Understanding meal patterns: definitions, methodology and impact on nutrient intake and diet quality

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Abstract
Traditionally, nutrition research has focused on individual nutrients, and more recently dietary patterns. However, there has been relatively little focus on dietary intake at the level of a ‘meal’. The purpose of the present paper was to review the literature on adults’ meal patterns, including how meal patterns have previously been defined and their associations with nutrient intakes and diet quality. For this narrative literature review, a comprehensive search of electronic databases was undertaken to identify studies in adults aged $\geq 19$ years that have investigated meal patterns and their association with nutrient intakes and/or diet quality. To date, different approaches have been used to define meals with little investigation of how these definitions influence the characterisation of meal patterns. This review identified thirty-four and fourteen studies that have examined associations between adults’ meals patterns, nutrient intakes and diet quality, respectively. Most studies defined meals using a participant-identified approach, but varied in the additional criteria used to determine individual meals, snacks and/or eating occasions. Studies also varied in the types of meal patterns, nutrients and diet quality indicators examined. The most consistent finding was an inverse association between skipping breakfast and diet quality. No consistent association was found for other meal patterns, and little research has examined how meal timing is associated with diet quality. In conclusion, an understanding of the influence of different meal definitions on the characterisation of meal patterns will facilitate the interpretation of the existing literature, and may provide guidance on the most appropriate definitions to use.

Key words: Meal patterns; Diet quality; Nutrient intake; Diet quality indicators

Introduction
It is widely recognised that a nutritionally sound diet is fundamental to human health and wellbeing across the lifespan\(^1\). A poor diet contributes to poor health and is a well-established, modifiable risk factor for the development of non-communicable diseases, which are leading causes of death globally\(^2\). Traditionally, research has focused on the relationship between individual nutrients and health outcomes, yet this approach has often resulted in conflicting findings\(^2\). Hence there has been a gradual shift in the past decade towards less reductionist approaches to examining diet–disease relationships (for example, dietary patterns analysis) that better capture the interaction of nutrients and bioactive compounds within the whole diet\(^2,5\). However, people consume combinations of foods as meals and snacks rather than as individual foods and nutrients. Understanding the nutritional composition of meals and the ways in which different meal patterns make an impact on diet quality might help to elucidate important diet–disease relationships. Moreover, a meals-based approach could complement current dietary advice, which currently uses a food-based framework (for example, the Australian Dietary Guidelines\(^4\)) to assist populations in achieving the recommended daily intakes of foods and nutrients. That is, dietary advice in the context of meals could help populations with their daily meal preparation and therefore be a more practical and salient way to assist populations to follow dietary guidelines.

Most of the research in this area, however, has focused on how different meal patterns (also referred to as eating patterns) make an impact on energy balance and weight status\(^5,6\). An oft-cited drawback to interpreting the evidence from these studies has been the different approaches employed to operationally define meals and/or snacks\(^5,7\). However, previous reviews of the impact of different definitions on the interpretation of meal pattern studies have examined snacking only\(^7,8\). Moreover, to date there has been no comprehensive review of studies investigating associations between meal patterns and diet...
quality; previous reviews have focused on dietary contributions in relation to eating frequency or snacking\(^{(8,9)}\).

Therefore, the primary purpose of the present paper is to provide an overview and critique of meal pattern research, including previous approaches to the characterisation, definition and measurement of ‘meals’. Second, the potential implication of these approaches will be further examined in a critical review of the literature of the contributions of meal patterns to energy and nutrient intakes and overall diet quality among adults.

**Characterisation of meals**

The term ‘meal patterns’ is an overarching construct that is often used to describe individuals’ eating patterns at the level of a ‘meal’, such as a main meal (for example, breakfast, lunch or dinner) or a smaller-sized meal (for example, supper or snack). The neutral terms ‘eating occasion’ (EO) or ‘eating event’ are also used to describe any occasion where food or drink is ingested, and therefore incorporates all meal types. Meals have been described according to three constructs: (1) patterning (for example, frequency, spacing, regularity, skipping, timing); (2) format (for example, types of food combinations, sequencing of foods, nutrient profile/content); and (3) context (for example, eating with others or with the family, eating in front of the television or out of the home) (Table 1)\(^{(10–15)}\).

Table 1 provides an overview of these constructs, including a description of the different meal patterns variables that have been examined previously along with their corresponding operational definitions. Examples of how meals have been measured in past studies are also presented in Table 1.

**Table 1.** Overview of the three meal pattern constructs, and examples of variables currently assessed in the literature and the assessment methods that have been used to collect the meal pattern data

| Construct      | Variable                                      | Operational definition(s)                                                                 | Example(s) of methods                                      |
|----------------|-----------------------------------------------|-------------------------------------------------------------------------------------------|-----------------------------------------------------------|
| Patterning     | Frequency of EO (meals and snacks)            | Mean number of EO/meals/snacks per d\(^{(14)}\)                                            | Dietary recall (24 h)\(^{(14)}\) Meal patterns questionnaire\(^{(16)}\) Single questionnaire items\(^{(17)}\) |
|                | Spacing of EO                                 | Mean time between EO \(^{(14)}\)                                                          | Dietary recall (24 h)\(^{(14)}\)                           |
|                | Regularity of meals                           | Consistency of EO frequency and spacing\(^{(18)}\) Usually eats breakfast, lunch and dinner each day\(^{(19–21)}\) | Semi-quantitative food records\(^{(18)}\) Single questionnaire items\(^{(19,20)}\) Food records (3 d)\(^{(21)}\) |
|                | Meal skipping                                 | Usually omits breakfast, lunch or dinner\(^{(17,22)}\)                                   | Single questionnaire items\(^{(17)}\) Meal patterns questionnaire\(^{(22)}\) Dietary recall (24 h)\(^{(23)}\) |
|                | Meal timing                                   | The timing of breakfast, lunch or dinner (early/late)\(^{(24)}\) Time-of-day wherein majority of daily EI is consumed (morning, midday, evening/late)\(^{(25–27)}\) Late-night eating (eating after going to bed)\(^{(28)}\) | Food records (7 d)\(^{(24)}\) Prescribed diet (intervention studies)\(^{(28)}\) Dietary recall (24 h)\(^{(27)}\) Single questionnaire items\(^{(28)}\) |
| Format         | Meal food type/combinations                   | Classifications of combinations of foods in meals\(^{(29)}\)                             | Food records (7 d)\(^{(29)}\)                              |
|                | Meal food sequencing                          | Temporal distribution of consumption of food groups and intake of energy and nutrients within a meal\(^{(30)}\) | Food records (2 d)\(^{(30)}\)                            |
|                | Nutrient composition                          | Energy, protein, fat and carbohydrate composition of a meal\(^{(25,26,31)}\)             | Prescribed diet (intervention studies)\(^{(26)}\)         |
| Context        | Presence of others at a meal (for example, friends/family) | Types of food eaten in different social contexts (for example, alone v. with others)\(^{(32)}\) Macronutrient composition of meals eaten alone v. with others\(^{(33)}\) | Personal digital assistants\(^{(32)}\) Weekly food diary\(^{(33)}\) |
|                | Eating while doing activities (for example, watching TV) | Types of food consumed while watching TV v. other activities\(^{(32,34)}\) | Personal digital assistants\(^{(32)}\) Food records and ecological momentary assessment\(^{(34)}\) |
|                | Meal location (for example, eating at home v. eating out) | Energy and macronutrient content of meals consumed at home v. out of the home\(^{(30)}\) Types of food consumed by location\(^{(32)}\) | Food records (2 d)\(^{(30)}\) Personal digital assistants\(^{(32)}\) |

EO, eating occasions; EI, energy intake; TV, television.
| Approach                        | Description                                                                                                                                  | Examples in the literature                                                                 | Advantages                                                                 | Disadvantages                                                                 |
|--------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------|----------------------------------------------------------------------------|------------------------------------------------------------------------------|
| **Time-of-day**                | According to time intervals during which EO occur (for example, morning, mid-morning, midday, mid-afternoon, evening and late evening) | Participants record all foods and drinks consumed according to six time slots/feeding periods\(^{35,36}\) | Easy to apply and understand. Emphasis on ‘when’ foods are eaten            | Bias towards traditional eating patterns. Does not cater for individuals with varied meal times (for example, shift workers) |
| **Participant-identified**     | Participants report their own EO, usually from a list of pre-specified meal labels                                                                 | Participants identify EO as a main meal, light meal, snack or drink only\(^{16}\)          | Avoids use of a complex ‘a priori’ definition of different EO                | Definition not standardised. Meal labels may be influenced by the researcher’s existing understanding of eating patterns and introduce researcher bias |
| **Food-based classification**  | Foods are firstly categorised into food categories based on their nutritional profile. Food category combinations determine the type of EO | Six EO types ranging from a complete meal (high nutrient density; contains both animal and plant foods) to a low-quality snack (low nutrient density)\(^{39}\). Meals and snacks defined by ‘core’ and ‘non-core’ foods, respectively\(^{39}\). | Provides information on the nutritional quality as well as the patterning of eating events | Complex categorisation system. Differences in classification criteria of meals and snacks may limit comparison across studies |
| **Neutral**                    | A neutral term (for example, ‘eating event’) is used to collect meal pattern data. Aspects of meal patterns are then analysed using standardised criteria | An EO is any occasion when food (excluding drinks only)\(^{11}\) or food/drink is consumed\(^{34}\). An EO is considered separate if it occurs > 15 min apart\(^{40,41}\). An EO is an event that provides a minimum of 50 kcal (210 kJ) and is separated by 15 min\(^{42}\). | Standardised and consistent. Findings may be more comparable over time and across studies | Loss of qualitative information about individuals’ perceptions of what constitutes a meal/snack. Differences in ‘standardised criteria’ may limit comparison across studies |

This led the authors to use the neutral term ‘eating event’ for an occasion where food was consumed, different dimensions of meal labelling became clear, and participants were asked to identify each event as a meal, snack, or neither. This approach allows for an understanding of individual preferences and cultural factors influencing meal patterns.

In 1999, Mäkelä et al.\(^ {26}\) recognised that conventional meal labels are culturally laden and therefore may mean different things for people from different cultural backgrounds. For example, in some cultures, breakfast may be considered a snack, while in others, it may be a main meal. This led the authors to use the neutral term ‘eating event’ for an occasion where food was consumed, different dimensions of meal labelling became clear, and participants were asked to identify each event as a meal, snack, or neither. This approach allows for an understanding of individual preferences and cultural factors influencing meal patterns.

This approach is easy to understand and apply, avoids the imposition of a complex criterion to classify EO as meals or snacks, and is not standardised due to subjectivity in the respondents’ allocation of an eating event as a meal or snack, often from a list of pre-specified meal labels. This definition relies on the respondent to identify an EO as a meal or snack, often from a list of pre-specified meal labels. This can lead to bias on the part of the researcher due to differing conceptualisations of ‘meal’ and ‘snack’. However, not all studies ask respondents to identify the EO as a meal or snack. Therefore, it is important to consider the context in which the definition is used and the potential for bias.
patterns using standardised criteria (for example, time-of-day, number of hot/cold eating events) were used to describe the data. The advantage of a neutral definition is that it can be standardised and can allow for comparison across different population groups and cultures. However, despite this neutral definition, additional criteria have been applied in the literature with regards to the time intervals between EO, a minimum-energy criterion to define each individual EO and whether beverage-only EO are included or excluded. It is important to note that these additional criteria have also been applied to the time-of-day and participant-identified definitions in order to define an 'individual' or 'separate' meal and/or snack\(^{(15,50,51)}\), thus adding another layer of diversity to these meal definitions.

When the time of eating is recorded, researchers must decide how to delineate separate EO\(^{(35,52)}\). Indeed, the period of time used to separate different EO varies across studies, with intervals of 15 min\(^{(40,42,50)}\), 30 min\(^{(53)}\) or 45 min\(^{(15)}\) or 1 h\(^{(51)}\) reported. Some studies also include a minimum energy criterion as part of the meal definition. For example, in some studies, EO were only treated as an EO if they contributed a minimum amount of energy (for example, 210 kJ)\(^{(15,42,54)}\). These variations in criteria are likely to make an impact on the frequency, spacing and nutritional contribution of the EO reported and on associations with health outcomes. In support of this, Murakami & Livingstone\(^{(55)}\) found the number of reported EO per d was reduced by two or more EO for both men and women after applying a minimum-energy criterion of 210 kJ. In the same study, the different definitions of an EO greatly affected the results of the association between eating frequency and BMI and waist circumference.

The methodological differences in spacing between EO and energy content may also indirectly influence the inclusion\(^{(50)}\) or exclusion\(^{(56)}\) of beverage-only occasions as part of the meal definition. A larger time interval criterion applied to 24 h recall data to separate individual EO may not be able to capture smaller EO (including beverage-only occasions). The findings from one study suggest that smaller intervals may also be useful to detect important changes in energy intake (EI) from beverage-only occasions over time\(^{(14)}\).

### Measurement of meals

There have been a number of different approaches to the measurement of meals. Much data on meal patterns have been derived from dietary assessment methods such as 24 h recalls and food records. These methods provide detailed information on the types and quantities of food/beverages consumed and, usually, time of consumption\(^{(14,15,36,50,57)}\).

During a 24 h recall, participants may be asked to report the type of EO as a main meal or a snack\(^{(14,50,57)}\), whereas food records are often segregated by the researcher into meal time slots (for example, pre-breakfast, breakfast, mid-morning, etc.)\(^{(35,30)}\). Contextual information is not always collected as part of the recall or food record and thus only examination of meal patterning may be possible. While meal format could be examined with this type of data, little research in this area has been conducted. One possible reason for this is that there has been little exploration of statistical techniques that are able to examine complex combinations and sequencing of foods at a meal. Hearty & Gibney\(^{(29)}\) explored the potential use of supervised data-mining techniques in meal pattern analysis, specifically to predict diet quality based on different combinations of foods at a meal. However, to our knowledge, this is the only study that has applied these analytic tools in meal pattern analysis.

Many food diaries collect data on time of eating, and/or self-identified meals, and similar to 24 h recalls, some collect contextual information (for example, location of eating, presence of others). The weekly food diary method developed by de Castro\(^{(58)}\), in addition to the time and amount of food eaten over a 7 d period, asks participants to record detailed contextual information (for example, mood and hunger levels before eating, the number and nature of other people eating with them). While this method elicits rich contextual information, participant burden is high, thus reducing its practicality in larger-scale studies. In a recent study, participants used personal digital assistant devices to record real-time information on dietary intake, EO type, location and context\(^{(52)}\).

As a result, the researchers were able to assess contextual influences on the types of foods that participants consumed at an EO. However, while this type of assessment method lends itself to the examination of meal patterning, format and context, these ‘real-time’ assessment devices have not yet been extensively developed\(^{(59)}\).

FFQ are also commonly used to collect dietary data, particularly in large-scale studies\(^{(60)}\). While FFQ provide estimates of the frequency and types of foods that are usually consumed, they do not provide data that directly allow examination of EO, and additional questionnaires\(^{(46,56)}\) or short questionnaire items\(^{(17)}\) have been used to collect information on meal patterns. Example of questionnaire items include: ‘Indicate the times of day you usually eat\(^{(17)}\)’, ‘Do you eat regular breakfast, lunch and dinner or evening meal each day?’\(^{(19)}\) or ‘Do you usually have the following meals (breakfast, lunch, snack, dinner, evening snack)?’\(^{(20)}\). Some questionnaires may only ask about ‘eating’ frequency, and thus may not capture beverage-only EO. The reliability and validity of meal pattern questionnaires are often not reported\(^{(16)}\).

### Associations between meal patterns, nutrient intakes and overall diet quality

Due to the current limited methods available to collect meal pattern data, most research to date has examined meal patterning\(^{(5,61)}\), with relatively little focus on meal...
form(29) and context(32). As stated previously, studies on meal patterning have examined meal frequency, spacing, skipping and timing. However, these studies have differed in their approach to defining meals, and even within a given approach, there have been differences in the delineation of individual EO, meals and/or snacks. The ways these different methodological differences affect the characterisation of meal patterns have been little explored(55) and, to the best of our knowledge, how these differences affect the associations between meal patterns and nutrient intakes or diet quality has not previously been examined. Understanding the relationships between adults’ meal patterns and nutrient intakes and diet quality is necessary to determine if they are markers of the healthiness and variety of the whole diet(62). Therefore, the associations between ‘meal patterning’, nutrient intake and overall diet quality among adults were examined considering the impact of different meal definitions used for the characterisation of meal patterns.

A literature search was undertaken in the PubMed and EMBASE electronic databases using the following terms: meal, snack, breakfast, lunch, dinner, eating frequency, eating pattern, eating behavior, eating behaviour, eating occasion, eating episode, diet quality, dietary quality, dietary pattern, dietary behavior, dietary behaviour, nutritional quality, dietary intake, food intake, energy intake, nutrient, macronutrient, dietary composition and nutritional composition. The search terms were limited to the title/abstract and the following filters were applied: journal article, human, adult and English. Two searches were conducted: the first between February and May 2013 and the second between February and April 2014. The criteria for inclusion in the review were: original research studies that examined the nutritional contributions of meal patterns or associations between meal patterns and nutrient intakes and/or overall diet quality in free-living, healthy men and women aged 19 years and over. Diet quality was defined as the quality of a individual’s overall food intake determined by compliance with national dietary guidelines or an a priori diet quality score(65). Studies that examined populations with conditions or circumstances that may affect meal patterns (for example, elite athletes, shift-workers, individuals with chronic diseases, recipients of meal programmes and pregnant or breast-feeding women), or examined associations with EI only, were excluded.

Characteristics of studies which examined associations between meal patterns and nutrient intakes

A total of thirty-four studies (Table 3) were identified which examined the nutritional contribution of different meal patterns, in adults. However, only thirteen of these examined more than one micronutrient(23,30,46,47,52,64–71). All except two studies(35,72) were cross-sectional. Of the studies, fifteen and five studies were conducted in the USA(41,46,48,52,57,68,70,72–79) and Scandinavia(45,47,53,65,80) respectively, with fewer studies conducted in Western Europe(15,30,67,81), the UK(35,40,82), East Asia(64,71,83), Australia(36,69), Canada(66) and Brazil(84). Meal patterns were mostly participant-identified(15,23,45–48,52,53,57,66,69,70,75,77,79,82), although these studies varied in the additional criteria used to determine an individual EO, meal and/or snack, and their treatment of beverages. For example, eleven studies(23,45–47,52,66,69,75,78,80,82) applied no additional criteria, whereas in other studies, EO were delineated using 15-min time intervals(57,70,77), a 30-min interval(53), a 45-min interval plus a 50 kcal (210 kJ) energy criterion(15) and a 59-min interval (applied to meals only)(48). All beverage types (energy and non-energy) could constitute an individual EO in nine studies(35,45–47,53,66,70,75,77), whereas other studies excluded water beverages(23,52), non-nutritive beverages (for example, water, tea, black coffee)(80) or did not address/include beverages as part of the definition(48,57,71,78,82). Time-of-day definitions were also common(35,36,46,67,72,76) as well as a combination of two definitions (for example, self-identified and time-of-day, or time-of-day and type/combination of foods eaten)(50,65,68,75,81).

The most common methods used to assess both dietary intake and meal patterns were 24 h recalls(23,45–48,52,57,66,68–70,73,76,77,83) or food records (2–7 d)(15,30,35,36,40,41,57,64,65,79,81). Only four studies excluded energy misreporters(48,80) or energy under-reporters(40,41). There was significant variation in the aspects of meal patterning examined and these aspects could be broadly categorised as: meals v. snacks, eating frequency, meal skipping/regularity and meal timing. These categories are used below to direct discussion on the studies’ findings in relation to associations with nutrient intakes. The potential impact of different definitions on the characterisation of meal patterns and their associations with nutrient intakes is also discussed.

Meals v. snacks in relation to nutrient intakes

A total of ten studies(15,30,35,36,65,73,75,79,81,84) were identified that examined the contributions of meals and/or snacks to energy and nutrient intakes. In a prospective study of 1253 adults from the UK, Almoosawi et al. (35) examined 17-year changes in the contributions of breakfast, lunch and dinner to macronutrient intake. The authors found that the lunch and evening meal contributed the greatest proportion of total daily energy, protein, fat and carbohydrate intake, which was consistent over time. This is supported by other research highlighting that main meals are when the largest volume of food is normally consumed(15,83). When the nutritional contribution of meals and snacks are analysed relative to their contribution to EI, a finding across five studies was that snacks provided a lower proportion of total energy from fat and/or protein than did meals(15,36,48,65,75). This finding was consistent despite the
### Table 3. Summary of studies that have examined the contribution of meal patterns to macronutrient and/or other nutrient intakes

| First author (year) | Country and study design | Sample | Aspect(s) of meal patterns examined | Diet and meal pattern measure | Meal or snack definition | Macronutrients | Other dietary components | Covariates | Selected key findings |
|---------------------|--------------------------|--------|------------------------------------|-------------------------------|--------------------------|-----------------|---------------------------|------------|-------------------------|
| Almoosawi (2012)    | UK Prospective (17 years) | 562 men and 691 women, 36 years at baseline in 1982 | Distribution of nutrient intake from EO across the day | 5 d FR | Time-of-day* | Protein, fat, CHO | EI, NSP, alcohol | Stratified by sex | The lunch and evening meal contributed the greatest proportion of daily EI and nutrient intake compared with other EO. Between 1982 and 1999 there was a shift towards greater EI, macronutrient intake in the mid-afternoon and evening. |
| Barr (2012)         | Canada C/S               | 8973 men and 10 940 women, ≥ 19 years | Breakfast skipping | 24HR | Participant-identified* | Protein, fat, CHO, sugars, SFA, MUFA, PUFA | EI, fibre, cholestrol, vitamins A, B6, B12, C and D, thiamin, riboflavin, niacin, folate, Zn, Ca, Fe, Mg, P, Na and K | EI, age, sex, race, education, PA, food security, language spoken at home, smoking and supplement use | Breakfast skippers had significantly lower intakes for energy, niacin, folate and vitamin C, fibre, thiamin, riboflavin, Fe, Mg, P and K than breakfast consumers. Breakfast skippers had a significantly higher prevalence of inadequate total intakes of vitamin D, Ca, vitamin A and Mg than breakfast consumers. |
| Basdevant (1993)    | France                   | 273 obese women, ≥ 18 years (mean age 41 (± 12) years) | Snacking (≥ 15 % EI from snacks) v. non-snacking | Diet history interview | Time-of-day | Protein, fat, CHO | EI | – |
| Bellisle (2003)     | France C/S               | 15 men and 39 women, 26–58 years | Meals and snack frequency. Distribution of nutrient intake from meals and snacks across the day | 4 × 7 d FR across four seasons | Participant-identified* | Protein, fat, CHO | EI, alcohol | – |
| Berner (2013)       | USA C/S                  | 893 men and 875 women, ≥ 51 years | Distribution of protein intake from meals and snacks across the day | 2 × 24HR | Self-identified and time-of-day* | Protein, animal protein | Stratified by age group and sex | Percentage of protein intake was highest at dinner (about 44–48 %) and lowest at snacks (about 10–12 %). Percentage of protein from animal sources was also highest at dinner (about 65–68 %) and lowest at snacks (about 29–32 %). |
| Berfè univers Forslund (2005) | Sweden C/S | Obese group: 1891 men and 2368 women, 30–60 years; reference group: 505 men and 587 women, 37–60 years | Meal, snack and total EO frequency* | FFQ and meal pattern Q | Participant-identified* | Protein, fat, CHO | EI, fibre, alcohol | Age, PA and stratified by sex | EI increased with increasing number of meals in obese men and women only and snacking frequency was associated with higher EI in obese and reference men and women. The proportion of EI from protein decreased while the proportion from fat increased by increasing snacking category among obese men and women. |
| First author (year) | Country and study design | Sample | Aspect(s) of meal patterns examined | Diet and meal pattern measure | Meal or snack definition | Macronutrients | Other dietary components | Covariates | Selected key findings |
|---------------------|--------------------------|--------|-----------------------------------|------------------------------|--------------------------|----------------|--------------------------|------------|-----------------------|
| Coates (2002)⁷²     | USA Case–control          | 2380 healthy control men and women, 30–79 years | Eating frequency          | Dietary history interview  | Time-of-day                  | EI, Ca, fibre | Control men and women eating 1–2 times/d were more likely to have lower intakes of energy, Ca and fibre than those eating ≥3 times/d (P<0·001) |
| Dattilo (2011)⁸⁴  | Brazil                    | 24 men and 28 women, 19–45 years | Meal distribution across the day/meal timing | Dietary recall (recall period not given) | Not clear | Protein, fat, CHO | EI | Stratified by sex | Among women only, EI was significantly higher (P<0·01) at lunch than at breakfast, snacks and at supper. CHO and protein intake at night (among men) and afternoon (among women) was higher in than in the morning. A higher proportion of daily EI in the afternoon and evening was associated with lower and higher overall EI, respectively (P<0·05) |
| de Castro (2004)⁷⁹  | USA C/S                   | 375 men and 492 women, mean age 36.3 (so 13.8) years | Meal distribution across the day/meal timing | 7 d FR Neutral* | Protein, fat, CHO | EI | Stratified by sex | Sensitivity analysis excluding energy under-reporters | Intakes per meal of energy as CHO, fat, protein and alcohol were significantly higher in the evening period (18.00–22.00 hours) than the other four periods of the day (P<0·05). Among both sexes, a higher proportion of daily EI in the morning and evening was associated with lower and higher overall EI, respectively (P<0·01) |
| Deshmukh-Taskar (2010)²³ | USA C/S                  | 2615 men and women, 20–39 years | Breakfast skipping | 24HR Participant-identified* | Protein, fat, CHO, added and total sugars, SFA, MUFA, PUFAs, discretionary oils and solid fats | EI, fibre, vitamins A, B₆, B₉, C, D and E, thiamin, riboflavin, niacin, folate, Zn, Ca, Fe, Mg, P, Na, K and cholesterol | EI, age, ethnicity, sex, sex x ethnicity, poverty income ratio, smoking, PA, marital status and alcohol intake | Compared with breakfast consumers, total energy, dietary fibre, vitamin A, thiamin, riboflavin, vitamin B₉, folate, Ca, P, Mg and K intakes were significantly lower in breakfast skippers (P<0·0001). Nutrient adequacy ratios for vitamins A and C, Ca, Mg, K and fibre were also significantly lower among breakfast skippers (P<0·01) |
| Drummond (1998)⁴⁰  | Scotland                  | 48 men and 47 women, 20–55 years | Eating frequency          | 7 d FR† Neutral‡ | Protein, CHO, fat, sugar | EI, alcohol | Stratified by sex | Eating frequency was positively correlated with total EI (r 0·31, P=0·01) among women only and percentage of energy from CHO (women: r 0·38, P=0·02 and men: r 0·3, P=0·05) |
| Duval (2008)⁴³      | USA C/S                   | 85 women, 47–56 years | Eating frequency          | 7 d FR† Neutral | Protein, CHO, fat | EI, alcohol | Eating frequency was positively correlated with total EI (r 0·41, P=0·005) and percentage of energy from CHO (r 0·21, P=0·045) and total weight of CHO (r 0·37, P=0·001) and protein (r 0·31, P=0·005) |
| First author (year) | Country and study design | Sample | Aspect(s) of meal patterns examined | Diet and meal pattern measure | Meal or snack definition | Macronutrients | Other dietary components | Covariates | Selected key findings |
|---------------------|--------------------------|--------|-----------------------------------|------------------------------|--------------------------|----------------|------------------------|------------|------------------------|
| Edelstein (1992)    | USA C/S                  | 2034 white adults, 50–89 years | Eating frequency | FFQ | Participant-defined | Fat, SFA | EI, cholesterol, fibre | Age and sex | Eating frequency was positively associated with EI, total fat and SFA (P<0.001) and total fibre (P<0.012) |
| Hampl (2003)        | USA C/S                  | 1756 men and 1511 women, 39–43 years | Snacking frequency and timing | 2 × 24HR | Participant-identified* | CHO, fat, protein | EI, all nutrients with an RDA except vitamins D and K, Se and I | EI stratified by sex and ‘snacker’ type | Male and female multiple snackers had lower intakes of protein, cholesterol and Na, but higher EI and Ca intake compared with non-snackers. Female evening snackers had significantly higher EI than did morning snackers |
| Holmback (2010)     | Sweden C/S               | 1355 men and 1654 women, 47–68 years | Eating frequency | Diet history interview† | Participant-identified* | CHO, fat, protein | El, fibre, Fe, Ca, Mg, α-carotene, ascorbic acid, vitamin E, folate and alcohol | Stratified by sex and excluded individuals with past food habit change | Total EI and percentage energy from CHO significantly increased with increased eating frequency (P<0.01). Percentage energy from fat (women only), protein and fibre density decreased. Nutrient densities of vitamin C, folate and Fe were significantly higher among women who ate ≥ 6 times/d (P<0.01) |
| Howarth (2007)      | USA C/S                  | 1792 young adults, 20–59 years; and 893 older adults, 60–90 years | Meal and snack frequency, meal skipping | 2 × 24HR† | Participant-identified | CHO, fat, protein | El, fibre, fibre density | Age group | Among both age groups lunch and dinner provided the highest proportion of EI from protein and fat and snacks provided the least amount of fibre density. Dinner provided the highest fibre density among younger adults. Among older adults, breakfast was higher in fibre density |
| Kant (1997)         | USA Prospective (mean follow-up 10.1 years) | 2580 men and 4567 women, 25–74 years | Meal timing (evening eating) | 24HR | Time-of-day (eating after 17.00 hours) | CHO, fat, protein | El, alcohol | Stratified by sex, age, and EI (unless EI was the dependent variable) | C/S analysis of baseline data showed that with increasing percentage of energy consumed after 17.00 hours, mean daily energy and alcohol intake increased and percentage energy from CHO decreased |
| Kearney (2001)      | Holland C/S              | About 6000 participants (age/sex not provided) | Contribution of meals v. snacks to nutrient intakes | 2 d FR | Time-of-day and type of foods eaten (for example, lunch = bread meal; dinner = hot meal) | Protein, animal and vegetable protein, fat, SFA, MUFA, PUFA, CHO | EI, cholesterol, fibre, Ca, P, Fe, haem Fe, non-haem Fe, Zn and vitamins B₁, B₂, B₆, D, E and C | — | The (hot) dinner meal was the main contributor to the intake of all micronutrients except Ca. The dinner meal also provided 71% of haem Fe and the lunch (bread) meal was the main contributor of Ca intakes |
| First author (year) | Country and study design | Sample | Aspect(s) of meal patterns examined | Diet and meal pattern measure | Meal or snack definition | Macronutrients | Other dietary components | Covariates | Selected key findings |
|---------------------|--------------------------|--------|------------------------------------|-----------------------------|--------------------------|----------------|--------------------------|------------|------------------------|
| Kerver (2006)52      | USA C/S                  | 15 978 adults, ≥ 20 years | Eating frequency, meal skipping | 24HR                        | Participant-identified* | Protein, CHO, fat | EI, cholesterol, vitamins B6 and C, folic acid, Fe, Ca, Mg, Na, K, fibre | Age group, sex, ethnicity, income, smoking status, alcohol intake, vitamin and mineral supplement use, BMI, PA | More frequent eaters had higher intakes of CHO, folic acid, vitamin C, Ca, Mg, Fe and fibre and lower intakes of fat, protein and cholesterol than those who ate 1–2 times/d Breakfast skippers had the lowest intake of all micronutrients except Na |
| Khan (1982)75        | USA C/S                  | 71 men and 179 women students, ≤ 25 years | Contribution of meals v. snacks to energy and nutrient intakes | Q (based on a 24HR) | Participant-identified* | Protein | El, Ca, Fe, vitamins A and C, thiamin, riboflavin, niacin | Stratified by sex | Snacks contributed significantly to the percentage of the RDA for protein (13.4–24.1 %), Ca (9.9–20.2 %), Fe (11.3–34.8 %), vitamin C (13.5–29 %), thiamin (12–18 %), riboflavin (12.4–24.7 %) and niacin (14.2–30 %). The contribution of snacks to women’s Fe intakes was important as meals only provided about 57.5 % of the RDA |
| Kim (2010)83         | Korea C/S                | 292 men and 391 women, 20–65 years | Meal and snack frequency. Combinations of meals and snacks | 24HR                        | Participant-identified and time-of-day* | Protein, fat, CHO | EI | Stratified by sex | Absolute energy and CHO intake highest in the three meals plus three snacks group. There were no differences in protein or fat intakes between more frequent snackers v. less frequent snackers |
| Kuroda (2013)71      | Japan C/S                | 275 women students, 19–25 years | Meal skipping | Diet: diet history Q Meal patterns: Q | Participant-identified | Protein, fat, CHO | El, Ca, phosphate, vitamins D and K | – | Skipping any meal was negatively correlated with total EI (P< 0.05). Skipping breakfast was negatively correlated with the absolute intake of all nutrients examined (P<0.05). Skipping lunch or supper was negatively correlated (P< 0.05) with absolute CHO intake and vitamin K (lunch only) and vitamin D intake (supper only) |
| Min (2011)64         | Korea C/S                | 118 men and 297 women, 30–50 years | Breakfast skipping | 1 x 24HR and 2 d FR (also included a weekend day) | Time-of-day* | CHO, protein, fat | Cholesterol, fibre, Ca, P, Fe, Na, K, Zn, folate, vitamins A, C, E, B1, B2 and B3 | Age, sex and EI | Those who skipped breakfast on two or more of the days (rare breakfast eaters) had lower total EI, fibre, Ca, CHO and K, but higher fat and Fe intakes. Prevalence of not meeting the EAR for Ca, vitamin C and folate was significantly higher among rare breakfast eaters, compared with regular breakfast eaters |
| First author and year | Country and study design | Sample | Aspect(s) of meal patterns examined | Diet and meal pattern measure | Meal or snack definition | Macronutrients | Other dietary components | Covariates | Selected key findings |
|-----------------------|--------------------------|--------|-----------------------------------|-----------------------------|-------------------------|----------------|------------------------|------------|-----------------------|
| Nicklas (1998)(68)    | USA C/S                  | 504 men and women, 19–28 years | Breakfast skipping | 24HR | Time-of-day and type of food(s) consumed | CHO, sugars, sucrose, lactose, fructose, protein and vegetable protein, fat, SFA, MUFA | Fibre, starch, vitamins A, B6, B12, C and D, niacin, thiamin, folacin, Ca, riboflavin and P | Breakfast skippers had significantly lower total daily EI ($P<0.0001$) and significantly lower protein ($P<0.05$), SFA ($P<0.01$) and lactose per 1000 kcal (4184 kJ) than breakfast consumers ($P<0.0001$). A significantly higher percentage of breakfast consumers did not meet two-thirds of the RDA for all vitamins and minerals that were examined |
| Ovaskainen (2006)(47) | Finland C/S              | 912 men and 1095 women, 25–64 years | Meal and snack frequency | 48 h recall | Participant-identified | Fat, protein, CHO, sugars, sucrose | EI, vitamins A, C, E and D, fibre, Ca, Fe, Mg, K, Na, alcohol | Age group, region, Stratified by sex | A snack-predominant meal pattern was associated with higher energy-adjusted sugar, sucrose and alcohol intakes and lower protein, vitamin E, Fe, K and Na intakes among both men and women ($P<0.01$) |
| Ovaskainen (2010)(53) | Finland Repeat C/S (2002 and 2007) | 912 men and 846 women in 2002, 728 men and 1095 women in 2007, 25–64 years | Contribution of meals and snacks to nutrient intake | 48 h dietary interview | Participant-identified | Fat, SFA, sucrose | EI, fibre, vitamins C and E, energy density, energy from alcohol | Age and region, Stratified by sex | There were 5-year increases in the contributions of snacks to vitamin C and fibre intakes (per unit of energy) among men and fibre only among women. For both sexes, 5-year decreases in contributions of percentage EI from SFA and vitamin E were observed for both meals and snacks |
| Roos (1997)(65)       | Finland C/S              | 870 men and 991 women, 25–64 years | Adherence to a conventional meal pattern (breakfast, warm lunch, dinner) | 3 d FR and Q | Participant-identified and time-of-day and foods eaten warm/cold | Fat, SFA, CHO, sugar, protein | EI, alcohol, fibre, vitamin C, carotenoids, cholesterol | Age and region, Stratified by sex | Per unit of energy, meals contributed higher intakes of fat, protein, fibre carotenoids and cholesterol but lower intakes of sugar, vitamin C and alcohol than snacks ($P<0.05$) |
| Summerbell (1995)(36) | Australia C/S            | 71 men and 149 women, 17–60, 38–59 and 65–91 years | Contribution of meals and snacks to nutrient intake | 7 d FR | Time-of-day | Protein, fat, CHO, total sugars | EI, alcohol | Analysed separately by age group | Snacks had a lower EI contribution from protein and fat but a higher EI contribution from total sugars than did meals, consistent across all age groups |
| Titan (2001)(92)      | England C/S              | 6890 men and 7776 women, 45–75 years | Eating frequency | FFQ Meal patterns: Q (one item) | Participant-identified | Fat, SFA, MUFA, PUFA, CHO, protein | EI, alcohol | Analysed separately by sex | Eating frequency was associated with higher daily EI and absolute intakes of fat, fatty acids, CHO and protein |
Table 3. Continued

| First author (year) | Country and study design | Sample | Aspect(s) of meal pattern examined | Diet and meal pattern measure | Meal or snack definition | Macronutrients | Other dietary components | Covariates | Selected key findings |
|---------------------|--------------------------|--------|-----------------------------------|------------------------------|--------------------------|-----------------|--------------------------|------------|-----------------------|
| Williams (2005)(69)  | Australia C/S            | 5081 men and 5770 women, $\geq$ 19 years | Breakfast skipping           | 24HR                          | Participant-identified   | Fat, CHO, sugar, protein | El, fibre cholesterol, vitamins A, C, and E, thiamin, riboflavin, niacin, folate, Zn, Ca, Fe, K and P | Stratified by sex | Compared with breakfast skippers, those who ate breakfast regularly ($\geq$ 5 times/week) had higher mean daily intakes for all nutrients and minerals examined except for fat ($P<0.05$). In older adult ($\geq 65$ years) breakfast skippers, the prevalence of not meeting 70% of the RDI for almost all nutrients was twice that of regular breakfast eaters. |
| Winkler (1999)(81)   | Germany C/S              | 899 men, 45–64 years                     | Eating frequency distribution of nutrition intake across EO | 7 d FR                       | Participant-identified and time-of-day* | Protein, fat, CHO | El, fibre, Ca, alcohol | –          | On 85.2% of reported days, dinner provided most of the energy. Macronutrient intake was contributed mostly by meals and alcohol was mostly drunk at dinner. Snacks in the afternoon or late in the day contained less protein and fibre than the morning snack. |
| Zizza (2001)(57)     | USA C/S (survey years: 1977–1978, 1989–1991 and 1994–1995) | 3789 men and 4706 women, 19–29 years | Snacking (v. non-snacking) | 1997–1991: 1 x 24HR and 2 d FR; 1994–1995: 2 x 24HR | Participant-identified* | Protein, fat, CHO, SFA | –          | Within each survey, compared with non-snackers, snackers had significantly higher intakes of CHO, fat and SFA ($P<0.01$). In the 1994–1996 survey, snackers had significantly greater protein intakes than non-snackers ($P<0.01$). However, there were no significant differences when all the above macronutrients were expressed as percentage of EI. |
| Zizza (2007)(77)     | USA C/S                  | 2002 men and women, $\geq$ 65 years     | Snacking (v. non snacking)   | 24HR                         | Participant-identified* | Protein, CHO, fat, SFA | El, alcohol | Age, poverty income ratio, sex, race, education, marital status, smoking | Snackers had significantly higher intakes of energy, protein, CHO, fat and SFA, compared with non-snackers ($P<0.05$). Snacking contributed approximately 25% of daily energy and CHO intakes, and 20 and 12% of daily fat and protein intakes, respectively. With increasing snack frequency, mean daily intakes of vitamins A, C and E, β-carotene, Mg, Cu and K significantly increased, whereas Se intake significantly decreased ($P<0.05$). |
| Zizza (2010)(77)     | USA C/S                  | 2056 men and women, $\geq$ 65 years     | Snack frequency              | 2 x 24HR                     | Participant-identified* | Vitamins A, B$_6$, B$_12$, C, E and K, folate, niacin, β-carotene, Cu, lycopene, Fe, Ca, Zn, P, K, Se | El, sex, race, education, income, BMI | –          | E0, eating occasion; FR, food record; CHO, carbohydrate; EI, energy intake; C/S, cross-sectional; 24HR, 24 h recall; PA, physical activity; Q, questionnaire; RDA, recommended daily allowance; EAR, estimated average requirement; RDI, recommended daily intake. |

* Beverages could qualify as a separate eating occasion.
† Energy misreporters or under-reporters excluded from analyses.
‡ Milk in excess of 0.5 pints (284 ml) was the only beverage that could qualify as a separate eating occasion.
difference in definitions adopted across these studies. Interestingly, two studies noted that snacks provided a greater percentage of total sugars but not total carbohydrate than meals, and Winkler et al. noted that snacks eaten after lunchtime contained less protein and fibre than the morning snack. Two studies showed that the percentage of protein intake was highest in the evening, particularly among older adults. This suggests that macronutrient differences between meals and snacks may be influenced by both the type and timing of food consumed.

There is a paucity of information on the relative contributions of meals or snacks to intakes of micronutrients and other dietary components. Roos & Prättälä examined the impact of adherence to a conventional Finnish meal pattern (breakfast, warm lunch and warm dinner plus two snacks) among 1861 adults aged 25–64 years and found, per unit of energy, that meals contributed more fibre and carotenoids but less sugar, vitamin C and alcohol than snacks. This finding remained consistent across sex and after adjustment for age and region. Additionally, a study on the adherence to a Dutch meal pattern (breakfast, morning snack, lunch bread meal, afternoon snack, hot dinner meal) found that the (hot) dinner meal was the main contributor to the intake of (haem) Fe, Zn and vitamins B1, B6, B12, C, D and E. Snacks may also be important in assisting populations to meet dietary guidelines for micronutrients; one study of young adult students found that snacks contributed significantly to the percentage of the recommended daily allowances for Ca, Fe, vitamin C, thiamin, riboflavin and niacin. In the same study, snacks were important contributors of Fe and Ca intake among women, whose meal contributions of these micronutrients were only about 65 % and about 79 % of the RDA, respectively.

**Eating frequency and nutrient intakes**

Of eighteen studies that examined eating frequency (including snacking frequency), fourteen found that eating frequency was associated with higher EI and other important confounders. However, the evidence to support associations with nutrient intake is less consistent. Two large population-based studies, one in US adults and the other in Swedish adults, found that those who ate six or more times per d had higher intakes of carbohydrate and fibre but lower intakes of fat and protein compared with adults who ate once or twice per d or less than three times per d, respectively. In these studies, a higher eating frequency was also associated with higher nutrient densities of folate, vitamin C and Fe, and Ca and K. Adjustment for multiple important sociodemographic and lifestyle-related confounders and exclusion of energy misreporters did not attenuate the significance of the results in these two studies.

Snacking frequency also appears to be an important contributor to intakes of macro- and micronutrients among older US adults aged ≥ 65 years. Snackers (consumers of one or more snacks per d) had significantly higher intakes of protein, carbohydrate and fat compared with non-snackers, and a higher snacking frequency was associated with higher mean daily intakes of vitamins A, C and E, β-carotene, vitamin Mg and K, after controlling for important confounders in both of these studies.

In contrast, three studies found that the proportion of energy from protein but not fat was negatively associated with snacking frequency. Additionally, Ovaskainen et al. found that men with a snack-dominated meal pattern (defined as the majority of daily EI derived from snacks) had significantly lower fibre and micronutrient intakes (vitamins A, C, E, Ca, K, Na, Fe, Mg) when compared with men with a meal-dominated pattern. The inconsistency in findings may be partly explained by how snacks have been examined relative to the overall eating pattern: that is, snack consumption in addition to main meals v. snacking in place of meals.

**Meal skipping and nutrient intakes**

A total of six studies were identified that examined the influence of breakfast skipping on nutrient intakes and only one study was identified that examined the nutritional impact of omitting the lunch or dinner meal. Breakfast skipping was consistently associated with lower micronutrient intakes, even after adjustment for EI and other important confounders. Breakfast skipping was also associated with a higher prevalence of not meeting the recommended intakes for Ca, vitamin C, folate, vitamin A, and Mg compared with regular breakfast consumers. In addition, Williams found that, among older Australian adults (aged ≥ 65 years), the prevalence of not meeting the recommended daily intakes for almost all nutrients examined was, among breakfast skippers, twice that of regular breakfast eaters. In a study of Japanese women, skipping lunch or supper was negatively correlated with total EI and absolute intakes of carbohydrate and vitamin K (lunch only).

**Meal timing and nutrient intakes**

Only three studies were identified that examined associations between meal timing and EI or macronutrient intake. In these studies, the proportion of EI consumed in the evening was positively associated with overall EI. Among a large sample of US men and women, an increasing proportion of energy consumed after 17:00 hours was associated with an increase in mean daily alcohol intake but a decrease in mean carbohydrate intake (P<0.05).
Studies examining meal patterns and overall diet quality

A total of fourteen studies were identified that examined associations between meal patterns and measures of overall diet quality (Table 4). Most studies were conducted in the USA, with fewer studies conducted in Australia, Canada, Western Europe and Iran. Of the studies, seven used bivariate analyses to determine whether diet quality was associated with meal patterns with the purpose of identifying its role as a covariate in the relationship between meal patterns and health outcomes. Meal patterns were mostly assessed using a participant-identified approach, however, the methods used to measure participants’ EO also varied across these studies. For example, some studies asked participants to report their EO in response to one or two questionnaire items whereas other studies used 24 h recall methodology. Importantly, where questionnaire items were used, the reliability and/or validity of these measures were rarely reported. Additionally, in three studies, the approach used to define a ‘meal’ could not be readily identified.

The most common measure used to assess overall diet quality was a previously validated and reliability tested a priori diet quality index which reflects an individual’s adherence to the dietary guidelines for the country of the sample population (for example, the Healthy Eating Index (HEI), the Alternative HEI (AHEI) and the Dietary Guidelines Index (DGI)). The measures used in the remaining studies were varied and included scores that measured adherence to: a traditional Mediterranean diet (MEDAS score); Dietary Approaches to Stop Hypertension (DASH) diet score, a dietary approaches to prevent heart disease diet score (Optimal Macronutrient Intake Trial to Prevent Heart Disease (OmniHeart) score); hypothesised healthy eating patterns (a priori diet score); and national guidelines for healthy eating. The associations between these diet quality measures and different meal patterns are discussed below.

Eating frequency and diet quality

Few studies have examined associations between eating frequency (including meal and/or snack frequency) and diet quality. Among US male health professionals, a higher eating frequency was associated with higher DASH scores, reflecting higher diet quality (r 0.14; no P value provided). A higher meal frequency was also associated with higher diet quality as measured by the Canadian HEI among older male and female adults aged 67–84 years old (men: β 1.91, P<0.02; women: β 3.61, P<0.0001). Of note, neither of these studies adjusted for total EI. The mean score for HEI-2005 also increased with increased daily snacking frequency (for example, no snacks = 49.3 (SE 0.5) v. ≥ 4 snacks = 51.5 (SE 0.6), P<0.001) among US adults, after adjustment for sociodemographic factors, BMI, eating three or more meals daily and EI from meals. Conversely, another study reported no association between snacking between meals and diet quality, and Kim & Kim found that a HEI score significantly decreased according to each increased quartile of a snack-dominant eating score (high snack frequency and low meal frequency) (P<0.01). Again, neither study reported adjustment for total EI.

Meal skipping/regularity and diet quality

Of the nine studies identified that examined associations between skipping breakfast and diet quality, six found a negative association and three found no association. However, the lack of association in two of these latter studies may be explained by their respective study populations; overall diet quality was high among men in the US Health Professionals Follow-up study while Dewolfe & Millan used a small convenience sample of eighty-four female and twenty-one male older adults from a single region in Canada. In the latter study, eating lunch daily was associated with higher diet quality scores that assessed compliance with the Canadian Guide to Healthy Eating. No other studies were identified that have examined skipping/regularity of meals other than breakfast.

Meal timing and diet quality

Studies examining associations between meal timing and diet quality are rare. In the US Health Professionals Follow-up study, Cahill et al. found no association between late night eating (defined as eating after going to bed) and AHEI scores; however, as mentioned previously, the authors acknowledged that AHEI scores were high in this sample, irrespective of their reported meal patterns.

Potential impact of different meal definitions on the characterisation of meal patterns and associations with nutrient intakes and diet quality

Clear and objective definitions of what is a meal and what is a snack are critical for determining the energy and nutrient contributions of meals v. snacks, meal skipping or meal timing. Without a clear definition misclassification bias is likely, thus affecting the interpretation of associations with nutrients both within and across studies. In allowing participants to identify meals and snacks, subjective decision-making is inherently present. Previous research suggests that situational cues such as the type, quality or amount of food and the presence of others may affect a participant’s decision to classify an EO as a meal or a snack. It is also unclear whether the same meal or snack situation would be classified similarly by different individuals; research in this area is needed in order to...
| First author (year) | Country and study design | Sample | Aspect(s) of meal patterns examined | Measure(s) to assess diet and meal patterns | Meal or snack definition | Diet quality indicator(s) | Covariates | Selected key findings |
|---------------------|--------------------------|--------|-----------------------------------|---------------------------------------------|--------------------------|---------------------------|-------------|---------------------|
| Azadbakht (2013)    | Iran C/S                 | 411 women students, 18–28 years | Breakfast skipping                   | FFQ                                      | Time-of-day*            | HEI, DDS                  | Not clear if covariates were adjusted for in the multivariate ANOVA | HEI and DDS scores and diversity scores for fruits, vegetables and whole grains were significantly lower among breakfast skippers than consumers \( (P < 0.001) \) |
| Deshmukh-Taskar (2010) | USA C/S                 | 2615 men and women, 20–39 years | Breakfast skipping                   | 1 × 24HR                               | Participant-identified* | HEI                      | Ethnicity, sex, sex × ethnicity, age, poverty income ratio, smoking status, marital status and PA | Breakfast skippers had significantly lower \( (P = 0.0001) \) HEI scores than those who consumed ready-to-eat breakfast cereals or other breakfast foods |
| Dewolfe (2003)      | Canada C/S               | 84 men and 21 women, ≥ 65 years | Meal skipping and snacking           | 3 × 24HR                               | Participant-identified  | Diet score based on compliance with national dietary guidelines | Preparing own meals, how well food tastes, prescription medication use, sex | Eating lunch daily was positively associated (standardised \( \beta = 0.24, 95\% \ CI 0.05, 0.42 \) with the diet score reflecting adherence to Canadian dietary guidelines |
| Cahill (2013)       | USA Prospective (16-year follow-up) | 29,209 health professional men, 40–75 years | Breakfast eating and late-night eating | FFQ†                                   | Time-of-day              | AHEI-2010                | –                     | Based on age-standardised baseline data, no significant differences in AHEI scores were reported between breakfast consumers and non-breakfast consumers or late-night eaters and non-late-night eaters |
| Kim (2011)          | USA/Puerto Rico C/S     | 27,983 women, 35–74 years | Snack dominance and conventional eating pattern | Modified block FFQ†                      | Participant-identified* | HEI                      | –                     | A higher conventional eating score (eating meals and snacks during conventional times) was associated with higher HEI scores \( (P < 0.01) \) whereas a higher snack-dominant eating score was associated with lower HEI scores \( (P < 0.01) \) |
| Mekary (2012)       | USA Prospective (14-year follow-up) | 34,968 men, 40–75 years | Eating frequency                     | FFQ†                                   | Participant-identified  | DASH score               | –                     | Based on age-standardised baseline data, there was a positive association between eating frequency and the DASH score \( r = 0.14 \) |
| Mekary (2013)       | USA Prospective (6-year follow-up) | 46,289 women | Eating breakfast regularly and eating frequency | FFQ†                                   | Participant-identified* | AHEI-2010                | –                     | Based on age-standardised baseline data, women who ate breakfast ≤ 6 times/week had lower scores for the AHEI-2010 than regular breakfast consumers. Diet quality by eating frequency was not assessed |
| First author (year) | Country and study design | Sample | Aspect(s) of meal patterns examined | Measure(s) to assess diet and meal patterns | Meal or snack definition | Diet quality indicator(s) | Covariates | Selected key findings |
|---------------------|--------------------------|--------|------------------------------------|-----------------------------------------------|--------------------------|---------------------------|-------------|----------------------|
| Mesas (2012)<sup>(20)</sup> | Spain C/S | 10,791 men and women, ≥ 18 years | Skipping breakfast | Diet history Q† Meal patterns: Q | Never eating anything at the breakfast occasion (meal definition could not be established) | MEDAS score; the OmniHeart diet score | Age, sex, education, social class, smoking, alcohol, binge drinking, PA at work, BMI and morbidity | No significant associations were found between skipping breakfast and either the MEDAS score or the OmniHeart diet score |
| Odegaard (2013)<sup>(21)</sup> | USA Prospective (follow-up: 18 years) | 3,598 men and women, 18–30 years at baseline | Breakfast frequency | Diet history Q† Meal patterns: Q | No definition provided | A priori diet quality score (no specific name given) | – | Based on C/S data at the 7-year follow-up, higher levels of breakfast intakes were associated with higher diet quality scores. Among males and females, number of meals/d was positively associated with Canadian HEI scores ($\beta = 1.91, P < 0.02$ and $\beta = 3.61, P < 0.0001$, respectively). |
| Shatenstein (2013)<sup>(22)</sup> | Canada C/S | 853 men and 940 women, 67–84 years | Meal frequency (snacks not included) | 3 × 24HR Meal patterns: Q | No definition provided | Canadian HEI | Sex-specific models. Inclusion of the following covariates depended on model: education, diet, income, alcohol, wears dentures, perceived physical health, eats in restaurants, nutrition knowledge, hunger, BMI, chewing problems | – |
| Smith (2010)<sup>(23)</sup> | Australia Prospective | 1,020 men and 1,164 women, 5–15 years at baseline and 26–36 years at follow-up | Breakfast skipping | FFQ Meal patterns: Q (meal patterns chart) | Participant-identified and time-of-day | Compliance with dietary advice in the Australian Guide to Healthy Eating | – | Participants who skipped breakfast in both childhood and adulthood were less likely to meet recommendations for fruit, dairy products, lean meat and alternatives and take-out foods ($P < 0.001$) than those who did not skip breakfast at either time point. |
| Smith (2012)<sup>(24)</sup> | Australia C/S | 1,273 men and 1,502 women, 26–36 years | Eating frequency | FFQ Meal patterns: Q (meal patterns chart) | Participant-identified | Diet score based on compliance with national dietary guidelines | Stratified by sex | There was a positive association ($P < 0.001$) between daily eating frequency and dietary scores, and meeting recommendations for fruit and dairy products among both men and women. |
| Smith (2013)<sup>(25)</sup> | Australia C/S | 4,123 women from low-SES areas, 18–45 years | Breakfast skipping | FFQ Meal patterns: Q (one item) | Participant-identified | DGI | – | Compared with women who ate breakfast < 1 d/week or 1–2 d/week, those who ate breakfast ≥ 3 d/week were more likely to be in the highest tertile for DGI scores. |
better understand the between-subject variation when applying a participant-identified definition. While a time-of-day approach can be applied consistently for all participants, it may not capture meals and snacks eaten at varied times. Furthermore, it is unknown whether meals and snacks would be classified similarly if either a participant-identified or a time-of-day approach were applied. Research on the comparability of the different definitions that seek to define meals and snacks would help address this issue.

It is important to note that studies that have examined eating frequency (including meal and/or snack frequency) differ in both the methods used to define meals and snacks and the time-gap to separate individual EO, which may make an impact on the frequency of the respective EO reported. For example, while most meal or snack definitions include beverages alongside food, not all studies explicitly considered a beverage-only occasion as a separate EO. In addition, larger time intervals used to separate EO may result in EO, including beverage-only occasions, being overlooked and this may affect associations between eating frequency and energy and nutrient intakes. For example, Kant et al. demonstrated a positive association between 24 h beverage EI with saturated fat, sugar, Na and alcohol intakes, after adjustment for EI from foods. However, a definition that excludes ‘low-energy’ beverage-only EO (for example, 210 kJ) may also be important. A recent study showed that, compared with a definition that included all energy-containing EO, there was a stronger correlation between eating frequency and EI after applying a definition that used a minimum energy criterion of $210 \text{kJ}$ (men: $r = 0.45$ vs. $0.53$; women $r = 0.39$ vs. $0.57$, respectively), which remained after excluding energy misreporters.

As few studies have examined associations between meal patterns and diet quality, the impact of different meal definitions is difficult to assess. Breakfast skipping was consistently inversely associated with diet quality in six out of nine studies, despite the different definitions used (time-of-day and participant-identified). Of note, many studies that have examined meal patterns and diet quality also used questionnaire items with unreported reliably and validity to collect meal pattern data. The lexical and semantic features of questionnaire items can differ between studies and may influence participant responses. For example, items may ask participants to indicate the times of the day they usually eat or how many days they usually have something to eat for breakfast, whereas other items provide additional instruction such as include all beverages or all nutritive beverages. Questions that use the word ‘eat’ but provide no additional examples or cues as to what to include may therefore only elicit information about food-only EO or combined food and beverage EO but not beverage-only EO. However,
Understanding meal patterns

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Discussion

Meal patterns are multidimensional and can be described according to their patterning, format and context. However, due to the limited dietary assessment methods available, most research has focused on meal patterning. To date, a variety of definitions has been used to examine meal patterns. In addition, a number of additional criteria have been adopted in meal pattern research, which may have an impact on the types of meal patterns reported and described in the literature. Although over the past few decades there has been general consensus that a universally accepted definition of a meal is crucial, there have been few attempts to define meals in a consistent and standardised way.

Research suggests that different meal and/or snack patterns are related to both nutrient intakes and overall diet quality, with the most consistent finding being an inverse relationship between skipping breakfast and nutrient intakes/diet quality. Skipping meals other than breakfast has rarely been examined but may be important, particularly for vulnerable groups such as the elderly. In addition the nutritional impact of snack, meal and overall eating frequency remains unclear and little research has looked at the how meal timing influences nutritional intake/overall diet quality. This may be an important area of research in light of preliminary evidence suggesting that the timing of energy and/or macronutrient intake during the day is associated with cardiometabolic risk.

The conflicting findings for the associations between eating frequency (including snack/meal frequency) and nutrient intake/diet quality may be, in part, attributed to not only the heterogeneity of meal patterns examined, but also to different definitions of meals and snacks. While meals and snacks are hypothesised to exert different effects on EI and nutrient intake, some researchers suggest that the sociocultural and value-laden nature of the terms used to identify different meals and snacks precludes such delineation. Although it is widely acknowledged that different definitions used to define meals/snacks are likely to hamper interpretation of findings across studies, research explicitly examining the impact of these different definitions is rare. There has been little attempt to examine meal patterns in a consistent and standardised way.

Another important consideration for future research examining eating frequency is potential overlap in the meal patterns that are being examined, which further complicates comparisons between studies. For example, a study that examines eating frequency comparing eating one or two times per day versus four to six times per day is also encapsulating meal skipping and meal patterns with snacks, respectively. That is, depending on cultural norms, an individual who only eats one or two times per day may also be considered to be skipping one or two meals. Categorising individuals as being high snack consumers may include individuals who consume snacks in lieu of meals, and therefore future research should consider eating frequency and/or snack frequency in the context of meal frequency/skipping to better differentiate the impact of different types of meal patterns. Some evidence also suggests that healthy and unhealthy dietary patterns can exist among individuals who are high-frequency snack consumers. This may also partially explain the lack of consistent findings for the association between snack frequency and nutrient intakes, and therefore future research should consider examining meal patterns in the context of an individual’s overall dietary pattern. Measures of eating frequency may include beverage-only occasions, however, these types of eats have not always been considered when examining the relationship between meal patterns and nutritional intake. This may be an important consideration given the emerging evidence of sugar-sweetened beverages (SSB) in the aetiology of obesity and cardiometabolic risk. Moreover, beverage-only occasions may be especially relevant among certain subgroups of the population; for example, adolescent and young adult males have been shown to be high consumers of SSB.

A limitation of the literature to date on diet quality is that the primary purpose of many of the included studies was to examine associations between meal patterns and health outcomes. Therefore, few of these studies adjusted for total EI and important sociodemographic and lifestyle factors. Another limitation of these studies was that meal patterns were often assessed using simple questionnaires with unreported reliability or validity. Importantly, questions regarding meals in questionnaires may not be well defined and this may extend to how respondents should consider beverages.

Under-reporting of EI is a common and well-known limitation of studies that assess dietary intakes. Despite this, very few studies on meal patterns have examined the impact of energy misreporting. As eating frequency is positively related to EI, it may be that those who under-report EI also under-report their eating frequency. There is also some evidence that snacks are more prone to being under-reported. Results from a pooled analysis of five large validation studies showed that under-reporting of EI with a single 24 h recall was approximately 15%. Unless adjusted for, energy misreporting may obscure important relationships between meal patterns, nutrient intakes/diet quality and, ultimately, health outcomes.
Recommendations to advance the field

To advance the area of meal pattern research, the methods used to collect meal pattern data require further development. Measures that are administrable and have low participant burden (for example, questionnaire items) need to be developed and tested for reliability and validity. Contextual information is not always collected as part of a 24 h recall, yet additional questions about eating location and activities while eating could be considered in order to better understand the contextual factors that influence associations between meal patterns and diet quality. While specific food records have been adapted to collect contextual information (for example, the Weekly Food Diary method), this method also involves a high participant burden. Dietary assessment methods that utilise new technology (for example, smartphones) may assist in the development of meal pattern research. Devices that people use and carry alongside them every day with the added capacity of a personal digital assistant used in a previous study may be a low burden and efficient way to collect meal pattern data in ‘real time’. A major advantage of such technology would be that researchers could collect information allowing examination of all three meal pattern constructs: patterning, format and context. Furthermore, rich contextual data collected in real time could provide insight into the factors that influence participants’ decisions to classify an EO as a meal or snack and therefore help in refining existing meal definitions. Currently little research has examined meal format; however, understanding how different combinations of foods in a meal influence overall diet quality could be an important step in developing a meals-based framework for dietary guidelines. Further work is also required in developing and applying innovative statistical techniques to examining meal patterns, with few applications tested in the literature.

However, it is important to acknowledge that developing new methods to collect and analyse meal patterns data will take considerable time. A major issue still remains of the different definitions available to researchers when conducting meal patterns research. Further analysis (for example, sensitivity analysis) that examines more than one definition from the current literature would facilitate the interpretation of findings across studies in this field of research. Future research that examines the influence of different meal definitions on the characterisation of meal patterns will facilitate the interpretation of the existing literature, and provide recommendations on the most appropriate methods to advance the field.

Conclusion

Overall, there are a number of gaps and limitations in meal pattern research that need to be addressed to further our understanding of how meal definitions influence the characterisation of meal patterns, and the contribution of different meal patterns to nutrient intake and overall diet quality. While current evidence suggests breakfast skipping may be detrimental to diet quality, the nutritional impact of eating frequency, skipping meals other than breakfast and meal timing is inconclusive and warrants further investigation. Future studies should consider how different contexts, beverage-only occasions and energy misreporting affect the relationship between meal patterns and diet quality. The heterogeneity of meal definitions is a major impediment to the interpretation of findings across studies in this field of research. Future research that examines the influence of different meal definitions on the characterisation of meal patterns will facilitate the interpretation of the existing literature, and provide recommendations on the most appropriate methods to advance the field.

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