Seasonality of food groups and total energy intake: a systematic review and meta-analysis

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BACKGROUND/OBJECTIVES: The aim of this systematic review and meta-analysis was to assess the effect of season on food intake from selected food groups and on energy intake in adults.

SUBJECTS/METHODS: The search process was based on selecting publications listed in the following: Medline, Scopus, Web of Science, Embase and Agris. Food frequency questionnaires, 24-h dietary recalls and food records as methods for assessment of dietary intake were used to assess changes in the consumption of 11 food groups and of energy intake across seasons. A meta-analysis was performed.

RESULTS: Twenty-six studies were included. Articles were divided into those reporting data on four seasons (winter, spring, summer and autumn) or on two seasons (pre-and post-harvest). Four of the studies could be utilized for meta-analysis describing changes in food consumption across four season scheme: from winter to spring fruits decreased, whereas vegetables, eggs and alcoholic beverages increased; from spring to summer vegetable consumption further increased and cereals decreased; from summer to autumn fruits and cereals increased and vegetables, meat, eggs and alcoholic beverages decreased; from autumn to winter cereals decreased. A significant association was also found between energy intake and season, for 13 studies reporting energy intake across four seasons (favors winter) and for eight studies across pre- and post-harvest seasons (favors post-harvest).

CONCLUSIONS: The winter or the post-harvest season is associated with increased energy intake. The intake of fruits, vegetables, eggs, meat, cereals and alcoholic beverages is following a seasonal consumption pattern and at least for these foods season is determinant of intake.

INTRODUCTION

A seasonal food can be defined as 'food that is outdoor grown or produced during the natural growing/production period for the country or region where it is produced. It needs not necessarily be consumed locally to where it is grown'.[1] A definition 'that takes the consumers' perspective, by incorporating a local link between production and consumption, produced and consumed in the same climatic zone without high energy use for climate modification or storage'.[2] With such definition of food seasonality different climatic zones need to be considered. In West Africa, there are two rainy seasons: the long rainy season from March to May and the short rainy season from September to October, in-between pre-harvest season from May to June and post-harvest season from January to February. In Europe and US four seasons can be recognized: spring (March to May), summer (June to August), autumn (September to November) and winter (December to February).[3] The equatorial parts of Southeast Asia, including Malaysia, Brunei, Indonesia, Singapore and the Philippines, have only two seasons—wet and dry.[3]

Food seasonality could therefore be a factor determining dietary behavior and have an impact on food and energy intake. For example, it has been shown that cold seasons are related to higher consumption of hot non-alcoholic beverages and hot seasons with higher consumption of fruits and dairy products.[4] Studying and understanding the relationship between the availability of food according to seasons and food intake will help shaping dietary assessment instruments and help explaining the association between diet and health. However, such an investigation needs to take into account the differentiation in seasons in different parts of the world. Seasonal fluctuations in food availability are especially visible in developing countries and in rural communities underlining the link between seasons and food intake.[5]

The first pilot action of the European Joint Programming Initiative ' A Healthy Diet for a Healthy Life' is the knowledge hub on the DEDIPAC (DEterminants of DIet and Physical ACtivity). The DEDIPAC project focuses on the determinants, at both the individual and group levels, of dietary, physical activity and sedentary behaviors using a wide multidisciplinary approach. Food seasonality was identified as a determinant of diet, thus being a target for DEDIPAC.

The aim of this systematic literature review was therefore to explore food seasonality as a determinant of dietary behavior by summarizing the current knowledge on food seasonality and assessing the seasonal variation of food intake of selected broader food groups and energy intake in adults. Energy intake was selected because it represents a measure of overall intake and is less sensitive for substitution effects.

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METHODS

Search strategy

The protocol was registered in 'PROSPERO International prospective register of systematic reviews' PROSPERO 2014:CRD42014014007 and is available from http://www.crd.york.ac.uk/PROSPERO/display_record.asp?ID=CRD42014014007.[6] The manuscript followed the PRISMA Statement how to conduct a systematic review.[7]

Between June and August 2015 we have systematically searched the following databases, MEDLINE, SCOPUS, AGRIS, WEB OF SCIENCE and EMBASE, to identify the experimental (intervention studies) and observational studies describing the seasonal variation in food group intake and variation of energy intake. No restriction was made as for the date of publication. The search strategy was restricted to human adults, English language and included the following type of documents: article, review, book and book chapter. The search was performed using the following index terms in title or abstract:

#1 'Food' OR 'Food, Organic' OR 'Functional Food' OR 'Food and Beverages' OR 'Health Food' OR 'Water' OR 'Vegetables' OR 'Meat' OR 'Cereals' OR 'Fruit' OR 'Food groups' OR 'Food consumption', #2 'Periodicity' OR 'Season' OR 'Season-*'*-s, -al, -ality, #3 'energy intake'. Search #1 AND #2 AND #3.

Inclusion and exclusion criteria

Only studies conducted in healthy, adult populations were included. Studies reporting consumption of food groups or energy intake in different seasons were eligible. Dietary data from food frequency questionnaires, 24-h dietary recalls and food records were analyzed. We considered studies with the following designs: experimental (randomized controlled trials, non-randomized controlled trials and pre-post intervention studies), observational (cross-sectional studies, and longitudinal cohorts and case–control studies) or ecological studies. We excluded publications that did not meet the inclusion criteria (studies performed in specific groups of patients or other age-specific groups, animal studies, other than mentioned above type of documents, articles in any other language than English).

Data extraction and analysis

The study selection process was subdivided into (1) titles and abstracts and (2) full-text and was performed by two independent researchers in parallel with each database. In the two steps of the process, all disagreements between the researchers were solved after consultation with the review coordinator. Only in the case of agreement, a document was passed to the next step. Full-texts of all selected studies according to title and abstract were obtained through libraries. In special cases, the corresponding or leading author was contacted via e-mail. For each full-text paper, information was extracted according to general information (study title, authors, year and journal), study characteristics (study design, country, inclusion and exclusion criteria and length of follow-up), characteristics of studied population (nationality, age and gender of participants and number of participants), assessment methods (food frequency questionnaire and 24-h dietary recalls), type of exposure (season and period) and type of outcome (food groups and energy intake).

The relationships between season and food groups and energy intake were described as 'favors summer' if higher food group consumption and higher energy intake were observed in summer and 'favors winter' if intake of food groups and energy intake were linked with higher energy intake and food consumption in winter. The deviation of seasonal intake from mean intake was expressed in absolute term. To assess the study quality, a 9-point scoring system according to the Newcastle–Ottawa Scale was used.[8] The full score was 9, and a high-quality study was defined by a threshold of ⩾7 points.

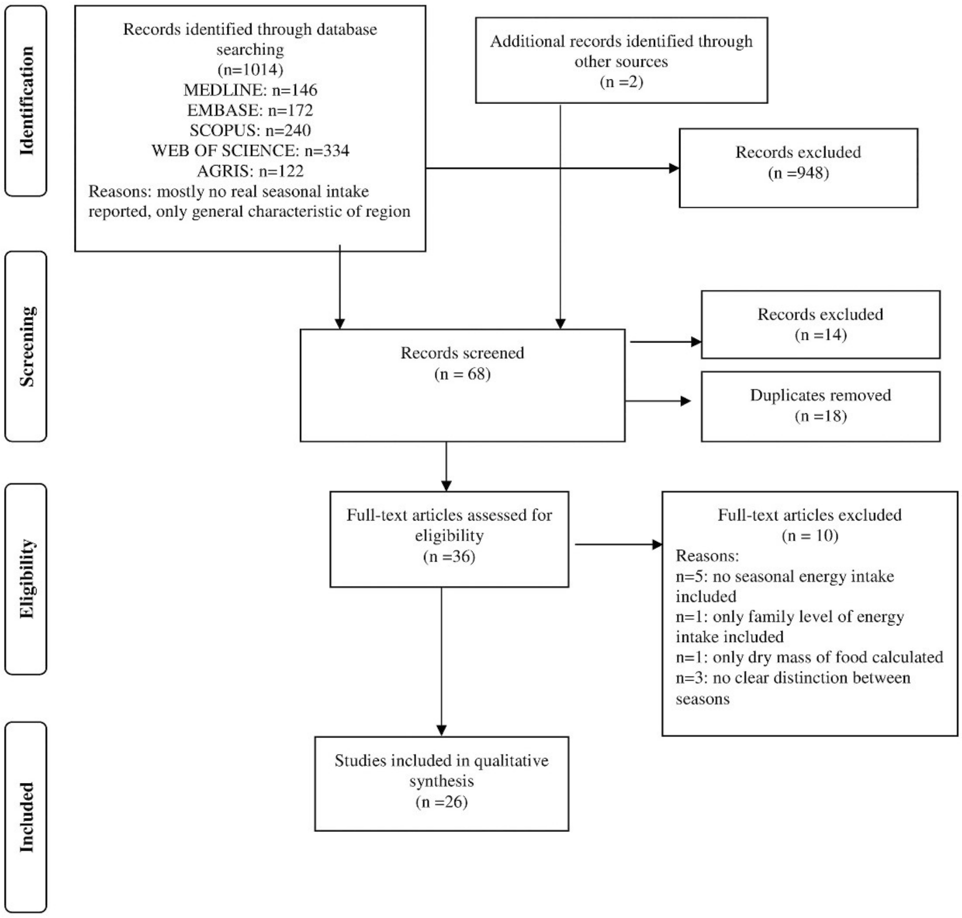

Figure 1. Process of literature search linking the influence of season on food and energy intake.

Statistical approach

Where appropriate, the recorded energy intake levels were converted to kilocalories (kcal) in order to homogenize the results. Meta-analyses of 4, 11 and 8 studies were performed separately to combine the available results (presented in proper format) of individual studies concerning food group consumption and energy intake across four seasons, and energy intake across pre- and post-harvest seasons, respectively. Data were analyzed using a random-effects model that allowed that the true effect could vary from study to study. The effect size of a study was investigated by calculating standardized mean difference with 95% confidence interval. The heterogeneity of the sum of studies was tested for significance. As measure for quantifying inconsistency, I^2 was selected.[9] The results of the meta-analysis were visualized using a forest plot that illustrates the results of the individual studies and the summary effect. Funnel plots were used for identification of publication bias. The analysis was performed with Comprehensive Meta-Analysis software (Biostat, Inc., Engelwood, CO, USA).

RESULTS

Search results

The search process is presented in Figure 1. We identified 146 potentially relevant publications in Medline, 172 in EMBASE, 240 in Scopus, 331 in Web of Science, 122 in Agris and two in additional source (book chapters); finally, we included 66 articles according to title and 52 according to abstract into further steps of the search process. These articles were retrieved for full-text review. Finally, after removal of duplicates with multi publications of the same study and sufficiency of data given in the publications, 26 studies met the inclusion criteria and were further analyzed.

Study and population characteristic

Baseline characteristics of the 26 studies and populations are presented in Table 1. The majority of the studies were cross-sectional ($n=24$) and only one was a randomized clinical controlled trial.[19] The individual studies represented 21 different nations (6 in Europe, 5 in America, 7 in Asia, 7 in Africa and 1 in Oceania). The age ranged from 14 (in only one study where adulthood is recognized early) to 85 years and the BMI value from 17.2 to 25.8 kg/m^2; however, in 10 studies BMI was not reported.[4,12,14,18,22,24–27,29] Eleven studies were conducted in a female population only[4,5,17,19,22,23,25,26,29,31] and one study in a male population only.[33] Thirteen studies were performed in urban communities[4,10–21] and 13 studies in rural populations.[5,22–33] The energy intake was noted in 25 studies[4,5,10–28,30–33] and the consumption of food groups in seven only.[4,10,17,18,21,22,27] All studies were of high quality (Newcastle–Ottawa Scale ⩾ 7).

Seasonality in food group consumption

The consumption of different food groups across seasons is presented in Table 2. Seven studies quantified the consumption of food groups.[4,10,17,18,20,21] The available data allowed us to investigate the consumption of 11 food groups (fruit, vegetables, dairy products, cereals and cereal products, meat and meat products, fish and seafood, eggs, oil and fat, legumes, alcoholic beverages and non-alcoholic beverages); however, information on all food groups was only available in four studies.[10,20,21,27] In one study, the intake of food was reported only in two seasons only (winter and summer)[17] and in another study in dry and rainy seasons.[27] In five studies[10,18,20,21,27] data of food consumption

Table 1. Basic characteristics of selected studies ($n=26$) and population ($n=104\,777$)

Study	*Number of participants*	*Study design*	*Age*	*Ratio of women and men*	*Country*	*Region*	*BMI (kg/m^2)*	*Study quality (Newcastle–Ottawa scale)*
Capita and Alonso-Calleja[10]	303	Cross-sectional	Mean:25.6/24.7	$N=142/161$	Spain	Urban	23.4/20.8	8
Fyfe *et al.*[11]	260	Cross-sectional	Younger:21–44 Older: 45–64	$N=169/91$	Great Britain	Urban	26.0	8
Behall *et al.*[12]	29	Cross-sectional	20–53	$N=16/13$	USA	Urban	N/A	7
Arnaud *et al.*[13]	106	Cross-sectional	27–59	N/A	Cuba	Urban	23.9	7
Rossato *et al.*[14]	162	Cross-sectional	20–69	$N=114/48$	Brazil	Urban	N/A	7
Westerterp *et al.*[15]	52	Cross-sectional	Mean: 29.0	$N=42/10$	Netherland	Urban	21.8	7
Prasad *et al.* [4]	4880	Cross-sectional	25–44	Only women	Finland	Urban	N/A	8
Ma Y *et al.*[16]	593	Cross-sectional	20–70	$N=277/316$	USA	Urban	27.2	8
Fowke *et al.*[17]	74 049	Cross-sectional	40–70 Mean: 52.1	Only women	China	Urban	24.0	7
Sasaki *et al.*[18]	215	Cross-sectional	N/A	113/102	Japan	Urban	N/A	7
Amanatidis *et al.*[19]	123	RCT	18–54	Only women	Australia	Urban	22.4	7
Adolf *et al.*[20]	7831 6561 4310	Cross-sectional	18–34 35–54 55–74	$N=4252/3579$ $N=3330/3231$ $N=2419/1891$	Germany			8
Heseker *et al.*[21]	1988	Cross-sectional	l > 18	$N=1138/856$	Germany			8
Nyambose *et al.*[22]	184	Cross-sectional	14–51	Pregnant women	Malawi	Rural	N/A	7
Rao *et al.*[23]	797	Cross-sectional	Mean:21.4	Only women	India	Rural	18.1–20.5	7
Nobmann *et al.*[24]	351	Cross-sectional	21–60	$N=186/165$	USA	Rural	N/A	7
Singh *et al.*[25]	90	Cross-sectional	75% below 40 y	Only women	India	Rural	N/A	7
Huss-Ashmore *et al.*[26]	110	Cross-sectional	N/A	Only women	Swaziland	Rural	N/A	8
Oguntona *et al.*[27]	112	Cross-sectional	65–85	$N=59/53$	Nigeria	Rural	N/A	7
Tetens *et al.*[28]	1361 (lean season) 1281 (peak season)	Cross-sectional	18–60	524/736	Bangladesh	Rural	17.8–18.8	7
Kigutha *et al.*[5]	24	Cross-sectional	Mean:28.7	Only women	Kenya	Rural	23.3	7
Bentley *et al.*[29]	65	Cross-sectional	16–45	Only women	Congo	Rural	N/A	7
Murayama and Ohtuska[30]	16	Cross-sectional	N/A	$N=8/8$	Thailand	Rural	19.8–25.6	7
Ategbo *et al.*[31]	45	Cross-sectional	Mean:31	Only women	Rep. of Benin	Rural	19.5	7
Schultink *et al.*[32]	150	Cross-sectional	31.6–41.3	Only women	Rep. of Benin	Rural	17.2–25.8	7
Tin-May-Than and Ba-Aye[33]	10	Cross-sectional	18–60 Mean: 38.4	Only men	Burma	Rural	19.74	7

Abbreviations: N/A, not available; RCT, randomized controlled trial.

Table 2. Mean consumption of different food groups across seasons (gm per day)

Study	Food groups										
	Fruit	Vegetables	Dairy products	Cereals and cereal products	Meat and meat products	Fish/seafood	Eggs	Oils and fat	Legumes	Alcoholic beverages	Non-alcoholic beverages
Capita and Alonso-Calleja[10]											
Summer: M	128.7 ± 28.9	169.4 ± 47.7	380.0 ± 128.4	182.1 ± 93.9	153.5 ± 46.9	37.2 ± 22.8	20.1 ± 8.1	25.7 ± 12.2	21.4 ± 10.7	36.8 ± 59.5	233.3 ± 226.1
Summer: F	113.0 ± 95.0	168.9 ± 62.9	396.8 ± 209.2	195.6 ± 64.8	117.3 ± 42.3	40.7 ± 24.2	29.8 ± 12.4	27.7 ± 14.1	11.3 ± 9.6	28.3 ± 56.1	289.5 ± 173.9
Winter: M	114.4 ± 72.0	214.5 ± 58.9	373.5 ± 115.4	312.7 ± 58.8	173.7 ± 81.8	57.0 ± 29.9	26.4 ± 15.8	34.6 ± 13.0	19.7 ± 6.9	88.0 ± 81.7	366.4 ± 204.8
Winter: F	107.3 ± 65.9	154.1 ± 72.8	394.0 ± 196.7	192.7 ± 69.6	123.3 ± 40.5	49.8 ± 30.0	33.0 ± 15.5	24.4 ± 12.1	15.3 ± 15.3	26.7 ± 38.4	293.5 ± 224.6
Prasad et al.[4]											
Spring	210 ± 147	245 ± 139	836 ± 405	174 ± 62	157 ± 69	24 ± 20	—	—	—	—	808 ± 467
Summer	188 ± 134	267 ± 144	828 ± 422	171 ± 62	158 ± 66	25 ± 21	—	—	—	—	827 ± 470
Autumn	229 ± 196	246 ± 161	861 ± 408	178 ± 61	157 ± 71	24 ± 21	—	—	—	—	835 ± 451
Winter	228 ± 162	221 ± 129	852 ± 445	174 ± 61	159 ± 72	23 ± 21	—	—	—	—	803 ± 446
Sasaki et al.[18]											
Spring: M	109 ± 95	310 ± 92	141 ± 125	331 ± 97	62 ± 27	143 ± 52	41 ± 19	10 ± 5	—	361 ± 345	287 ± 151
Spring: F	141 ± 96	298 ± 94	166 ± 102	234 ± 59	52 ± 22	111 ± 41	35 ± 17	8 ± 4	—	28 ± 48	280 ± 148
Summer: M	166 ± ± 146	388 ± 157	156 ± 145	332 ± 113	67 ± 33	143 ± 50	42 ± 19	11 ± 4	—	387 ± 334	300 ± 176
Summer. F	193 ± 133	391 ± 134	178 ± 110	228 ± 66	52 ± 24	113 ± 40	35 ± 20	10 ± 5	—	33 ± 56	287 ± 155
Autumn: M	167 ± 129	299 ± 98	134 ± 133	338 ± 94	66 ± 31	154 ± 48	42 ± 19	9 ± 5	—	264 ± 273	276 ± 154
Autumn: F	209 ± 100	278 ± 98	140 ± 104	233 ± 66	50 ± 21	123 ± 41	36 ± 17	8 ± 4	—	25 ± 51	263 ± 120
Winter: M	119 ± 84	302 ± 97	131 ± 106	324 ± 92	66 ± 36	151 ± 59	40 ± 16	9 ± 4	—	280 ± 295	287 ± 153
Winter: F	160 ± 93	294 ± 110	140 ± 93	220 ± 50	52 ± 32	116 ± 41	33 ± 15	8 ± 4		23 ± 53	278 ± 133
Fowke et al.[17]											
Summer	404	314.9	—	—	56.5	77.3	—	—	—	—	—
Winter	387.2	336.4	—	—	59.1	51.7	—	—	—	—	—
Adolf et al.[20a]											
Aged:18–34											
Spring: M	70.3	142.8	197.7 (184.5–210.9)	247.0 (239.3–254.7)	194.5	15.6 (14.1–17.0)	35.5 (33.8–37.2)	22.7 (21.7–23.7)	—	452.2 (421.5–482.9)	547.0 (521.3–572.7)
Spring: F	84.9	134.0	170.7 (162.1–179.4)	187.3 (182.3–192.2)	128.0	12.8 (11.6–14.0)	28.9 (27.6–30.2)	17.6 (16.9–8.3)	—	146.5 (132.3–160.6)	519.5 (500.2–538.8
Summer: M	76.8	146.6	199.0 (181.8–216.2)	242.7 (234.8–250.0)	194.8	14.6 (13.0–16.3)	34.0 (32.2–35.9)	24.3 (23.0–25.6)	—	447.1 (413.3–481.0)	556.0 (528.2–583.8)
Summer. F	101.8	145.4	172.2 (161.7–182.7)	179.6 (174.3–184.9)	127.3	12.0 (10.7–13.3)	28.9 (27.3–30.4)	18.2 (17.5–19.0)	—	145.0 (132.1–157.9)	534.4 (512.9–555.8)
Autumn: M	78.0	137.9	194.0 (180.3–207.8)	258.6 (250.6–266.6)	197.3	16.1 (14.6–17.6)	31.8 (30.3–33.4)	23.4 (22.2–24.6)	—	366.7 (340.1–393.3)	497.8 (474.4 521.2)
Autumn: F	92.7	128.5	153.6 (145.4–161.8)	184.6 (179.4–189.8)	128.4	12.7 (11.6–13.9)	26.5 (25.3–27.6)	18.0 (17.2–18.8)	—	134.2 (122.5–145.8)	478.9 (460.2–497.6)
Winter: M	73.8	128.3	203.7 (189.3–218.1)	247.6 (240.8–254.4)	186.8	18.3 (16.7–19.9)	37.3 (35.6–39.1)	23.2 (22.1–24.3)	—	423.8 (394.2–453.3)	524.1 (501.0–547.3)
Winter: F	93.5	124.6	161.9 (153.6–170.1)	176.7 (172.0–181.3)	124.0	14.2 (13.1–15.4)	28.6 (27.5–29.8)	17.4 (16.7–18.1)	—	131.0 (120.4–141.6)	514.1 (492.8–535.3)
Aged: 35–54									—		
Spring: M	77.1	158.1	148.9 (138.1–159.7)	252.0 (244.5–259.6)	202.8	21.5 (19.4–23.5)	35.2 (33.4–37.0)	23.4 (22.2–24.5)	—	547.7 (510.6–584.8)	446.8 (421.3–472.3)
Spring: F	86.6	148.8	136.9 (128.1–145.7)	193.2 (187.0–199.3)	138.7	15.9 (14.4–17.4)	30.3 (28.8–31.8)	17.6 (16.7–18.6)	—	173.5 (158.9–188.1)	453.8 (431.2–476.4)
Summer: M	93.1	164.7	147.2 (134.7–159.7)	248.1 (239.8–256.5)	205.4	17.1 (15.3–18.8)	34.7 (32.8–36.6)	22.4 (21.2–23.6)	—	576.3 (538.7–614)	447.7 (419.4–476.1)
Summer. F	113.5	134.3	145.0 (135.7–154.3)	188.5 (182.6–194.5)	141.4	13.9 (12.4–15.4)	29.0 (27.5–30.4)	17.1 (16.2–17.9)	—	192.1 (174.0–210.3)	463.7 (439.2–488.2)
Autumn: M	89.2	148.5	136.4 (125.9–146.8)	254.8 (247.0–262.6)	200.3	20.4 (18.6–22.2)	32.6 (30.9–34.3)	22.9 (21.7–24.1)	—	502.6 (464.5–540.6)	390.5 (369.5–411.6)
Autumn: F	110.8	145.4	120.3 (112.7–128.0)	192.9 (187.1–198.6)	134.9	17.3 (15.5–19.1)	27.8 (26.6–29.1)	17.6 (16.7–18.5)	—	150.8 (136.0–165.6)	411.4 (391.1–431.8)
Winter: M	98.2	148.6	136.8 (126.0–147.5)	248.1 (241.0–255.2)	199.1	20.1 (18.4–21.9)	33.1 (31.6–34.7)	23.3 (22.1–24.5)	—	482.6 (451.0–514.0)	429.8 (405.8–453.9)
Winter: F	108.9	142.0	134.4 (125.2–143.6)	184.5 (178.8–190.1)	132.1	16.6 (15.0–18.1)	27.6 (26.3–28.9)	17.5 (16.7–18.4)	—	156.2 (142.5–170.0)	463.7 (441.8–485.5)
Aged: 55–74									—		
Spring: M	87.8	166.4	148.0 (129.3–166.7)	261.4 (251.0–271.9)	197.5	23.8 (20.7–26.9)	36.6 (34.0–39.1)	23.9 (21.9–26.0)	—	445.8 (400.7–490.9)	445.8 (400.7–490.9)
Spring: F	108.2	158.5	147.9 (136.1–159.7)	208.6 (201.4–215.8)	136.3	19.5 (17.5–21.5)	29.7 (28.0–31.5)	18.7 (17.4–20.0)	—	120.6 (106.2–135.1)	491.9 (459.0–534.8)
Summer: M	97.9	184.6	146.6 (133.7–159.4)	250.5 (242.0–259.2)	181.6	19.7 (17.4–22.1)	34.7 (32.6–36.9)	25.3 (23.6–27.0)	—	480.2 (438.5–522.0)	480.2 (438.5–522.0)
Summer. F	128.7	175.7	149.1 (139.1–159.1)	207.8 (201.3–214.4)	135.9	15.8 (14.2–17.5)	29.6 (28.1–31.1)	20.3 (19.1–21.5)	—	129.6 (115.6–143.6)	424.1 (401.7–446.5)
Autumn: M	131.6	161.4	137.7 (124.5–150.9)	258.3 (249.6–266.9)	175.9	22.8 (20.5–25.1)	31.3 (29.3–33.2)	23.9 (22.3–25.5)	—	405.7 (370.1–441.4)	405.7 (370.1–441.4)
Autumn: F	136.0	153.0	145.7 (134.9–156.5)	208.7 (202.3–215.2)	132.2	19.3 (17.4–21.2)	27.1 (25.6–28.7)	18.8 (17.7–19.8)	—	117.7 (104.6–130.9)	452.7 (425.9–479.6)
Winter: M	114.1	152.8	150.4 (134.4–166.4)	259.8 (248.7–270.8)	177.6	27.1 (24.2–30.0)	33.6 (31.6–35.6)	25.0 (23.1–27.0)	—	394.9 (355.6–434.2)	394.9 (355.6–434.2)
Winter: F	138.9	141.3	141.5 (131.0–152.1)	202.2 (195.2–209.3)	130.9	20.2 (18.1–22.3)	28.1 (26.6–29.6)	19.4 (18.2–20.6)	—	115.1 (95.7–134.5)	476.9 (447.3–506.5)

Table 2. (Continued)

Study	Food groups									
	Fruit	Vegetables	Dairy products	Cereals and cereal products	Meat and meat products	Fish/seafood	Eggs	Oils and fat	Legumes	Alcoholic beverages	Non-alcoholic beverages
Heseker et al.[21a]											
Spring: M	76.9	156.7	182.2 ± 24.0	246.4 ± 14.2	192.6	17.7 ± 3.3	34.7 ± 3.5	23.4 ± 2.1	—	566.6 ± 76.1	572.4 ± 59.8
Spring. F	94.2	143.6	159.2 ± 515.1	192.9 ± 7.9	127.0	13.2 ± 2.2	29.3 ± 2.2	17.3 ± 1.3	—	173.0 ± 25.7	544.7 ± 40.7
Summer: M	98.3	149.6	172.1 ± 25.7	250.8 ± 13.8	180.7	20.7 ± 4.0	32.7 ± 3.4	24.5 ± 2.3	—	573.3 ± 68.1	538.4 ± 63.1
Summer: F	156.7	158.8	170.6 ± 17.9	187.1 ± 9.2	116.9	15.0 ± 2.7	27.1 ± 2.5	18.1 ± 1.6	—	167.2 ± 26.9	570.7 ± 41.3
Autumn: M	133.6	144.8	162.6 ± 27.7	259.3 ± 15.2	194.2	19.6 ± 4.0	26.1 ± 3.1	24.4 ± 2.5	—	418.3 ± 76.8	513.4 ± 58.7
Autumn: F	123.4	138.6	161.0 ± 20.7	198.2 ± 12.3	119.8	14.3 ± 3.1	25.0 ± 2.8	17.0 ± 1.5	—	129.8 ± 24.3	551.5 ± 57.3
Winter: M	95.9	131.7	192.8 ± 27.2	258.8 ± 15.7	179.6	20.7 ± 4.5	35.2 ± 3.7	25.1 ± 2.6	—	444.1 ± 57.1	500.3 ± 45.3
Winter: F	119.6	136.1	161.4 ± 15.2	187.6 ± 8.9	122.5	13.7 ± 2.4	27.9 ± 2.2	17.0 ± 1.2	—	147.5 ± 21.5	563.5 ± 45.2
Oguntona et al.[27]											
Dry season: M	53	277	10	96	4	49	4	23	35	14	359
Dry season: F	59	218	11	118	6	50	0	10	66	0	326
Rain season: M	356	463	15	231	15	74	2	12	30	70	219
Rain season: F	344	439	40	226	16	71	0	8	40	0	222

[a]Expressed as mean and 95% CI.

were presented stratified by gender. General eating habits were reflected in the overall amounts of food consumption. In Spanish men, fruits and dairy products were more often eaten in summer time, in contrast to Finnish and German populations, who ate higher amounts of fruit and dairy products in the autumn–winter time.[4,10,20,21] In general, cereals and cereals products and non-alcoholic beverages were more frequently consumed in the autumn–winter time[4,10,18] and alcoholic beverages in the spring–summer time.[20,21] Similar observations were also made for the rainy/dry seasons. Higher amounts were eaten in the rainy season compared with the dry season.[27]

In the meta-analysis of six studies,[4,10,17,18,20,21] we found significant associations between seasons in the consumption of the following food groups: spring–winter—fruits ($P < 0.0001$) (higher in winter), vegetables ($P = 0.006$), eggs ($P = 0.03$) and alcoholic beverages ($P = 0.0005$) (higher in spring); autumn–winter—cereals and cereals products ($P < 0.00001$) (higher in autumn); summer–spring—vegetable ($P = 0.02$) (higher in summer) and cereals and cereals products ($P = 0.0006$) (higher in spring); summer–autumn—fruits ($P = 0.006$) and cereals and cereals products ($P < 0.0001$) (higher in autumn), vegetables ($P = 0.02$), meat and meat products ($P = 0.04$), eggs ($P = 0.07$) and alcoholic beverages ($P < 0.0001$) (higher in summer) (Figures 2a–d); and spring–autumn—fruits ($P = 0.0002$), cereals and cereals products ($P = 0.03$) and alcoholic beverages ($P < 0.0001$) (Supplementary Figure 4—Supplementary information).

Limited data from the studies precluded a formal meta-analysis on the association between legumes intake and season, as well as on the association between food group consumption and pre-harvest, harvest and post-harvest seasons.

Seasonality in relation to energy intake

Energy intake across the seasons was reported in 15 studies, and the results are given in Table 3. In most of the studies, 24-h recalls were used to assess energy intake with the exception of seven studies, which used 7-day food records,[10,11,13,15,19,32,33] one study, which used 4-day food records,[32] and four studies, which used an food frequency questionnaire.[17,19,20,21] In 11 studies,[5,22,23,25–28,30–33] the energy intake was reported for the pre-, post- and harvest season. In these studies, the energy intake was the highest in the post-harvest season.[4,10–21] In 10 studies,[10–14,16–18,20,21] the energy intake was reported for the four seasons (spring, summer, autumn and winter) and in three studies[10,15,19] for two seasons (winter and summer or spring and summer), with the spring period being more strongly associated with higher energy intake.

In the quantitative meta-analysis of 10–13 studies across seasons, significant associations between energy intake and following seasons were observed: spring–summer ($P = 0.03$), winter–spring ($P = 0.006$) (favors higher energy intake in spring) (Figure 3) and summer–winter ($P = 0.03$) (Supplementary Figure 5—Supplementary information). In the meta-analysis of eight studies across pre- and post-harvest seasons, a significant association between season and energy intake (favors higher energy intake in post-harvest season) was observed ($P < 0.00001$) (Figure 3).

Significant heterogeneity was evident in the meta-analysis of food group analysis ($P < 0.001$). Visual inspection of the funnel plot revealed some degree of publication bias (Supplementary Figures 6 and 5—Supplementary information). Similarly, significant heterogeneity was observed in the models of energy intake in four seasons (summer, spring, autumn and winter) ($P < 0.0001$) and across pre- and post-harvest seasons. The funnel plots did reveal some publication bias (Supplementary Figure 7—Supplementary file).

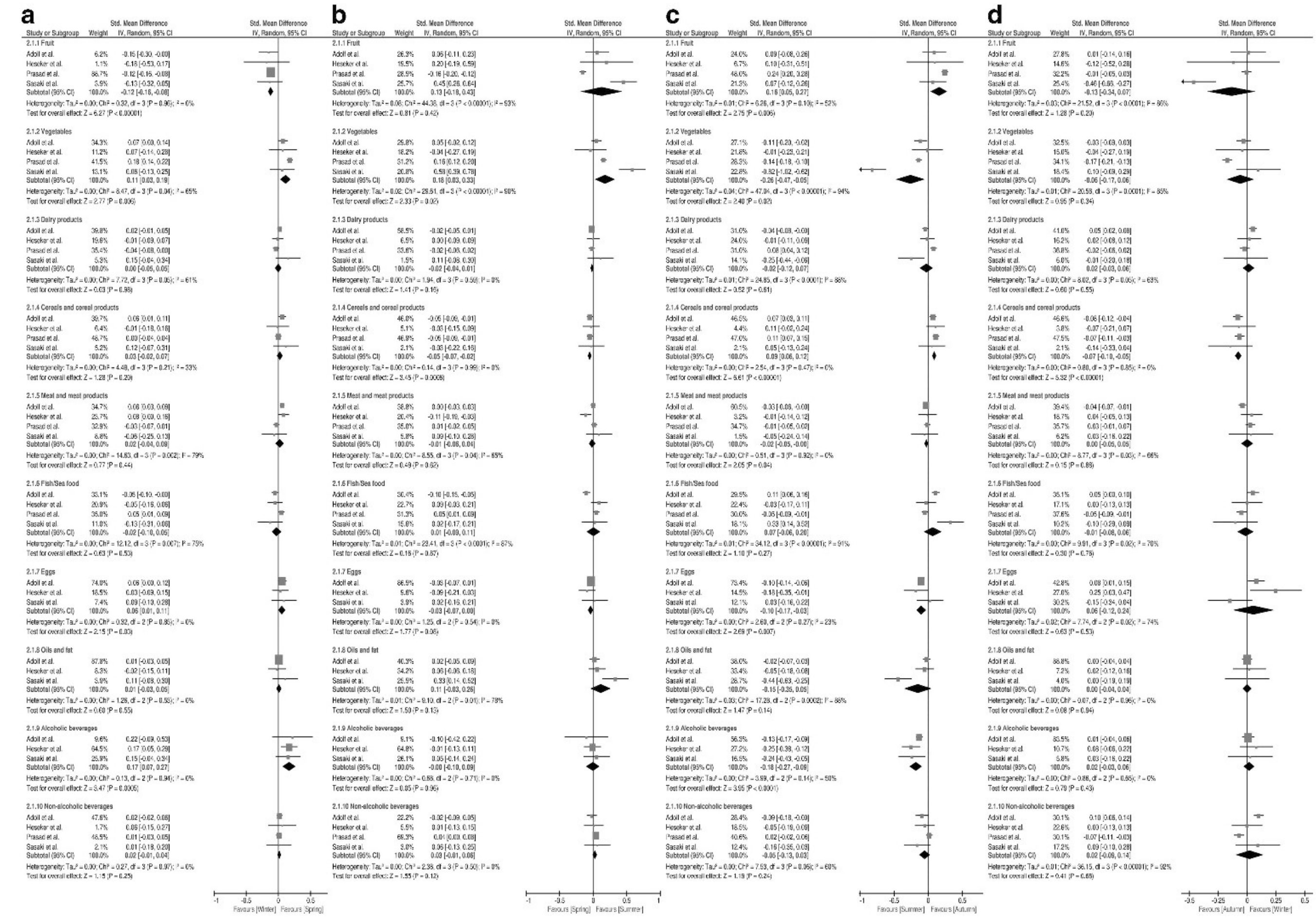

Figure 2. Forest plot for mean food intake change between (**a**) winter–spring, (**b**) spring–summer, (**c**) summer–autumn and (**d**) autumn–winter.[4,18,20,21] *For each study, the square represents the point estimate of the effect. Horizontal lines join lower and upper limits of the 95% CI of this effect. The area of shaded squares reflects the relative weight of the study in the meta-analysis. Diamonds represent the subgroup mean difference and pooled mean differences. CI indicates confidence interval (upper and lower limit),

DISCUSSION

This is the first systematic literature review and meta-analysis on the impact of seasons on food intake. Our results support the assumption that there is higher consumption of vegetables, eggs, alcoholic beverages, meat and cereals during spring–summer time and higher consumption of fruits and cereals in autumn–winter time. This is the first quantitative assessment to examine different food group's consumption as well as energy intake in relation to seasons across different studies via a quantitative meta-analysis.

In the systematic review, we have collected data from 21 different Nations. Nevertheless, a significant finding in our meta-analysis regarding an association between season and consumption of different food groups was reflected in the results of the single studies.[4,10,17] For example, Sasaki *et al.*[18] found a significant seasonal difference in the mean intake of vegetables, fruits and alcoholic beverages as well as Capita and Alonso-Calleja[10] and Prasad *et al.*[4] with the exception of alcoholic beverages. However, the observed differences in the consumption of selected food groups across the seasons in a study were probably related to local cultural habits and not consistent in respect to food groups involved and direction of differences across studies conducted in different dietary contexts. Thus, a higher consumption of hot non-alcoholic beverages in the autumn and winter in one study could be a likely reflection of the adjustment to the cold season not existing in each country and the consumption of fruits and dairy products to the hot season also not existing in each country.[7] In this context, it seems to be not surprising that we have observed a higher intake of alcoholic beverages in the spring–summer time, at which the intake of alcohol-rich drinks also increases.[20,21] Moreover, the broad availability of fruits across the year with higher intake of citrus fruits in cold seasons could strongly influence the results of our meta-analysis. However, we only considered larger food groups and not single foods that usually represent better seasonal production and thus also seasonal consumption due to amount and price reasons. Within the single food level there could be therefore even more detailed seasonal associations with food consumption. Moreover, the consumption of cereals and cereals products was statistically more pronounced in autumn and eggs in spring. The single results of Adolf *et al.*[20] and Heseker *et al.*[21] also confirmed this observation.

In our meta-analysis, we could observe that seasons are characterized by different energy intakes.[4,11–22,24] Significant winter/summer decreases in energy intake among Spanish men was mostly due to changes in food energy density.[10] In a US population, the highest energy intake was observed in autumn/winter time,[11,12,16] which confirmed that cold temperatures may be a stimulant of appetite associated with an increase in the basal metabolic rate. Nevertheless, the thermogenic effect of feeding is different depending on whether carbohydrates, proteins or lipids are consumed being small for fat when comparable caloric intake is considered.[34] Spring is the season that favors higher energy

Table 3. Mean energy intake across four seasons (spring, summer, autumn and winter; kcal per day)

Study	*Energy intake (mean ± s.d.)*				
	Spring	*Summer*	*Autumn*	*Winter*	*Method*
Capita and Alonso-Calleja[10]					
Males	—	2032.6 ± 508.7	—	2913.7 ± 433.3	7-day food records
Females	—	2080 ± 433.9	—	2186.6 ± 536.3	7-day food records
Fyfe et al.[11]					
Males	2225.8 ± 344.2	2488.8 ± 175.8	2505.5 ± 248.6	2174.2 ± 359.5	7-day food records
Females	2132.4 ± 233.8	1938.7 ± 145.7	1896.7 ± 166.9	1942.3 ± 248.6	7-day food records
Behall et al.[12]					
Males	2783 ± 194	2806 ± 209	2779 ± 200	2775 ± 196	24-h dietary recalls
Females	1863 ± 110	1791 ± 90	1879 ± 87	1861 ± 96	24-h dietary recalls
Arnaud et al.[13]					
All	1676 ± 473	1628 ± 473	1615 ± 437	1580 ± 442	7-day food records
Rao et al.[23]					
All		1665 ± 551.83		1863 ± 524.17	24-h dietary recalls
Rossato et al.[14]					
Males	2475	2450	2350	2550	24-h dietary recalls
Females	1890	2050	1950	1900	24-h dietary recalls
Nobmann et al.[24]					
Males	2500	2800	2600	2700	24-h dietary recalls
Females	1800	2000	2010	1975	24-h dietary recalls
Westerterp et al.[15]					
All	—	2031.55 ± 286.8	—	2246.65 ± 334.61	7-day food records
Prasad et al.[4]					
All	2722.8 ± 816.8	2722.8 ± 795.3	2770.6 ± 785.8	2722.8 ± 809.7	24-h dietary recalls
Y Ma et al.[16]					
All	1958 ± 22.9	1956 ± 23.5	1987 ± 23.4	1958 ± 22.9	Three 24-h dietary recalls
Fowke et al.[17]					
All	1692.8	1648	1665.1	1547.9	FFQ
Sasaki et al.[18]					
All	2447 ± 457	2466 ± 497	2491 ± 449	2415 ± 413	7-day food records
Amanatidis et al.[19]					
All	—	1949	—	1958.5	FFQ
Adolf et al.[20a]					
Males	2724 (1529–4448)	2730 (1386–4520)	2713 (1487–4320)	2670 (1490–4489)	FFQ
Femles	2047 (1034–3411)	2048 (998–3263)	2040 (1028–3270)	2015 (962–3315)	
Heseker et al.[21a]					
Males	2621 (1366–4255)	2518 (1242–4324)	2551 (1365–4044)	2540 (1349–4162)	FFQ
Femles	1968 (974–3234)	1958 (850–3388)	1911 (922–3236)	1964 (990–3073)	

Abbreviation: FFQ, food frequency questionnaire. [a]Expressed as mean and 95% CI.

intake in comparison with summer or winter. Probably during the summer time, energy density of food is lower than in spring, and observed higher physical activity within spring could be related to higher energy intake in comparison with winter.[20,21] Nevertheless, no differences of energy intake across seasons in Japanese and Finnish population can be recognized as a sign of high sustainability of diet in these populations.[4,18] The observed differences in energy intake in developing countries were not surprising even in view of improved food preservation techniques and increased exchange of foods through exports and imports.[4,11,22,25–33] Especially, if we take into account that changes in energy intake across pre- and post-harvest seasons are strongly associated with food availability.[27] It was interesting for us that our conclusion regarding energy intake can be also valid for populations living in the four-seasonal climatic zones (spring–summer–autumn–winter), specific for European and North American populations, as these populations are not characterized by limitations in the access to food.

Usually, when economic resources are limited, the link between energy intake and income is strong, and even small differences in income can lead to high inter-individual variation and potentially also seasonal effects.[22] This finding is seen in the nutritional data obtained from populations of Indonesia, Bangladesh, Mexico, Kenya and Egypt.[35–37] Subjects with low socioeconomic status

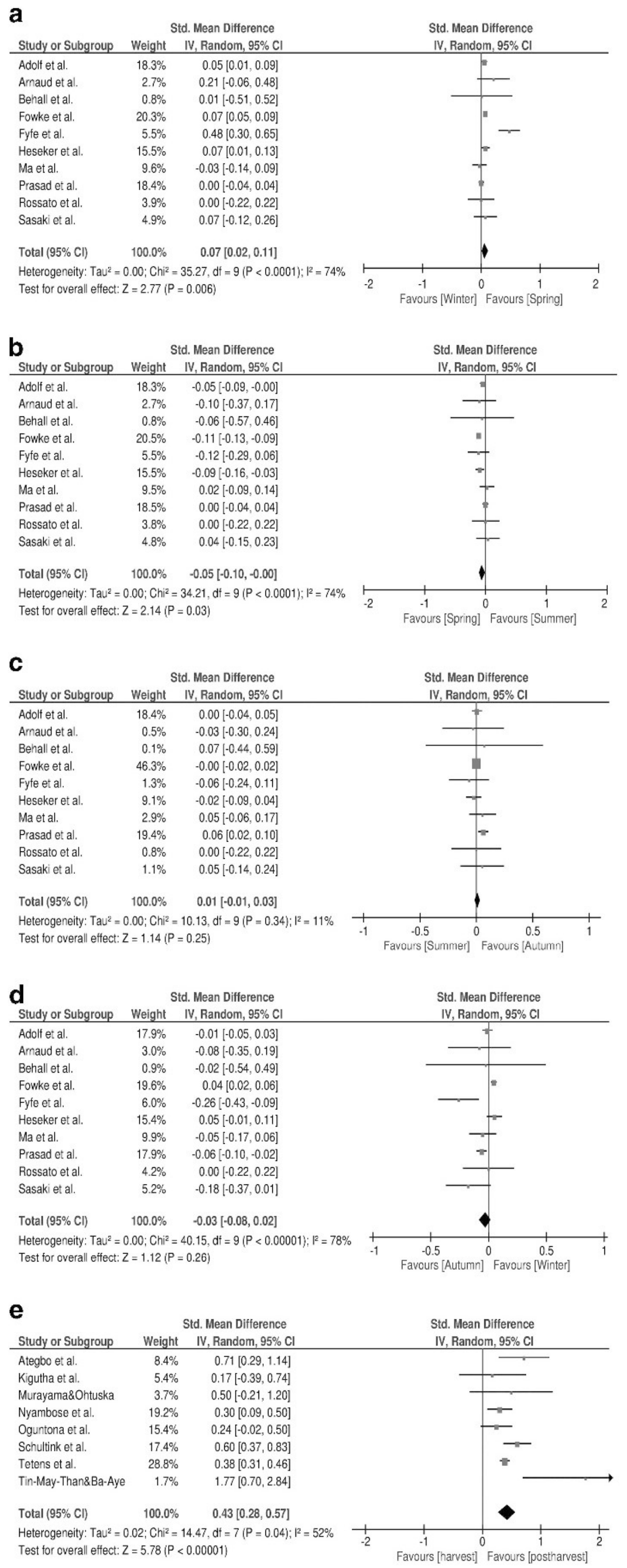

Figure 3. Forest plot for mean energy intake change across (**a**) winter–spring, (**b**) spring–summer, (**c**) summer–autumn, (**d**) autumn–winter[4,10–12,14,16–18,20,21,23] and (**e**) pre- and post-harvest seasons.[5,22,26–28,30,32,33] *For each study, the square represents the point estimate of the effect. Horizontal lines join lower and upper limits of the 95% CI of this effect. The area of shaded squares reflects the relative weight of the study in the meta-analysis. Diamonds represent the subgroup mean difference and pooled mean differences. CI indicates confidence interval (upper and lower limit).

may have an irregular food access—for example to animal products being consumed infrequently and result in higher or lower protein and/or fat intake in some of the days during the year. In European countries, seasonal intake of food could be incorporated in commonly used dietary counseling based on lifestyle modification in, for example, obese subjects to decrease the cost of diet modification.[38,39]

Limitations

There are few limitations of the systematic review. The difficulty in the conduction of presented meta-analysis was due to the existing different seasons across the world and heterogeneity in living conditions. The studies published in the gray literature (articles published in electronic or print format that are not controlled by commercial publishers, such as technical reports and similar sources) could be omitted. We have to take further under consideration that studies with statistically significant results are more likely to be cited by others and therefore easier to identify. Similarly, the restriction due to the English language might have affected the search process. Moreover, because of the limited published data some studies were not included into the meta-analysis. Visual inspection of funnel plot raised some concerns regarding a publication bias, indicating that there could be more information on seasonality than we could reveal.

CONCLUSIONS

In this meta-analysis, we observed a significant association between season and energy intake. In general, associations were found for different seasons: consumption of vegetables, eggs, alcoholic beverages and cereals was higher in spring and summer time and consumption of fruits and cereals was higher in autumn and winter time. Our study confirms the hypothesis that season is determinant of energy intake in adults. Although seasonal variation of food intake across seasons was observed, still methodological researches regarding a development of novel dietary assessment tools are needed to carefully investigate whether season should be taken into account in the design of nutritional assessment in the epidemiological studies.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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