Snacking in nutrition and health

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Abstract

A number of studies suggest that distributing energy and nutrient intake throughout the day (4-5 eating occasions/day, rather than in the usual 3 meals) could favourably affect human health at any age. The inclusion of 1-2 snacks in the daily pattern might in fact reduce the metabolic and digestive load caused by the consumption of a lower number of meals with individual higher energy content. At the same time, it might contribute to meet recommendations both for food groups (e.g. fruits, milk) and for nutrients (e.g. fibre and vitamins). The snack composition should be evaluated, nutritionally and calorically, taking into account the whole day's diet, rather than considering the nutritional value of each component. In early and late age, or in conditions like professional physical activity, snacking may need to follow specific characteristics to be optimal, both in terms of composition and timing.

This document, which is the result of a collaboration of experts across several fields of research, intends to provide a review of the current scientific literature on meal frequency and health, highlighting the beneficial effects of correct snack consumption across the whole human life.

Keywords: snacking, eating occasion, meal frequency, meal timing, dietary intake

Introduction

An active and healthy lifestyle, together with a balanced diet, is essential to maintain health and well-being across all ages. This premise is supported by a wide scientific literature, and represents the foundation of national and international dietary guidelines.

In recent decades, many studies have shown that food and meal consumption habits can also influence the relationship between diet composition and health. Most scientific evidence relates to breakfast's role in addition to lunch and dinner: the regular consumption of a breakfast characterised by an adequate energy and nutrient intake is associated with a healthier overall diet pattern, a favourable metabolic profile, and a better health status (Marangoni et al. 2009). However, significant changes occurring in daily consumption habits have prompted health professionals and nutritionists to focus also on the effects of caloric distribution across multiple meals throughout the day.

Some interesting (and in part counterintuitive) data have already been collected. Although an excess of calories and specific nutrients is known to produce negative consequences for health, recent studies have focused on the association between energy distribution throughout the day and diet quality and specific health parameters (Koletzko & Toschke 2010; Schoenfeld et al. 2015; Murakami & Livingstone 2016).

A number of scientific bodies and scientific societies currently argue that distributing energy and nutrients across 4 to 5 daily meals could potentially benefit health (Institute of Medicine 2007; Agostoni et al. 2011) . Specifically, in a healthy population, it has been found that consuming 1 to 2 nutritionally and calorically balanced snacks between meals may contribute to meet the recommendations for healthy foods such as milk and fruit, as well as for vitamins (e.g. folate), minerals (e.g. calcium, zinc and iron) and fibre (Sebastian et al. 2008; Lloyd-Williams et al. 2009; Zizza et al. 2010). This eating pattern may also alleviate the potential digestive and metabolic overload caused by a lower number of meals with higher energy content, particularly at dinner (Maffeis et al. 2000).

A small meal consumed at either mid-morning and/or mid-afternoon has also been associated with other positive metabolic effects (Gatenby 1997; St-Onge et al. 2017). Recent findings suggest that preventing a rapid increase in hunger is an essential tool for weight maintenance in all age groups (Zeevi et al. 2015). It is important to consider that such effects, as well as its nutritional value as a meal, also depends on the timing of snack consumption (Leech et al. 2015; Hess et al. 2016).

This document presents the shared view of a group of experts from different specialties (paediatrics, geriatrics, nutrition and sports medicine), convened by NFI – Nutrition Foundation of Italy with the aim to review the most solid data available in the literature regarding the effects on health of snack consumption and energy distribution through the day.

What does "snack" mean?

Three main factors, according to the American Heart Association (St-Onge et al. 2017), allow to differentiate snacks from main meals:

- Consumers' perception, who traditionally consider breakfast, lunch and dinner as main meals and all other eating occasions (e.g. afternoon tea) as snacks.
- The timing of consumption: breakfast, lunch and dinner are commonly considered to take place between 6 am and 10 am, 12 pm and 3 pm and 7 pm and 9 pm respectively. All other eating occasions are considered snack times.
- Energy intake: meals and snacks are categorised according to the energy content: over 15% and less than 15% of the daily recommended energy intake respectively.

Another distinction must be made in terms of nutritional composition between mid-morning and mid-afternoon snacks, as the two may play different roles in the diet. The mid-morning snack is intended to maintain a sense of satiety, allowing to reach lunch time with a sufficient but not exaggerated appetite, and should therefore be easily digestible and not excessively rich in calories. The timing and the energy content of the afternoon snacks, on the other hand, must be commensurate both with the

longer duration of the afternoon compared to the morning, and with the engagement in physical activity in the afternoon if appropriate.

In addition, snacks provide the opportunity to include in the diet foods whose consumption at main meals is for any reason inadequate . For example, eating fruit as a mid-morning snack is a perfect way to achieve the recommended daily intake of fruit in addition to that consumed at lunch or dinner. Furthermore, snack represents an excellent opportunity to introduce into the diet this precious group of foods, which is usually scarcely consumed.

With regards to the nutritional characteristics of snacks, it is both unrealistic and unpractical to consider mandatory to follow the same macronutrient distribution usually proposed for the overall diet (e.g. 45-60% carbohydrates, 20-35% fat and the remaining part from protein, as indicated by EFSA). Such distribution will in fact easily be reached in the total daily diet, whichever the snack composition, provided that the main meals composition is appropriate. As a consequence, no food should be *a priori* excluded from the snack, provided that all daily eating occasions and energy requirements are adequately taken into account. Moreover, following such a tight caloric distribution in the snacks would imply, as an example, that a piece of fruit would be nutritionally inadequate, while it obviously is.

Snacking habits and consumption around the world

Snack consumption habits vary greatly from one country to another. It has been shown that Australia and the United States are the top snack consumers, followed by Mexico and China (Wang et al. 2018). Between 1977 and 2014, in the United States, an increasing trend in snack consumption took place across all socioeconomic classes which resulted in a significant increase in calories pro capita derived from between-meal snacks (Dunford & Popkin 2018).

If the different types of food consumed as snack are considered, fruit and milk/yogurt consumption appears to be very low amongst adolescents (9-13 years) compared to children aged 4-8 years.

United States, together with Australia and Mexico, have the highest snacks' nutritional density, added sugars and saturated fat content. An increasing trend in savoury snack consumption, especially in China, Mexico and the United States, can be identified.With the exception of Blacks and Hispanics, the consumption of sugary beverages has decreased amongst the general population, whereas the preference for savoury snacks is increasing.

The caloric intake from snacks has especially increased (by over 100%) for children with lower educational and socioeconomic backgrounds.

Significant differences between industrialised countries versus developing countries, can be also found regarding to the prevalence, frequency, energy content and nutrient intake of snacks. In the United States, in the 90's, 80% of children aged between 2 and 18 years consumed snacks, versus 95% in 2013-2014, contributing to 24% of the average daily energy intake (Piernas & Popkin 2010). Similarly in Australia, snacks contribute to 30% of total calories during childhood and adolescence (Fayet-Moore et al. 2017). In China, the current situation has significantly changed compared to previous decades and is progressing towards a more western model (Wang et al. 2018). In 1991, only 14% of children aged 7-12 years consumed snacks while, in 2009, 54% of Chinese children habitually consumed snacks, on average once per day, although the snacks were relatively low in energy density (6-8% of daily energy intake). In 2012, 68% of Mexican children consumed snacks on average 1.2 times per day and recent data suggests that approximately 19% of the energy intake for Mexican children is derived from snacks (Taillie et al. 2015).

Recommendation on snack consumption

As recently pointed out by Potter and coworkers, among more than 200 countries and organization, 136 snacking-specific recommendations were identified, significantly different from one another (Potter et al. 2018). Despite this, with the exception of certain countries such as China (Bureau of Disease Control and Prevention of the Ministry of Health et al. 2008) and Mexico (Secretería de Educación & Secreteria de salud 2014), most nutritional recommendations focus on the diet as a

148 whole and do not specifically address snacking (National Health and Medical Research Council 2013;
149 Arenas et al. 2015; U.S. Department of Agriculture & U.S. Department of Agriculture 2015). This
150 approach can be justified considering, as previously mentioned, that a single snack has a modest
151 impact on the diet in terms of energy (less than 10% of total daily intake). Therefore the impact of
152 the varying nature of snacks on overall diet quality should be relatively limited.
153 Current leading nutritional advice suggests that children should consume snacks between main meals
154 in order to meet their nutritional requirements. For example, the Italian guidelines in this regard state
155 that three main meals are not sufficient to meet the needs of children and teenagers and it is therefore
156 advisable to provide them with two calibrated snacks to meet the particular needs of calories and
157 nutrients of this age (INRAN - Istituto Nazionale di Ricerca per gli Alimenti e la Nutrizione, 2003);
158 the American Paediatrics Academy (American Academy of Pediatrics Committee on Nutrition 2004)
159 and the United States Department of Agriculture (USDA Food and Nutrition Service 2016) suggest
160 2 to 3 small snacks per day for pre-school aged children. More specifically, the USDA suggests that
161 "smart snacks" should be prioritised, consisting of fruit, vegetables and water. In order to be
162 considered a "smart snack", a snack must first meet the general nutrition standards: be a grain product
163 that contains 50 percent or more whole grains by weight (have a whole grain as the first ingredient);
164 or have as the first ingredient a fruit, a vegetable, a dairy product, or a protein food; or be a
165 combination food that contains at least ¼ cup of fruit and/or vegetable; moreover, a "smart snack"
166 must meet the nutrient standards for calories, sodium, sugar, and fats.
167 Similarly in Canada, Alberta's Health Services considers that children require 2 to 3 snacks per day,
168 and that portions should vary based on age, physical activity level and the time period between the
169 snack and the subsequent meal (Alberta Health Services 2016).
170 In France, the recommendations provided by the Programme National Nutrition Santé (National
171 Health and Nutrition Program) suggest that a single afternoon snack is sufficient for children; it
172 should include food belonging to 2 of the three following food groups: bread or cereal, dairy and fruit
173 (Programme National Nutrition Santé 2013).

Why is snacking important? The physiology and circadian rhythms behind hunger and appetite

The field of energy regulation has recently focused on analysing not only what food is consumed but also how and when consumption takes place (Arble et al. 2009; Garaulet et al. 2013).

If food intake were to be exclusively regulated by energy homeostasis processes, our appetite would be greatest upon rising, following a night of fasting. However, breakfast is often the least caloric of all daily meals, and poor morning appetite (and consequently breakfast skupping) is especially prevalent amongst overweight and obese individuals (Deshmukh-Taskar et al. 2010). In the Western food tradition, dinner is generally the most important meal, contributing to over a third of total daily energy intake (De Castro 1997; Agricultural Research Service 2012). This is a potential issue given that energy intake at night is positively correlated with total energy consumption throughout the day (de Castro 2004).

There are several reasons that explain such changes in energy intake distribution including genetic predisposition (de Castro 2001) and social and family behaviours (Patrick & Nicklas 2005).

Over the past few years, circadian rhythms of hunger and satiety have also been considered (Scheer et al. 2013; Poggiogalle et al. 2018). Scheer was the first to demonstrate that hunger sensations peak around 8 pm and reach a nadir at 8 am. This finding was later confirmed by Australian researchers who observed a peak in hunger between 5 pm and 9 pm, while the lowest level was recorded during the night (1 am to 5 am) (Sargent et al. 2016). The findings from these studies are aligned with the hormonal secretions that regulate appetite, appetite-stimulating ghrelin on one hand and appetite-suppressing leptin on the other (Simon et al. 1998; Cummings et al. 2001).

Another study recently measured the response of obese subjects to a standard meal consumed either in the morning or in the afternoon. It was observed that ghrelin secretion and hunger were highest in the afternoon, whereas peptide YY was lower. The results were even more marked when subjects underwent a stress test (Carnell et al. 2018).

The increase in afternoon appetite mainly concerns high energy dense and highly palatable foods and does not involve vegetables for example (Scheer et al. 2013). It appears that at night, humans primarily seek energy and gratification.

Based on these observations, the role of mid-afternoon snacks appears particularly important. In fact, consuming a nutritionally adequate snack may prevent an overconsumption of food during the following hours that are considered critical in terms of regulating food behaviours.

When referring to "nutritionally adequate" food properties, the main factors include nutrient density and energy density which play major roles in maintaining energy balance (Drewnowski 2018). It was found that, for adolescent males, consuming a nutrient dense snack in the afternoon improves appetite control, satiety and overall diet quality (Leidy et al. 2015). A literature review also highlighted an improvement in satiety after consuming nutrient rich snacks (Njike et al. 2016). Such effects cannot be attributed to a specific nutrient, as evidenced by the comparison between protein-rich Greek yogurt and regular yogurt (Ortinau et al. 2013), and are instead related to the snack's overall nutrient density. On the other hand, snacks that have high energy density and low nutritional density can lead to a positive energy balance, resulting in overweight, especially when consumed regularly, mindlessly and in the absence of hunger signals (Larson et al. 2016).

Afternoon snacks may therefore represent a means of controlling appetite and eating behaviour, assuming that healthy options are chosen and consumed mindfully. The positive effects of an afternoon snack are particularly useful given the circadian cycle of hunger sensations. Consuming snacks that can limit the physiological hunger peak that takes place at night, can in fact assist with controlling food intake.

Time and frequency of meal consumption can also influence daily glycaemic variability and insulin secretion (Leidy & Campbell 2011).

Skipping meals, as opposed to a more frequent meal consumption (within an overall isocaloric context), leads to higher postprandial insulin peaks due to the proportionally higher carbohydrate intakes during the remaining meals. In health young males, for example, isocaloric diets (15 En%

protein, 30 En% fat and 55 En% carbohydrates) were divided into either 3 daily meals (a low consumption frequency pattern) or 14 meals (ensuring that subjects were in a constant postprandial state) (Bosy-Westphal et al. 2017). These diets induced different changes in blood glucose and insulin which were significantly greater in response to a lower number of meals, even in the presence of no variations of the overall macronutrient distribution over 24 hours. The metabolic consequences of these phenomena are important.

If the energy balance is positive, a reduced meal frequency (due to the greater insulin response induced) will lead to an increased absorption and oxidation of cellular glucose in the immediate postprandial phase, as well as to the accumulation of fat ingested through the diet in adipose tissue (for the insulin-induced activation of lipoprotein lipase). On the contrary, when insulin levels are kept lower (such as when carbohydrate intake is spread across several meals), lipolysis is activated and the resulting substrates flow follows the opposite pathway.

However, it must not be forgotten that insulin secretion is just one of the many drivers affecting the complex mechanism of regulation of the energetic homeostasis and a division in more than 6 daily meals should not be necessarily considered as advantageous. (McCrory & Campbell 2011).

Snack consumption: relationship with overall diet and health status

Given that most of the available data on this topic originates from the United States and America, it must be interpreted prudently while considering the clear differences in eating behaviour and lifestyle compared to Mediterranean countries.

In the United States for people aged between 2 and 18 years, average daily meal frequency has increased from 3 to 5 between 1970 and 2000 (Popkin & Duffey 2010), with an average daily caloric increase of 770 kJ (184 kcal) during the same time period (Piernas & Popkin 2010). American children consume an average of 3 snacks per day, and over a third of their total energy intake is provided by desserts and sugary drinks. A significantly higher energy density for snacks compared to the three main meals has also been recorded (Cole & Fox 2008).

In front of these data, there is currently no consensus regarding the relationship between the number of daily meals and child body weight (American Dietetic Association 2008; Evans et al. 2015).

In general, the literature suggests that there is an *inverse* relationship between meal frequency and weight status (Larson & Story 2013; Kaisari et al. 2013). Although the nature of this relationship is yet to be elucidated, it confirms the role of an increased eating frequency in maintaining low levels of hunger and appetite.

The most reliable data on this topic come from studies evaluating the association between meal frequency and total energy intake, taking into account the overall diet quality, measured using the Healthy Eating Index 2005 (HEI-2005).

A study of eating behaviours on 176 children (aged 9 to 11 years) and adolescents (12 to 15 years) showed that in the 82% of the participants who consumed an average of 3 daily meals, meal and snack consumption frequencies were significantly and positively associated with total energy intake (Evans et al. 2015). In fact, each additional meal and snack was associated with an increase in energy of 18.5% and 9.4% respectively ($P < 0.001$). However, the relationship between number of meals or snacks and diet quality varied across age groups: for primary school children, the number of eating and snacking occasions was generally associated with a greater score on the diet quality index. On the opposite, for adolescents each additional main meal was associated with an increase of 5.4 points ($P=0.01$) in the diet quality index, while a reduction of 2.73 points was observed for each additional snack.

In Canada, snacks contribute to over a third of total energy intake for 96% of children, who consume an average of 2.3 ± 0.7 snacks per day. For most of these children (78% of boys and 63% of girls), the snack was comprised of a food belonging to a healthy food category (Hutchinson et al. 2018).

Snacking and overweight/obesity in children

The snacking stereotype consists of consuming unhealthy and oftentimes excessive amounts of food, in terms of both calories and nutritional content, mainly rich in fat and/or sugar. Snacking, as a

consequence, has often been considered as a potential driver for overweight and abdominal obesity amongst children and adolescents (van Jaarsveld et al. 2014; Murakami & Livingstone 2016), especially amongst those who consume more than 15-20% of their daily energy intake in the form of snacks (Hampl et al. 2003). In this population group, as previously mentioned, snacking frequency was positively associated with total energy intake; however, the relationship between meal and snack frequency and overall diet quality showed an improvement in overall nutritional quality in school aged children, whilst for adolescents it is associated with a less favourable diet form a nutritional point of view (Evans et al. 2015).

An Italian study conducted on 1837 children aged between 8 and 10 years showed that overweight and obese children clearly preferred savoury snacks compared to sweet varieties and their consumption was directly associated with the degree of excess bodyweight (Maffeis et al. 2008).

It is likely that overweight children may be less sensitive to satiety cues and perhaps more sensitive to cues that promote food consumption (Cross et al. 2014). It was demonstrated that these differences in responses can influence weight gain during the early stages of life (Mallan et al. 2014; van Jaarsveld et al. 2014). A recent study conducted with 187 Hispanic pre-school aged children established a positive correlation between the pleasure derived from food and the frequency of snacks and calories consumed between meals in overweight and obese children. An inverse relationship was observed for normal weight children (Rudy et al. 2018). These observations call for a different approach with regards to snacking recommendations for overweight and obese children who have difficulty regulating their appetite (Bo et al. 2014).

Research on different food categories with varying characteristics has shown that protein and fibre rich foods play a major role in satiety if they are consumed as snacks (e.g. nuts, yogurt, dried prunes). However, certain authors have suggested that overall diet quality is mainly influenced by the nutritional quality of main meals, given their large contribution to total energy intake. Nonetheless, even if the contribution of snacks to total energy is relatively small, it is reasonable to assume that they can still potentially lower overall diet quality (Murakami 2018).

304 Consuming healthy snacks appears to influence satiety by promoting appetite control, thus reducing
305 the risk of overweight and obesity, as demonstrated in healthy children (Njike et al. 2016). This
306 finding is consistent with the Weizmann Institute's research on the general theory of weight control
307 (Zeevi et al. 2015).
308 A high level of emotion-driven impulsiveness has been also shown to be positively associated with
309 the frequency of snacking and particularly with the consumption of energy-dense snacks; such
310 observation supports the importance of targeting on impulsiveness to avoid excessive and/or
311 inappropriate quality snacking (Coumans et al. 2018). Stress has also been increasingly gaining
312 attention with regards to its role in conditioning food choices as early as at 8-9 years of age (Hill et
313 al. 2018; Carnell et al. 2018). According to this data, addressing emotional impulsiveness may be an
314 effective strategy to avoid excessive food consumption between meals.
315 In addition to potentially influencing weight, meal frequency also influences oral health if proper
316 hygiene practices are not followed. This is particularly relevant especially for sweet foods and drinks,
317 the consumption levels of which directly correlate with the development of dental caries (Paglia et
318 al. 2016; O'Malley et al. 2018). Both the amount and the nutritional content of snacks appear to
319 contribute to the risk of caries (Olczak-Kowalczyk et al. 2017). In particular, this risk is greater for
320 school-age children who consume numerous snacks instead of regular main meals (OR=2.32)
321 (Skafida & Chambers 2018). Similarly, consuming sweet foods in the evening may facilitate plaque
322 formation and thus dental caries in preschool-aged children (Wigen et al. 2018). Following the
323 nutritional advice of dentists and dietitians (for example choosing fruit and unsweetened/moderately
324 sweetened yogurt and thoroughly cleaning teeths after the last daily meal), in any case, significantly
325 reduces the risk of dental caries (Heima et al. 2016).
326 ***The benefits of mid-morning and mid-afternoon snacks***
327 There is no clear consensus in the literature regarding the appropriate number of meals per day. For
328 this reason, the American Society for Nutrition organised a symposium on this topic which was
329 published in 2011 to define a few practical suggestions for the general public.

The literature suggests that consuming 3 to 6 meals per day is associated with improved appetite control, provided that energy intake at each eating occasion is monitored in order not to exceed energy requirement (McCrory & Campbell 2011). Eating mindlessly increases the risk of destabilizing appetite cues, thus increasing caloric intake especially when consuming more than 6 meals per day.

However, as previously mentioned, a balanced snacking is essential for regulating satiety hormones between meals, which prevents ravenousness prior to the following meal. In contrast, reducing the number of meals per day is associated with a reduced capacity for appetite control (Leidy & Campbell 2011). Most researchers agree that regular and structured eating patterns can facilitate weight control, whereas "grazing" led by impulsiveness, as opposed to mindful decisions, negatively impacts overall diet quality and body weight (Berg & Forslund 2015; Leech et al. 2017). Moreover, regular small meals positively impact metabolism compared to fewer larger meals throughout the day (Jenkins et al. 1989).

Multiple studies have focused on the association between food consumption frequency and several chronic disease markers, such as body weight, blood pressure, lipid and glycaemic profiles, etc. (St-Onge et al. 2017). Although further studies are required, however a higher food consumption frequency is associated with a lower risk of obesity in children and adolescents. In contrast, regularly skipping meals is usually associated with greater metabolic risk, such as a higher BMI, waist circumference, fasting levels of blood insulin and glucose and triglycerides (Deshmukh-Taskar et al. 2010; Freitas Júnior et al. 2012; Schröder et al. 2017).

It must also be noted that snacks provide an opportunity to consume certain foods or macronutrients that may not be sufficiently consumed during mealtimes (Fayet-Moore et al. 2017). A typical example is fruit, which constitutes a healthy snack either mid-morning or mid-afternoon, especially if daily intake is not covered during breakfast, lunch and dinner. Fruit snacks can hence contribute to improving overall diet quality, whilst also helping consumers to reach their daily recommended target of 2-3 daily portions as suggested by dietary guidelines.

Finally, it must be underscored that consuming snacks as "comfort food" is not necessarily a sign of weakness, but may instead be beneficial, in specific cases, as part of a varied and balanced diet (Troisi & Gabriel 2011). This premise is supported by a study from the Department of Psychology at the University of California (Finch & Tomiyama 2015). The researchers analysed data from 2,379 women (aged 18-19 years) who were enrolled in a large observational study which also included psychological tests. The tests aimed to assess how participants would react during critical moments and, on the other hand, their tendency to resort to "comfort food" in times of boredom, stress, worry or anger. In women free from depressive disorders, it was found that measured stress perception, following critical moments, was lower in those who turned to comfort food.

Overall, it appears that snacks can reduce stress under certain circumstances, as well as represent enjoyable treats within very strict diets. Such diets are often unsuccessful in the long-term and can potentially lead to contrasting behaviours (for example compensatory eating or binges), while flexible eating patterns are easier to maintain, and can be consolidated through pleasurable eating habits such as snacking (Stewart et al. 2002).

Snacks: psychological aspects, social and educational role

The main factors influencing snacks food choice include food culture, education and socioeconomic status (Wang et al. 2016).

A moderate level of control and encouragement has been shown to be associated with a lower consumption of inadequate snacks. On the other hand, using food as a reward or in response to a negative mood has been associated with a higher level of unhealthy snack consumption amongst children (Sleddens et al. 2010; Rodenburg et al. 2014; Lo et al. 2015), as confirmed by a study evaluating the effect of limiting snacks in the absence of hunger for 64 groups of parents and their children 22-36 months old (Corsini et al. 2018). The study accounted for 3 specific factors: access to snacks, snack consumption frequency and proclivity for snacks. Snack consumption in non-hungry state was associated with restrictive behaviours on the parents' behalf (r=0.25, P=0.05, IC 95% 0.004-

382 0.47). In particular, access to snacks at home was on average greater and directly correlated with
383 restriction (van Ansem et al. 2015; Blaine et al. 2017; Corsini et al. 2018).
384 A behavioural study was conducted with school-aged overweight and obese children who were
385 provided with sweet and savoury snacks following a pizza dinner (Liang et al. 2016). Parents'
386 responses to an adequate questionnaire showed that excessive monitoring and control led to negative
387 effects on children's eating behaviours. For those children whose parents were the most
388 psychologically controlling, the tendency to consume snacks in the absence of hunger was greater.
389 Another survey, conducted in 2010 on 1215 children 6-10 years old, representative of the Italian
390 population for this age group, found that snacking is not a merely individual choice and is largely
391 influenced by peers (Gregori et al. 2011). In this study, the likelihood of eating 3 or more sweet
392 foods/drinks per day (typical snackers' behaviour) equivalent to an average caloric intake of 360-
393 400kcal (18-22% of the daily recommended intake of 1700-1900 kcal/day for children aged 6-10),
394 was higher in situations in which child's peers are also snackers. It was also shown that the increase
395 in energy intake due to snacking behaviours may be compensated through an active lifestyle. In fact,
396 in Italy, children considered "snackers" lead more active lifestyles compared to non-snackers (van
397 der Horst et al. 2008; Gregori et al. 2011). This finding contradicts another research which generally
398 describes snackers as children who spend most of their time involved in solitary activities (Gubbels
399 et al. 2009). In the Italian population, no correlation was observed between the parents' BMI and their
400 children's level of snack consumption. According to the results, the children's eating habits are
401 closely linked to their mother's attitude towards physical activity. Mothers of non-snackers are more
402 inclined towards healthy behaviours including a minimum of 2 weekly hours of physical exercise.
403 This issue does not necessarily imply a healthier lifestyle for their children who appear to have not
404 only a more sedentary lifestyle but also less social contact. On the contrary, children who regularly
405 snack spend more time watching TV but are also more active, most of them practicing physical
406 activity at least 4 hours per week.

In conclusion, the association between snacking behaviours in children and overweight-obesity remains unclear.

Snacking at different ages in life: practical issues

Children and adolescents

Snacks for children and adolescents should be wisely chosen, in order to provide a valuable contribution to the overall diet. Both sensory aspects of the foods that constitute the snack and a thorough evaluation of the food and beverages consumed during the rest of the day should be taken into account.

For children and adolescents, as an example, snacks are an opportunity to meet nutritional recommendations regarding the consumption of milk and dairy products, fruit and fibre.

Education plays a major role in this context, as demonstrated by the US government's plan to provide fruit and vegetables as snacks in primary schools (Ohri-Vachaspati et al. 2012). This initiative proved successful in increasing the consumption of vegetables throughout the day and encouraging healthy choices at home, suggesting that an educational intervention performed during the school lessons may provide benefits which extend beyond the time spent in the classroom.

In addition, given that snacks can contribute to up to 20% of daily calories, food and beverages should be selected to add nutritional value to the diet without exceeding the maximum energy limit (Zizza 2014). Also the importance of adequate hydration should not be underestimated, especially at this stage of life: it is in fact recommended to provide water to children along with their snacks.

Finally, it is important to ensure a variety of snacks throughout the week, within a varied diet, in order to prevent boredom created by routine and repetitiveness and to increase the likelihood of maintaining healthy habits in the long-term.

Adults

In adults snacking may be less important than in children and adolescents as a tool to meet daily requirements, but it can, nevertheless, play an important role also for the adult population. Rather than consuming 3 large meals (breakfast, lunch and dinner), adults can consume smaller portions of food spread across 4 to 6 eating occasions every 2 to 3 hours (St-Onge et al. 2017).

Distributing daily energy intake across 5 eating occasions, as opposed to concentrating it in the three main daily meals, can positively impact several metabolic and health parameters (Fábry et al. 1964). Guidelines from several countries including Italy (Italian Ministry of Health) suggest that breakfast should contribute 15-20% of total energy and lunch and dinner 60-70%, while the remaining amount should be divided between mid-morning and mid-afternoon snacks.

This energy distribution is associated with a proper energy distribution, matching the body requirements throughout the day, and resulting in a reduced appetite before the main meals. In addition, it promotes a more balanced secretion of gastrointestinal hormones (including insulin and ghrelin) and an improved control of glycaemia, appetite, cholesterol and body weight (Fábry et al. 1964; Bellisle et al. 1997; Palmer et al. 2009).

It should never be forgotten that, given the wide availability of food in our society, an increase in eating occasions may easily lead to an increased caloric intake (Bertéus Forslund et al. 2005). While increasing meals from 3 to 5-6 per day may have positive effects, exceeding this frequency may lead to weight gain. It is therefore important for adults and elderly people to consider mid-afternoon snacks as a means to obtain a proper energy distribution throughout the day and to increase the eating occasions for particular foods. Studies on obese adults undergoing weight loss treatment demonstrated that those who regularly consume snacks tend to consume more fibre, fruit and vegetables compared to those who don’t (Kong et al. 2011).

A greater consumption of snacks, if snaks are properly formulated, does not necessarily lead to an increase in body weight. This suggests that there may be compensatory factors which regulate energy intake during other meals, especially in normal weight individuals (Viskaal - van Dongen et al. 2010;

457 Njike et al. 2016). The composition and consistency of snacks, rather than the frequency of snacking
458 occasions, appears to impact on satiety and fullness feeling (Furchner-Evanson et al. 2010).
459 Since consumers are less likely to consider liquid or semi-liquid foods as sources of calories compared
460 to solid foods, compensatory behaviours during subsequent meals are less likely to take place after
461 these foods, potentially leading to an increase in total daily energy intake (Mourao et al. 2007).
462
463 *The elderly*
464 A well-timed and nutritionally appropriate snack can exert a positive effect on the diet of elderly
465 people. Malnutrition, nowadays, still affects about 38-50% of elderly patients admitted to the hospital,
466 14% of patients admitted to nursing homes and 6% of free-living individuals (Kaiser et al. 2010).
467 These data suggest that nutritional deficiencies affect a large part of the elderly population.
468 Food choices in the elderly are largely influenced by well recognised factors, including: biological
469 determinants (hunger and satiety signals: endogenous production of neuromodulators,
470 macronutrients, energy density), food palatability (taste, smell, texture, sight and hearing), economic
471 and environmental factors (accessibility, degree of autonomy), social aspects (cultural level, family
472 and social support) and psychological determinants (stress, depression) (Donini et al. 2016).
473 A sub-optimal diet that does not meet energy and nutrient requirements can be also the consequence,
474 among elderly people, of age-related physiological changes such as reduced chewing ability, reduced
475 salivary gland activity, altered gastroesophageal motility and secretions, reduction of the intestinal
476 absorption surface area, concomitant diseases; social issues (poverty, loneliness, social isolation) and
477 psychological factors (such as depression, often associated in the elderly with the loss of social
478 position) can also play a role.
479 In this context, meal distribution across 5-6 eating occasions can help food consumption, particularly
480 among individuals who cannot tolerate large quantities of food in one sitting. Even in the absence of
481 specific clinical trials, several guidelines regarding nutrition in the elderly suggest that eating smaller,
482 but more regular, meals can improve nutritional status in these persons (e.g. Best Practice Advocacy

Centre New Zealand, Henry Ford Allegiance Health, Irish Nutrition and Dietetic Institute, Senior Care Corner) (Wilkinson & McLeod 2008).

To reach this goal, snacks (as the other meals) should contain foods providing essential nutrients and meeting specific criteria, that may be different from those released for other age groups. For example, highly digestible yet appealing and energy dense foods should be prioritised. High energy density, in fact, allow for a reduction of up to 20% in volume of foods while maintaining energy intake. Appealing flavours and presentation can also enhance trigeminal stimuli (texture changes, temperature control) as well as visual stimuli (colour changes), thus improving appetite and overall food intake (Donini et al. 2016).

Athletes and highly active individuals

Physical performance of recreational and professional athletes requires proper nutrition habits to be reached and maintained (Rodriguez et al. 2009). The main priorities for athletes are adequate amounts of energy, fluids and carbohydrates. In addition, combining carbohydrates with an adequate protein intake, preventing excessively long fasting periods, can promote and maximize muscle protein synthesis.

Physical performance can be supported by adequate intakes for liquids, carbohydrates and protein before, during and after physical activity requiring muscle strength.

Compared to the general population, athletes require higher intakes of fluids (to compensate for sweat losses) as well as additional energy required for physical performance. Most athletes, therefore, may benefit from an increased meal frequency. The scientific literature concerning nutrition and physical activity, specifically, highlights that meal frequency plays an important role both before and during training, and when preparing for a competitive event (Kerksick et al. 2017).

First of all, the number of eating occasions and the macronutrient distribution in various meals are essential to resynthesize muscular and hepatic glycogen, for muscle mass repair, protein synthesis and to improve mood following physical exertion.

In fact, intense and prolonged exercise promotes the metabolic use of glycogen stores, that must subsequently be replenished (within 4 hours from exertion). This goal can be achieved consuming carbohydrates, also in combination with proteins, especially when intense physical activity is extended over a longer time period.

Individuals who train regularly and at high intensity (i.e. once per day for 2-3 hours, 5-7 days a week, for 9-10 months a year) also require higher protein intakes, generally set between 1.2 and 2.0 g/kg of body weight.

According to the American College of Sports Medicine (ACSM), muscle adaption to training can be optimized by consuming 0.3 g/kg of body weight of protein, over several meals, following training sessions and every 3 to 5 hours (Thomas et al. 2016). Interestingly, readily available carbohydrates promote protein sparing during physical activity (Kerksick et al. 2017).

Protein intake is especially relevant in the case of inadequate energy and carbohydrate intake, when protein enables good glycaemic balance and an increase in glycogen stores. Similar benefits are observed with carbohydrates during resistance training; in the long-term they promote muscle adaption if physical exercise is maintained.

Preliminary studies have shown the potential benefits associated with meal frequency on weight maintenance and body composition for physically active individuals (La Bounty et al. 2011).

Snacks are therefore essential for athletes performing at elite levels, given that they provide the required energy pre-training and the essential nutrients for post-training recovery. Considering that competitions or training sessions must take place at least 3 hours following a main meal (i.e. starter, main dish, sides and fruit/dessert), snacks prevent athletes from performing with a completely empty stomach, which would negatively affect performance itself (Thomas et al. 2016).

A snack consumed before a competition or training session should be characterised by a relatively low fat and fibre content, in order to promote gastric emptying and minimize gastrointestinal distress, and should be high in carbohydrates. It should also provide sufficient fluids to maintain adequate hydration throughout physical exertion. The presence of carbohydrates in such snacks is essential

since they maintain blood glucose levels during physical activity (30-60 g per hour on average). This is especially true for physical exertion that exceeds 60 minutes, if the athlete has not consumed sufficient amounts of carbohydrates before the competition or if training is taking place in extreme environmental conditions (e.g. extreme heat or cold, high altitudes) (Rodriguez et al. 2009).

The ACSM underlines that post-training recovery goals, in athletes, include restoring fluids and electrolytes lost through sweat, restoring the glycogen consumed during exercise, optimizing protein synthesis required to repair damaged muscles and to build new tissue. As a consequence, following training, the nutritional purpose of a snack becomes essentially to replenish lost fluids, energy, carbohydrates, protein, minerals and vitamins. Thus it must supply an adequate amount of energy, mainly from carbohydrate sources (in order to replenish muscle and liver glycogen stores). The after exercise snack is also essential for restoring protein and to provide the aminoacids required for repairing exercise-induced muscle damage. It is generally recommended that athletes consume carbohydrate and protein rich snacks before and after training that supply at least 2 and up to 4-5 grams of carbohydrates for each gram of protein. This ratio supports anabolic processes (muscle repair caused by physical exercise and muscle mass increase) that are most active immediately post-training (i.e within 30 minutes of completion), commonly referred to as the "anabolic window".

Generally speaking, the distribution of calories across meals, among athletes, mainly depends on the type of physical activity, on the time of training as well as on individual traits (La Bounty et al. 2011). If training takes place mainly in the afternoon, breakfast and lunch should contribute to 20% and 30% of total daily calories respectively. The addition of a mid-morning snack providing 5-10% total energy should involve the reduction of the energy intake at lunch, that should not exceed 25-30%, followed by a mid-afternoon snack providing 10% and a small snack during training providing 5%. In all cases, carbohydrates should be the main source of energy. Although requirements of protein and certain vitamins (especially B group vitamins) increase with exercise, the increase in energy, fluid and carbohydrate requirements is proportionately much greater. Ideally, the distribution of meals should

provide adequate and constant sustenance throughout the day thus preventing drops in blood sugar which may compromise performance (Thomas et al. 2016).

Conclusions

Many scientific bodies highlight the benefits of distributing total energy and nutrients across 4 -5 daily meals as opposed to 2- 3 main meals. This approach is based on available evidence suggesting that in healthy, normal weight adults, a favourable association between the number of meals consumed throughout the day and the nutritional diet quality and the individual cardio-metabolic profile can be demonstrated. This optimal pattern consists of 3 main meals (breakfast, lunch and dinner), one mid-morning and one mid-afternoon snack.

Both mid-morning and mid-afternoon snacks must be well characterised in terms of time of consumption, energy content (generally 10% of total energy intake, but with some flexibility according to individual factors) and mode of consumption. These features allow for mid-morning and mid-afternoon snacks to be distinguished from other snacking times.

From a nutritional perspective, allowing for 3 plus 1 or 2 eating occasions can also help to optimize the intake of certain foods such as fruit and milk (or yogurt) and to reach nutrient requirements especially for vitamins and minerals.

A mid-afternoon snack is also associated with psychological benefits. Given its favorable impact on mood, the occasional inclusion in this snack of foods that are nutritionally considered “non-optimal” can be acceptable, provided that the energy intake is compensated throughout the rest of the day.

Morning and afternoon snacks may also ensure that children and adults have sufficient energy to complete the daily cognitive and physical tasks that take place between main meals.

A strategically and well designed snack can also compensate for “quantitative” metabolic imbalances at all ages and in all contexts .

Moreover, snacks can provide specific benefits for various population groups, especially for those who can take great advantage from more frequent meal consumption such as children and the elderly.

Correct timing and planning of snacks (including water for adequate hydration) can also greatly impact the quality of a snack. Snacks for both amateur and professional athletes require special attention given that timing, nutritional composition and mode of consumption are crucial determining factors for athletic performance.

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