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Circadian patterns of beverage consumption within the EPIC-Germany cohorts

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Summary

To identify circadian patterns of beverage consumption, also considering regional differences, we analyzed data from 24-h dietary recalls of 1,606 men and women (mean age 67 years) participating in the two German EPIC-study populations in Heidelberg and Potsdam from 2010 to 2012. We found that the first peak of fluid consumption occurs during the morning at breakfast-time, followed by two smaller peaks in the afternoon and during dinner-time. With respect to meal patterns, beverage consumption was low at lunch-time compared to breakfast- and dinner-time. Beverage intake during the evening was found to be of minor importance in regard to overall beverage intake and was mainly confined to alcoholic beverages, particularly in men. The results indicate that while men and women from the EPIC-Potsdam cohort consume more coffee, especially in the afternoon, and men consume more tea and beer, participants from the EPIC-Heidelberg cohort consume more wine, especially in the evening, as well as more soft drinks during lunch-time. Furthermore, the recommendation of the German Nutrition Society (DGE) to drink at least 1.5 l of low-energy beverages was only met by 50% of the participants from Potsdam and by 46% of the participants from Heidelberg. These and other findings suggest the necessity of strategies to improve the beverage consumption behavior in older adults in Germany, especially among men. Moreover, the present data indicate regional differences in drinking patterns in Germany.

Keywords: fluid intake, Germany, beverage consumption, water, adults, drinking behavior, circadian patterns

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Introduction

Information on beverage consumption throughout the course of the day is rarely available from studies with nutritional data. However, the circadian intake of foods and beverages deserves more attention as it has been suggested that the timing of consumption of energy as well as the ratio of macronutrients by food and beverages may influence the overall intake [1] as well as metabolic processes [2]. While beverages in particular provide the level of fluid intake vital for physical and mental health by accounting for approximately 70–80% of total fluid intake [3, 4], beverages may contain compounds such as various sugars, proteins, macro- and micronutrients, secondary plant compounds and possibly fibers [5, 6]. Furthermore, certain beverages such as soft drinks are energy-rich and contribute to a high proportion of total energy intake [3, 7]. Thus, in countries with moderate climate a beverage intake of 1.5 l per day per person is recommended, of which water and low-energy beverages should make up the largest proportion [8]. In order to gain a deeper understanding of the average daily beverage consumption, also considering study populations of different regional backgrounds, the beverage intake assessed by 24-h dietary recalls was analyzed within sub-studies of the German EPIC-study populations in Potsdam and Heidelberg.

Methods

Design and study population

The European Prospective Investigation into Cancer and Nutrition (EPIC) study is a multi-center

prospective cohort study that was initiated to investigate the associations between diet, lifestyle and chronic disease risk with a special focus on cancer. It consists of about 520,000 participants in ten European countries [9]. The German EPIC cohorts are built up of 25,540 participants from Heidelberg and 27,548 participants from Potsdam, recruited between 1994 and 1998, and mostly aged between 35 and 65 years at both centers [10]. During 2010–2012, a sub-sample of about 3,766 participants from the two German EPIC cohorts was re-invited to perform more extensive measurements of body composition, physical activity and dietary intake [11]. The sub-study participants comprised 3,791 men and women from the two active EPIC cohorts equally distributed across age categories (45–55, 55–65, 65–75 years) [12]. 1,615 thereof were finally included into the study. All participants provided written informed consent. The study was approved by the local ethics committees in Potsdam and Heidelberg and was mainly funded by the German Federal Ministry of Education and Research (reference number 01ER0808).

Assessment of beverage intake

Within a period of 12 months after the follow-up visit in the study center, three 24-hour dietary recalls (24 h DRs) were carried out by trained interviewers using the program EPIC-Soft. Study participants were thereby inquired – either in the study center or by telephone interview – about the type and quantity of foods and beverages consumed during the previous day concerning all consumed meals [13]. The food intake was enquired according to eleven predefined categories of consumption occasions for which also the time of food intake was recorded ("before breakfast", "breakfast", "in the morning", "before lunch", "lunch", "after lunch", "in the afternoon", "before dinner", "dinner", "after dinner", "in the evening"). Recipes and mixed dishes were fractionalized into the ingredient foods, using the program EPIC-Soft, and each food was assigned to the appropriate food group. A detailed description of the standardization and implementation of EPIC-SOFT has been described in detail elsewhere [14]. From the 17 main food groups in EPIC-Soft, two contain solely beverages: non-alcoholic beverages (water, juices, soft drinks, coffee and tea), and alcoholic beverages (wine, beer and liquor/alcoholic mixed drinks). Milk and dairy beverages form the food group "dairy products" were also included in the analysis of beverage consumption.

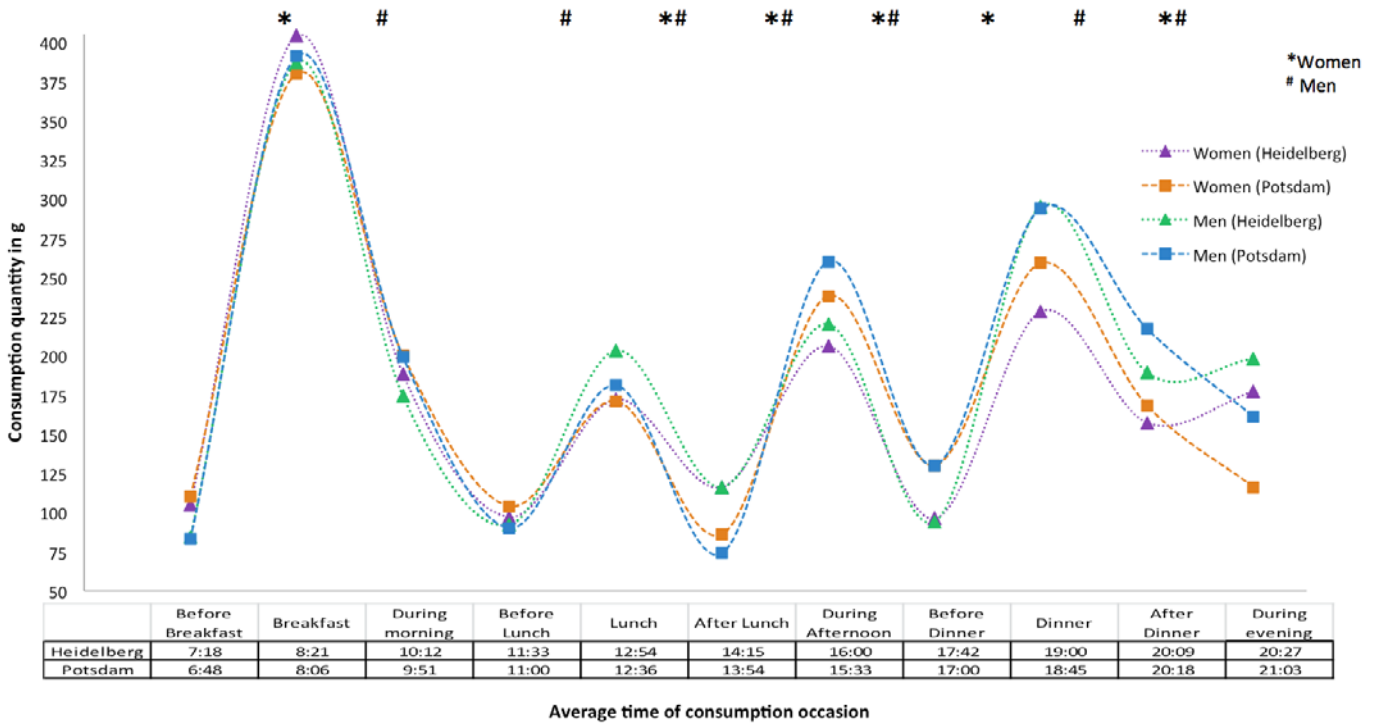
Assessment of anthropometric and sociodemographic variables

Anthropometric parameters (height, body weight and waist circumference) were obtained using a standardized protocol [12]. Body mass index (BMI) was calculated as weight/height^2 (kg/m^2). Sociodemographic variables, including age, gender and educational level, were assessed via a lifestyle questionnaire. Education was determined by using the highest educational level attained. Smoking status was subdivided into three categories ("never smoked", "formerly smoked" and "smoker"). Levels of daily physical activity were estimated using a combined heart rate and movement sensor (Actiheart, CamNtech, Cambridge, UK) [15]. The physical activity measurements were categorized into "sedentary or lightly active", "active or moderately active" and "highly active" [16].

Statistical analysis

The analysis at hand is based on the dataset of 1,606 participants (791 from Heidelberg, 815 from Potsdam) who completed at least one dietary recall. Descriptive statistics were performed for men and women separately in order to highlight gender-specific differences in beverage consumption. The eleven consumption occasions were summarized into five categories for the statistical calculation ("breakfast-time", "morning", "lunch-time", "afternoon" and "dinner-time/evening"). The beverage consumption was averaged for each participant across the three visits, whereby the statement "non-consumption" of an otherwise completely filled in recall was assigned "zero". The data is presented either as means and standard deviations (SD) or 95% confidence intervals (95% CI) for continuous variables, and as numbers and percentages for categorical variables. The differences of the selected characteristics between groups were compared using chi-square test (χ^2) (categorical variables) or student's t-tests (continuous variables).

Furthermore, the participants where categorized according to whether they met the recommendations of the DGE for daily beverage intake of 1.5 l (they should mainly consist of water and low-energy beverages) [8]. Beverages included in the analysis were water, tea and coffee (milk was subtracted if added). The value in g/day is then comparable to the recommended value in l. For the estimation of the usual intake a two-part model developed by the US National Cancer Institute was used [17]. The odds ratio (OR) for meeting the DGE recommendation for fluid intake (dependent variable) was assessed for several variables by logistic regression analysis adjusted for sex, age (years), BMI (kg/m^2), smoking status ("smoker", "formerly smoked", "never smoked"), leisure-time physical activity ("lightly active", "moderately active" or "highly active") and educational level ("low-qualified and with vocational training", "technical or medical education",



	Before Breakfast	Breakfast	During morning	Before Lunch	Lunch	After Lunch	During Afternoon	Before Dinner	Dinner	After Dinner	During evening
Heidelberg	7:18	8:21	10:12	11:33	12:54	14:15	16:00	17:42	19:00	20:09	20:27
Potsdam	6:48	8:06	9:51	11:00	12:36	13:54	15:33	17:00	18:45	20:18	21:03

Fig. 1: **Mean consumption of all beverages [g] throughout the day as average of three 24 h DRs per sex and study center, n = 1,606.** Data expressed as means. Comparisons between groups were tested by student's t-test, * and # denote p-values ≤ 0.05. 24 h DR = 24-hour dietary recall

"college/university"). The level of statistical significance was set at $p \leq 0.05$ for two sided testing. All analyses were performed with statistical software SAS (version 9.4; SAS EnterpriseGuide 6.1; SAS Institute Inc., Cary, North Carolina, USA).

Results

General characteristics of the study population

The mean age of the study participants was 67 (± 9) years. The study population was compared by cohort and gender regarding BMI, education, smoking status, physical activity and energy intake. Statistical significant differences were found for women from the Potsdam cohort who had a BMI higher by 1.3 kg/m² than women in the Heidelberg cohort as well as a higher total energy intake by 76 kcal/day. Men in Potsdam had an average higher daily energy intake by 230 kcal compared to men in Heidelberg. The proportion of non-smokers was higher among women in Potsdam, while there was a higher number of female former smokers in Heidelberg.

Overall circadian beverage consumption

The mean daily consumption of all beverages was circumstantially higher among men and women of the EPIC-Potsdam cohort with 1.96 kg/d compared to the consumption of the EPIC-Heidelberg cohort (1.95 kg/d). In total, men consumed more beverages than women: men from the EPIC-Potsdam cohort drank 2.08 kg/d, men from the EPIC-Heidelberg cohort drank 2.05 kg/d.

The circadian rhythm of beverage consumption in Heidelberg and Potsdam is depicted in ◆ Figure 1. For both men and women, differences between Heidelberg and Potsdam were as high as 20 to 60 g at individual consumption occasions. While women from Heidelberg consumed more beverages in total at breakfast-time, after lunch and during the evening, female participants from Potsdam consumed more beverages in the afternoon and till dinner-time. Male participants from the EPIC-Potsdam cohort consumed more beverages in the morning, in the afternoon and before as well as after dinner-time, whereas men from the EPIC-Heidelberg cohort consumed more beverages at lunch-time and afterwards as well as in the evening.

Fluid intake according to the DGE recommendation

50% of participants from Potsdam and 46% of participants from Heidelberg achieved the DGE recommendation of low calorie daily fluid intake. The respective odds for mee-

ting the recommendation for fluid intake was higher for women compared to men [OR: 2.66; 95 % CI: 2.14–3.32] (◆ Table 1). Men over 70 years of age had a higher chance for reaching the recommendation compared to younger men [OR: 1.65; 95 % CI: 1.13–2.42]. In addition, females with an active lifestyle had an OR of fluid intake of 1.80 [95 % CI: 1.20–2.74] compared to those with a sedentary lifestyle, as had female former smokers compared to women who had never smoked [OR: 2.07; 95 % CI: 1.49–2.86]. Interestingly, no differences were observed between overweight and normal-weight participants.

variables	all population (n = 1591)	women (n = 822)	men (n = 769)
gender (women vs. men)	2.66 (2.14–3.32)	/	/
center (Potsdam vs. Heidelberg)	1.17 (0.95–1.44)	1.27 (0.95–1.71)	1.13 (0.83–1.52)
age categories			
years < 60	1 (reference)	1 (reference)	1 (reference)
≥ 60 years < 70	1.17 (0.89–1.53)	1.17 (0.80–1.70)	1.19 (0.80–1.77)
years ≥ 70	1.38 (0.06–1.79)	1.19 (0.83–1.70)	1.65 (1.13–2.42)
BMI categories			
under- and normal weight	1 (reference)	1 (reference)	1 (reference)
overweight	1.10 (0.89–1.39)	1.11 (0.80–1.54)	1.13 (0.79–1.60)
obese	1.33 (1.00–1.78)	1.35 (0.90–2.02)	1.32 (0.87–2.03)
physical activity level categories			
lightly active	1 (reference)	1 (reference)	1 (reference)
moderately active	1.25 (0.96–1.64)	1.80 (1.20–2.74)	0.95 (0.66–1.37)
highly active	0.94 (0.51–1.73)	0.82 (0.35–1.93)	1.04 (0.49–2.41)
smoking			
never smoked	1 (reference)	1 (reference)	1 (reference)
formerly smoked	1.64 (1.31–2.06)	2.07 (1.49–2.86)	1.29 (0.93–1.79)
smoker	1.33 (0.95–1.88)	1.39 (0.87–2.22)	1.20 (0.72–1.98)
highest school level			
primary school completed	1 (reference)	1 (reference)	1 (reference)
technical/professional school	1.04 (0.78–1.40)	0.95 (0.64–1.43)	1.16 (0.74–1.80)
secondary school	1.28 (0.82–2.02)	1.10 (0.60–2.00)	1.54 (0.77–3.11)
longer education (incl. university)	0.79 (0.59–1.05)	0.73 (0.48–1.12)	0.84 (0.56–1.26)

Tab. 1: **Multivariable logistic regression of meeting the DGE recommendation for fluid intake by anthropometrical and sociodemographic variables, stratified by sex**
Data is expressed as odds ratios (OR) with 95 % confidence intervals (95 % CI) and adjusted for sex, age, BMI, smoking status, leisure-time physical activity and educational level.

Type of circadian beverage consumption

Women from both cohorts consumed a comparable amount of pure water in total (◆ Table 2), though participants from the Potsdam cohort had a higher consumption of water at breakfast-time yet a lower consumption of water at dinner-time and in the evening compared to women from Heidelberg. Female participants from Heidelberg consumed slightly more soft drinks during lunch-time and slightly more milk and dairy beverages at breakfast-time. For tea, female participants had a similar total consumption, however it could be noted that while women from the Heidelberg region consumed more tea at breakfast-time, women from the Potsdam region consumed more tea at dinner-time and in the evening. Female participants from the Potsdam cohort consumed more coffee as totaled for the day, especially in the afternoon when the consumption was twice as high. Yet during lunch-time, participants from the Heidelberg cohort consumed slightly more coffee. Women from the Heidelberg cohort consumed more wine in total, particularly at dinner-time and in the evening. Regarding fruit juices, beer and liquor/alcoholic mixed drinks, no differences could be seen in women.

The men from the two cohorts consumed comparable amounts of pure water as totaled for the day (◆ Table 3). However it could be noted that men from the Potsdam cohort had a higher intake during breakfast, yet a lower consumption of water during lunch-time and dinner-time/evening compared to Heidelberg. Male participants from the Heidelberg cohort had a higher soft drink consumption during lunch-time. Men from the Potsdam cohort drank more tea in total, particularly during dinner-time and in the evening. Similar to the Potsdam women, men from the Potsdam cohort consumed more coffee in total, especially in the afternoon when consumption was also twice as high, yet during lunch-time, men from the Heidelberg cohort consumed slightly more coffee. Milk and dairy beverages were consumed at higher amounts in the morning by the EPIC-Heidelberg cohort, while at dinner-time and in the evening men from the Heidelberg cohort consumed more milk and dairy beverages. As for wine, men from the Heidelberg cohort had a higher total consumption, as well as at lunch-time, dinner-time and in the evening. Inversely, men from the Potsdam cohort consumed more beer, especially in the morning and

type of beverage	breakfast-time		p value	morning		p value	lunch-time		p value
	Heidelberg	Potsdam		Heidelberg	Potsdam		Heidelberg	Potsdam	
water	90 (80–99)	104 (95–113)	0.03	165 (152–178)	178 (163–193)	0.2	150 (139–162)	145 (133–157)	0.51
juice	17 (13–21)	17 (13–20)	0.98	13 (9–16)	15 (12–19)	0.27	13 (10–16)	14 (11–17)	0.87
soft drinks	-	-	-	5 (2–7)	3 (1–5)	0.32	9 (6–13)	4 (2–6)	0.006
tea	127 (109–146)	83 (68–98)	0.0002	64 (51–76)	65 (52–78)	0.9	41 (34–49)	39 (30–47)	0.67
coffee	224 (207–241)	244 (229–258)	0.08	28 (22–33)	31 (25–37)	0.44	42 (36–48)	30 (24–36)	0.005
milk and dairy beverages	51 (44–57)	41 (35–48)	0.04	10 (7–13)	10 (6–13)	0.94	14 (11–19)	11 (8–14)	0.17
wine	-	0 (0–1)	-	1 (0–1)	1 (0–1)	0.77	10 (7–13)	7 (4–10)	0.15
beer only	-	-	-	0 (0–1)	1 (0–2)	0.17	3 (1–5)	6 (3–9)	0.13
liquor/ alcoholic mixed drinks	-	-	-	0 (0–1)	-	-	0 (0–1)	1 (0–2)	0.17

type of beverage	afternoon		p value	dinner-time/evening		p value	total (g/day)		p value
	Heidelberg	Potsdam		Heidelberg	Potsdam		Heidelberg	Potsdam	
water	141 (129–154)	137 (125–150)	0.67	283 (266–301)	246 (228–264)	0.003	830 (788–872)	810 (764–857)	0.54
juice	10 (7–13)	10 (7–13)	0.79	23 (17–28)	21 (17–26)	0.73	75 (63–87)	77 (67–88)	0.78
soft drinks	5 (3–8)	4 (2–7)	0.66	17 (10–24)	11 (6–17)	0.22	36 (24–49)	23 (71–16)	0.07
tea	56 (47–65)	54 (44–64)	0.74	97 (81–112)	140 (123–156)	0.0002	385 (445–525)	380 (340–420)	0.87
coffee	66 (58–74)	132 (122–141)	< 0.0001	7 (4–9)	5 (2–8)	0.41	366 (344–389)	441 (422–461)	< 0.0001
milk and dairy beverages	16 (12–20)	18 (14–21)	0.44	14 (9–18)	19 (13–25)	0.17	104 (92–117)	99 (87–110)	0.49
wine	5 (3–7)	6 (4–8)	0.3	72 (61–82)	46 (38–54)	0.0001	87 (76–99)	60 (51–69)	0.0003
beer only	3 (1–5)	5 (2–7)	0.26	39 (27–50)	47 (35–59)	0.32	45 (33–56)	58 (44–73)	0.15
liquor/ alcoholic mixed drinks	1 (0–1)	1 (0–2)	0.36	2 (1–3)	3 (2–4)	0.31	3 (2–5)	5 (3–7)	0.12

Tab. 2: Women: **Circadian consumption of different types of beverages as well as total daily consumption in "g/consumption occasion" or "g/day" as averages of three 24 h DRs, stratified by study center, n = 828.** Data expressed as means (95% confidence intervals). Comparisons between groups were tested by student's t-test. 24 h DR = 24-hour dietary recall

type of beverage	breakfast-time		p value	morning		p value	lunch-time		p value
	Heidelberg	Potsdam		Heidelberg	Potsdam		Heidelberg	Potsdam	
water	70 (60–79)	91 (83–100)	0.001	144 (128–160)	148 (134–163)	0.72	146 (133–159)	116 (105–127)	0.0005
juice	22 (17–27)	17 (13–20)	0.1	15 (11–20)	21 (16–27)	0.08	25 (19–30)	24 (18–30)	0.89
soft drinks	1 (0–2)	1 (0–2)	0.97	8 (3–14)	8 (4–11)	0.9	21 (14–29)	11 (7–14)	0.01
tea	104 (86–123)	103 (86–121)	0.95	41 (30–52)	43 (34–52)	0.81	25 (18–32)	31 (24–39)	0.23
coffee	222 (203–240)	220 (204–235)	0.88	42 (34–50)	47 (38–56)	0.43	50 (42–58)	27 (22–33)	< 0.0001
milk and dairy beverages	52 (44–60)	41 (33–49)	0.06	11 (7–14)	6 (4–8)	0.02	14 (10–18)	15 (10–19)	0.8
wine	-	-	-	-	1 (0–1)	0.1	12 (8–16)	5 (3–7)	0.004
beer	-	-	-	4 (0–8)	14 (7–21)	0.01	21 (14–27)	23 (17–30)	0.61
liquor/ alcoholic mixed drinks	-	-	-	0 (0–1)	0 (0–1)	0.62	0 (0–1)	1 (0–2)	0.2

type of beverage	afternoon		p value	dinner-time/evening		p value	total (g/day)		p value
	Heidelberg	Potsdam		Heidelberg	Potsdam		Heidelberg	Potsdam	
water	131 (118–145)	115 (103–128)	0.09	242 (221–262)	200 (182–217)	0.002	733 (684–781)	670 (625–716)	0.06
juice	18 (13–22)	15 (11–19)	0.36	35 (28–43)	34 (27–41)	0.83	115 (99–132)	111 (95–128)	0.75
soft drinks	12 (7–16)	9 (6–12)	0.38	30 (20–39)	21 (13–29)	0.18	72 (51–92)	50 (36–63)	0.08
tea	34 (26–42)	38 (30–47)	0.46	57 (45–70)	114 (98–130)	< 0.0001	262 (226–297)	330 (296–364)	0.006
coffee	73 (63–84)	152 (140–163)	< 0.0001	12 (7–17)	7 (4–10)	0.05	400 (369–429)	453 (428–477)	0.006
milk and dairy beverages	16 (13–20)	17 (13–20)	0.98	8 (4–12)	24 (17–31)	< 0.0001	102 (88–116)	102 (88–116)	0.97
wine	6 (3–9)	5 (3–7)	0.54	96 (81–111)	43 (34–52)	< 0.0001	115 (98–131)	55 (44–65)	< 0.0001
beer	20 (13–28)	35 (26–45)	0.02	165 (136–193)	212 (181–243)	0.03	210 (177–243)	285 (247–322)	0.004
liquor/ alcoholic mixed drinks	2 (0–4)	1 (0–2)	0.63	6 (3–9)	5 (4–7)	0.78	8 (4–12)	8 (5–10)	0.86

Tab. 3: Men: **Circadian consumption of different types of beverages as well as total daily consumption in "g/consumption occasion" or "g/day" as averages of three 24 h DRs, stratified by study center, n = 778.** Data expressed as means (95% confidence intervals). Comparisons between groups were tested by student's t-test. 24 h DR = 24-hour dietary recall

in the afternoon. For fruit juice and alcoholic mixed drinks, no differences were apparent in men.

Discussion

Analyzing the adherence to recommendations for daily fluid intake in two German cohort populations is especially relevant for public health measures. The finding that female participants of our study showed greater compliance with the recommendations as compared to men is consistent with the observation of a more health-conscious lifestyle pattern in women [18]. Furthermore, it has been demonstrated that adults with a healthier dietary pattern usually also show a healthier fluid pattern, which is especially associated with higher water consumption [19]. The better adherence to the recommendations of women with an active lifestyle can possibly be ascribed to their thereby increased fluid demand [3]. Men over 70 years of age were also more likely to reach the recommendations than men of younger age groups. This may be explained by a better awareness of fluid requirements.

The study results indicate that beverage consumption, especially in men, often includes beverages of low nutritional quality due to their additional energy content. Soft drinks and beer, for example, played a role in the habitual beverage consumption pattern of many study participants. Also regional differences could be observed between the cohorts located in the West and East of Germany in regard to beverages such as water, tea, coffee, wine and beer. The higher consumption of wine in the Heidelberg cohort and the higher consumption of beer in the Potsdam cohort had also been seen in previous evaluations of the EPIC study's baseline investigations [20]. Besides the high consumption of alcoholic beverages, it should be noted that high-energy soft drinks played a much bigger role in the Heidelberg cohort in comparison. Such differences in consumption patterns are believed not only to reflect food availability before German reunification but also different socially acquired nutritional behavior as well as distinctive regional cultivation of crops such as grapes in Heidelberg [21]. In a different study with population based surveys – MONICA in the east and VERA in the west – it was found that milk consumption was much lower in eastern Germany than in the western part [21]. Within this study milk consumption did not differ profoundly between the Potsdam- and Heidelberg-EPIC-cohort except for a three times higher consumption among men from Heidelberg at dinner-time and in the evening.

Similar to a British study, which also focused on the consumption pattern over 24 hours, we found that beverage consumption peaked at 8 a.m. (mainly tea and coffee) and that evening consumption was dominated by wine and beer, especially in men [22]. With respect to meal patterns, beverage consumption was low at lunch-time compared to breakfast- and dinner-time. However, some differences in the timing of meals were noted between the study cohorts: In Heidelberg, meals were consumed approximately 30 minutes later than were in Potsdam. The differences in eating and drinking patterns might have an impact on metabolic processes. The collection of metabolic parameters such as ghrelin, cholesterol and insulin levels in the course of the day could give initial basic information.

Limitations

The present study results can be considered as representative for individuals of middle and older age in Germany since the original study populations were drawn from the general population and equally represent men and women. Thus, the particular habits of younger individuals such as a high consumption of soft drinks might have remained undetected [23].

The results were primarily computed using a univariate analysis in order to keep the description of beverage consumption as the focal point. In place of a multivariate analysis, differences in beverage consumption due to anthropometric and sociodemographic characteristics in the study population were considered in the calculation of ORs in reference to the DGE recommendation.

The true value of beverage intake might be underestimated since water intake might not be reported accurately [24]. This also refers to alcohol consumption which is commonly under-reported [25]. Although the dietary intake data represent an estimation, the use of up to three 24-hour dietary recalls took into consideration intra-individual variations as well as long-term habitual dietary information of participants [26]. Besides study participant- and interviewer-specific measuring errors, a further limitation may lie in the overestimation of the mean values' standard variation of beverage consumption.

Conflict of Interest
The authors declare no conflict of interest.

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