonders bei Personen mit einem stabilen Körpergewicht. Anwendungen der Fettbiopsiemethode werden diskutiert.

## Introduction

Dietary survey methods, if carefully performed, can provide data on the mean composition of the diet of groups of subjects, but it is widely acknowledged that they usually do not yield reliable information on individuals[1–4]. Therefore, there is great interest in biochemical indicators of nutrient intake. In this communication we propose that the linoleic acid content of a fat tissue biopsy is a reliable indicator of the relative percentage of linoleic acid in the diet.

More than two decades ago *Hirsch* and colleagues[5] suggested that the fatty acid composition of human adipose tissue might be related to the intake of the type of dietary fatty acids over a period of 2 to 3 years. Measurements of the incorporation of linoleic acid into adipose tissue suggest that the fractional turnover rate of adipose tissue fatty acids is 0.12 % per day, assuming that other fatty acids exhibit similar kinetic characteristics to linoleic acid[6]. The total fat in human adipose tissue would thus completely be replaced in at least 833 days. Indeed, *Turpeinen*[7] reported that a change in dietary fat type is optimally reflected in the fatty acid pattern of subcutaneous adipose tissue after a period of about 3 years. Among the adult population, age, sex and race appear to play only a minor role in determining the fatty acid composition of subcutaneous adipose tissue[5,8–10].

## Linoleic acid in diet and adipose tissue of groups of subjects

Using literature data we have calculated the relationship between the mean dietary and adipose tissue fatty acid composition of 14 different, independent groups of human subjects on experimental or constant diets[11]. Correlation coefficients were calculated of all combinations of dietary and adipose tissue relative percentages of polyunsaturated, monounsaturated, and saturated fatty acids, as well as their ratios. The highest correlation coefficients were obtained when polyunsaturated fatty acids were present in both the dietary and adipose tissue parameter. The correlation coefficient between dietary and adipose tissue polyunsaturated fatty acids, which essentially represent linoleic acid, was 0.80[11]. For the ratio of polyunsaturated to saturated fatty acids (P/S ratio) a correlation coefficient of 0.77 was found[11].

Thus, for group means the linoleic acid content of adipose tissue appears to reflect the average percentage of linoleic acid in the dietary fat over a preceding period of 2 to 3 years. It seems logical that this also holds for separate individuals within a group. However, this is difficult to demonstrate experimentally because within-person day-to-day fluctuations in food intake interfere with the assessment of the habitual diet of an individual. By using group means these fluctuations are averaged out.

## Linoleic acid in diet and adipose tissue of individuals

We approached the question whether the linoleic acid in the diet correlates with the linoleic acid in the adipose tissue at the level of the individual in a study group of 324 subjects with different dietary patterns: omnivores and lacto-ovo-vegetarians[12]. Subcutaneous adipose tissue samples were

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collected from the buttock and the fatty acid profile analysed according to the method described by *Beynen* and *Katan*[13]. Subjects were asked to record everything they consumed on two consecutive days. Food intake data were converted into nutrients using a computerized Dutch food table.

A correlation coefficient of 0.52 ($n = 324$, $P < 0.01$) was found between the linoleic acid content of the diet and that of adipose tissue[14,15]. The correlation between the P/S ratio's in diet and subcutaneous fat stores was 0.49[12]. This implies that about 25% of the variance of the adipose tissue linoleic acid content or its P/S ratio is accounted for by differences in dietary fat composition. A problem with the dietary record method is the large day-to-day variation in the amount and composition of food consumed by one person[1-4]. Thus the observed correlation coefficients are probably lower than the "true" correlation coefficients. The weakening effect of within-person variability in food intake on the correlation coefficient between diet and physiological variables can be calculated. For this calculation one needs to know the quotient of two variances related to dietary intake, namely the day-to-day variance within persons, and the variance between persons. For the dietary P/S ratio *Beaton* et al.[4] found relative standard deviations within and between persons of 52 and 26%, respectively, for 24-hour recalls in North American adults. With two-day records and a variance ratio of $(52/26)^2 = 4$, any correlation between the dietary P/S ratio and physiological parameters such as body fat composition would be degraded by a factor of $(1 + 4/2)^{0.5} = 1.73$[4]. This suggests that the true correlation between the long-term average dietary P/S ratio and the adipose tissue P/S ratio might be as high as 0.85 (1.73 x 0.49) instead of the value of 0.49 observed here. In that case 72% of the variance between individuals in fat tissue would be accounted for by variance in dietary fatty acid intake. The value of 0.85 agrees well with the correlation coefficient of 0.77 observed between the mean P/S ratios of the diet and of the adipose tissue of various groups of people[11] discussed above.

The degrading effect of day-to-day variation in food intake on the correlation can be reduced by increasing the number of intake measurements. This was done in our next study. Fat biopsies were taken from 59 young Dutch housewives after a 2½-year period in which their food intake had been estimated 19 times by a 24-hour recall method[16]. The interviews were conducted by trained dietitians during home visits. The food consumption data were then converted into nutrient intakes.

If only one recall was used per subject then the variation coefficient of the intake of polyunsaturated fatty acids between recalls of different subjects was 41%. When the mean of 19 recalls per person was used, the variation coefficient decreased to a value of 21%[16]. This indicates that the apparent variation in dietary fatty acid composition seen with single recalls is due to a large extent to within-person variation, and that increasing the number of food intake measurements per person reduces this error term. Table 1 shows that the correlation between dietary and adipose tissue P/S ratio improves with the number of food intake measurements per subject. For comparative purposes the result of our previous study[12] is also shown in this table.

Fig. 1 shows the relationship between dietary linoleic acid intake calculated as the mean of 19 recalls, and adipose tissue linoleic acid. A separate analysis was conducted for subjects with large fluctuations in body weight. Body weight changes affect the turnover rate of adipose tissue fatty acids[17], which in turn will disturb the relationship between dietary and adipose tissue fatty acids. Indeed, the correlation coefficient was higher for women with body weight changes of less than 3 kg/2½ year ($r = 0.82$, $n = 32$) than for those with more pronounced fluctuations in body weight ($r = 0.62$, $n = 27$)[16]. Thus the linoleic acid content of fat tissue biopsies is a valid indicator of the long-term intake of linoleic acid of individuals, especially for subjects with a stable body weight.

Table 1

*Correlation coefficients between dietary and adipose tissue P/S ratio in individual subjects*

| No. of days of food intake measurements | Study 1[12] (n = 321) | Study 2[16] (n = 59) |
|---|---|---|
| 1 | | 0.28 |
| 2 | 0.49 | |
| 19 | | 0.62 |

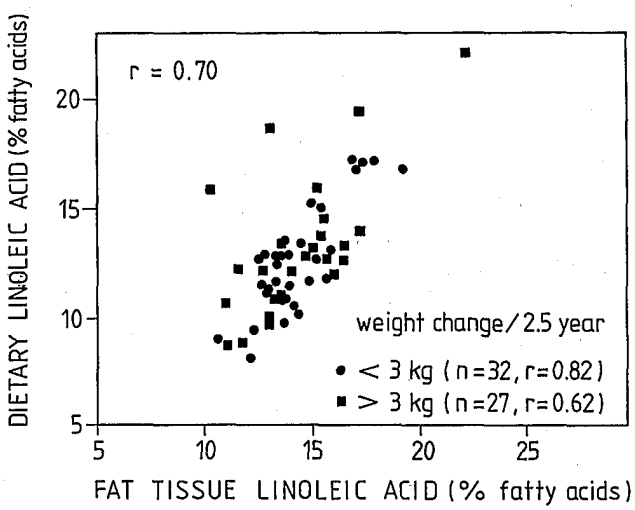


Fig. 1. Relationship between dietary linoleic acid (based on the mean of 19 24-h recalls over a 2½-year period) and adipose tissue linoleic acid (after *van Staveren* et al.[16])

If both dietary and adipose tissue linoleic acid are expressed in grams per 100 g of total fatty acids then the slope of the least squares line relating dietary intake to fat tissue level is remarkably consistent from one study to another. *Beynen* et al.[11] collated data from various populations and found that the population means fitted a line with a slope of 1.2. In two studies with free-living individuals a regression coefficient of 0.9 was found[12,16]. Thus roughly the same quantitative relation between dietary and adipose tissue linoleic acid has been found in a number of independent studies. This suggests that the intake of linoleic acid might be assessed, in absolute terms, on the basis of the relative percentage of linoleic acid in subcutaneous fat stores. However, further analysis of the available data is necessary to see whether a reliable formula can indeed be developed for calculating dietary intake from fat tissue analyses.

## Applications of the biopsy method

The effects of the consumption of various fatty acids, especially linoleic acid, on the development of certain diseases has evoked intense interest. As outlined above, this type of research has been greatly hampered by methodological problems in assessing fatty acid intake. Our data suggest that the fatty acid composition of adipose tissue faithfully reflects the fatty acid composition of an individual's usual diet. Subjects found such a fat biopsy to cause hardly more discomfort

or anxiety than a routine venipuncture [13]. The stability of the fatty acid composition of biopsies has been tested with excellent results and samples can be stored for at least 18 months without deterioration [13]. This indicates that samples can be collected in the field without special precautions as to storage conditions.

The fatty acid profile of adipose tissue has already been used in various types of research as an indicator of the qualitative fat intake. *Dayton* et al. [17] used the linoleic acid content of adipose tissue as a criterion of adherence to an experimental diet. We have recently used adipose tissue linoleic acid in order to compare linoleic acid intake in the USA and UK [18]. Furthermore, there is evidence that a low percentage of linoleic acid in subcutaneous adipose tissue correlates with a high risk for coronary heart disease [19,20] and a low risk for malignant melanoma [21]. Thus, it appears that the fatty acid composition of subcutaneous adipose tissue could be an important tool in various types of nutrition research.

## Literature


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