Influence of food consumption and packaging on urinary Bisphenol-A level in a sample of Egyptian students

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Background/aim
Bisphenol A (BPA) is a high-production volume industrial chemical used in the manufacture of plastic products as polycarbonate and epoxy resin that line food cans. It has a hazardous effect on human health. This study aimed to investigate whether increased consumption of different food types and food packing will be associated with higher urinary levels of BPA or not, in a sample of Egyptian students.
Subjects and methods
A random sample of 125 Egyptian children and adolescents from 6–18 years old of different social levels was included. Participants were classified into two groups. The first group included participants less than 12 years old, and the second group included those 12 years or above. Sixty four participants were males, and sixty-one were females. Urine samples were analysed from the studied children and adolescents to assess urinary BPA levels.
Results
The present results indicated that urinary BPA levels were significantly increased in older adolescents (≥12 years) than those less than twelve years old (P=0.01). Higher juice consumption was significantly associated with higher BPA levels in urine (P=0.002).
Conclusions
Food consumption had no obvious effect on BPA levels except for juice consumption which has a significant influence on BPA secretion. Also, food storage and packaging had no significant role in BPA levels.

Keywords:
adolescents, Bisphenol A, children, food, urine

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Introduction

Bisphenol A (BPA) is an organic synthetic chemical. It's frequently utilized in the industrial manufacture of polycarbonate (PC) plastics and epoxy resins [1,2]. It is found in daily life stuff as reused bottles, electronic equipment, medical devices such as dental sealants and plastic containers. Epoxy resins are utilized in the internal coating of food and beverage cans to shield food and drinks from direct contact with metals [3]. People are subjected to BPA *via* several routes and sources. Diet has been established as the main source [4]. The consumption of canned food has been reported to contribute substantially to BPA exposure [5,6]. BPA comes mostly from the migration of can-packaging in canned meat products, [7]. Many plastics, paper, and glass-packed raw or cooked meat products are sold daily in butcher shops, supermarkets, and takeaway restaurants. BPA has been found in these non-canned meat products [8]. Experimental and human evidence suggests that BPA is a reproductive toxicant [9]. Higher risks of cancer have been linked to BPA exposure [10,11].

A recent study demonstrates that cardiovascular problems such as angina, hypertension, heart attack, and peripheral artery disease are common among citizens exposed to BPA for a long time [12] and childhood obesity [13]. Additionally, prenatal BPA exposure has also been associated with unfavorable neurobehavioral consequences in children [14].

Although the principal route of exposure to BPA is thought to be oral via diet, [15] dermal and inhalation exposure are also possible [16]. BPA is absorbed rapidly and excreted mainly in the urine as BPA conjugates. The urinary concentration of total (free plus conjugated) BPA has been used to assess the exposure level of BPA from all sources [3]. Most of the orally ingested BPA is turned into its conjugated forms while only a low level of unconjugated or free

BPA has been identified in serum and urine samples [17,18]. Children can be more prone to BPA exposure in daily life due to their consumption of plastic bottles or bottled beverages. BPA is also recognized as xenoestrogen due to its ability to simulate estrogens in the human body. This is mostly due to the resemblance of phenol groups present in BPA and estrogen causing the synthetic compound to intervene with and promote the estrogenic pathways. This is attained by the attachment of BPA to estrogen receptors (ER) such as ERα, and ERβ. Even with being a selective modulator for estrogen receptors, too much BPA can bind freely with androgen receptors as well [19].

The aim of this study is to evaluate whether increased consumption of various food types and food packing will be associated with higher urinary levels of BPA or not in a sample of Egyptian students.

Subjects and methods

Patients

A random sample of 125 children and adolescents from 6-18 years old of different social levels was included. Three public and two private schools following the Egyptian Ministry of Education, and the directorate of schools in Cairo, Egypt, that participated in the research were chosen using a list of random numbers. In the preparatory schools, students from the 1st to 3rd grades were recruited. In the primary schools, students from the 4th to the 6th grades were recruited to be able to answer the interviewer's questionnaire. In each school, students were recruited according to systematic random sampling. Each child was given a numbered card to prove his/her inclusion in the project. This study was derived from a cross sectional survey of a project funded by National Research Centre (NRC) Egypt, 2016–2019 entitled 'The potential effects of exposure to Bisphenol A – an endocrine disrupting agent on neonates, children and adolescents health', included 201 children and adolescents.

Urinary levels of BPA may be a good indicator of BPA daily exposure [4]. This is because it has a short terminal half-life of 3–6 h. [20] It was found that the glucuronide conjugates of BPA are excreted within 24 h [21]. On this basis, we investigated the exposure of Egyptian children to BPA by estimation of BPA concentration in spot urine samples [22].

Children were disqualified if they had a history of liver disease, renal diseases, and thyroid disorders, endocrinal or genetic obesity. Also, children whose parents or guardians refused to participate were excluded.

Study design

In this descriptive cross-sectional study, the total number of the recruited population was 201 students. According to the availability and integrity of urine samples the actual studied number was 125 participants. They were classified into two groups according to age. The first group included participants less than 12 years old, and the second group included those 12 years or above.

Ethical consideration

The present study was conducted with the Code of Ethics of the World Medical Association, according to the principles expressed in the Declaration of Helsinki. The survey; from which this study was derived; has been approved by the local Ethics Committee of National Research Centre, Cairo, Egypt with approval number 16368. In addition, ethical approvals were obtained from the Egyptian Ministry of Education, and the directors of schools that participated in the research. Written informed consents were obtained from the parents and oral one from each student included in the research.

Methods

Personal history and physical examination were performed. Urine samples were collected from 201 children and adolescents. Forty-six samples were lost during transportation, and the rest were stored at –70 until assays. The integrity of 30 urine samples was potentially compromised due to a freezer malfunction, leaving a total of 125 urine samples for analysis. Urinary BPA levels were classified into two categories ($<$1.3 ng/ml,$\geq$1.3 ng/ml).

Estimation of urinary BPA concentration

The concentration of total species of urinary BPA was determined by HPLC (high-performance liquid chromatography), Agilent technologies 1100 series, equipped with a quaternary pump (G131A model), according to the method described by Alkaranfilly *et al.*, [23] and modified by Mohsen *et al.*, [24].

Determination of urinary creatinine

Urinary creatinine was determined and BPA concentration was adjusted to the urinary creatinine concentration to correct for the urine dilution [25]. The log total BPA, BPA/creatinine, and log BPA/creatinine were estimated. Urinary BPA and BPA/

Creatinine levels were log-transformed to improve normality of the distribution.

Analysing the relation of urinary BPA with different types of food consumption and food storage using the twenty-four hours recall

Each child and/or parent enrolled in the study was subjected to:

Filling out a structured questionnaire which included:

Assessment of Dietary intake through the 24-hours recall method. It is considered as a qualitative and quantitative method for identification of different food items and beverages consumed by each child [26].

Assessment of frequency intake of possible BPA dietary sources: Specific food frequency questionnaires which included the monthly ingestion of canned food and beverage, e.g., canned fruits, vegetables, soft drinks, and fast food.

Assessment of certain hazardous habits: These included the storage of food and water in plastic boxes or jars, the usage of plastic microwave utensils, the reuse of plastic water bottles, and drinking water from plastic tanks.

Statistical analysis

Statistical analysis was performed using the SPSS program (statistical package for social sciences) version 21 for windows (IBM Corp., Armonk, NY, USA). Categorical data were expressed as frequencies and percentages and were analysed with the two-tailed χ^2 test. We used BPA level of 1.3 μg/ml as the cut-off [27]. P value<0.05 was accepted as statistically significant.

Results

The total number of the studied population was 125. They were classified into two groups according to age. The first group included participants less than 12 years old, and the second group included those 12 years or above.

Table 1 shows the actual number of analysed samples (explained in patients and methods; 104 (51.7%) of participants had urinary total BPA level <1.3 ng/ml, while 21 (10.4%) had urinary BPA level ≥1.3 ng/ml.

Table 1 Categorization of Urinary Bisphenol A levels in the analyzed samples

Urinary total BPA levels	*N* (%)
<1.3 ng/ml	104 (51.7%)
≥1.3 ng/ml	21 (10.4%)

Table 2 shows the relation between urinary BPA levels and the two age groups. The number of studied children aged less than 12 years was 59 (47.2%) and 66 (52.8%) for those aged 12 years or more. It also shows that 64 (51.2%) were males and 61 (48.8%) were females; higher BPA levels were associated with the elder group, and that was statistically significant (P<0.05), while it was not significant on comparing with gender.

The data presented in Table 3 shows that there was insignificant difference between urinary BPA levels and different drinks and food consumption, except

Table 2 Association of Urinary Bisphenol A levels with age and sex

	BPA<1.3 ng/ml	BPA≥1.3 ng/ml	*P* value
Age:			
<12 years	54 (91.5%)	5 (8.5%)	*P*=0.019*
≥12 years	50 (75.8%)	16 (24.2%)	
Sex:			
Male	55 (85.9%)	9 (14.1%)	*P*=0.402
Female	49 (80.3)	12 (19.7%)	

*Significant difference using two-tailed χ^2 test at P<0.05.

Table 3 Association of Urinary BPA levels with 24 h Drinks and Food Consumption

24 h Drinks	BPA<1.3 ng/ml	BPA≥1.3 ng/ml	χ^2	*P* value
Milk				
Yes	37 (88.1%)	5 (11.9%)	1.084	0.298
No	67 (80.7%)	16 (19.3%)		
Juice				
Yes	1 (25%)	3 (75%)	10.014	0.002*
No	103 (85.1%)	18 (14.9%)		
Soft Drinks				
Yes	6 (85.7%)	1 (14.3%)	0.034	0.855
N0	98 (83.1%)	20 (16.9%)		
Processed Meat:				
Yes	8 (100%)	0 (0%)	1.726	0.189
No	96 (82.1%)	21 (17.9%)		
Animal Protein:				
Yes	30 (81.1%)	7 (18.9%)	0.169	0.681
No	74 (84.1%)	14 (15.9%)		
Carbohydrate:				
Yes	66 (81.5%)	15 (18.5%)	0.486	0.487
No	38 (86.4%)	6 (13.6%)		
Eggs:				
Yes	16 (84.2%)	3 (15.8%)	0.225	0.636
No	96 (82.8%)	20 (17.2%)		
Chips consumption				
Yes	36 (76.6%)	11 (23.4%)	2.35	0.125
No	68 (87.2%)	10 (12.8%)		

* Significant difference using two-tailed χ^2 test at P<0.05.

Table 4 Association OF Urinary BPA levels with Food Storage Utensils and Water Usage

	BPA<1.3 ng/ml	BPA≥1.3 ng/ml	χ^2	*P* value
Plastic Boxes:				
Yes	52 (77.6%)	15 (22.4%)	3.226	0.072
No	52 (89.7%)	6 (10.3%)		
Plastic Jars:				
Yes	44 (77.2%)	13 (22.8%)	2.705	0.100
No	60 (88.2%)	8 (11.8%)		
Source:				
Tap Water	89 (82.4%)	19 (17.6%)	0.367	0.550
Bottled Water	15 (88.2%)	2 (11.8%)		
Reused Water Bottles:				
Yes	84 (86.6%)	13 (13.4%)	3.577	0.059
No	20 (71.4%)	8 (28.6%)		
Reused Plastic Containers:				
Yes	40 (85.1%)	7 (14.9%)	0.196	0.658
No	64 (82.1%)	14 (17.9%)		
Storage in Water Tanks:				
Yes	22 (91.7%)	2 (8.3%)	1.523	0.217
No	82 (81.2%)	19 (18.8%)		
Storage in Plastic Containers:				
Yes	76 (80%)	19 (20%)	2.900	0.089
No	28 (93.3%)	2 (6.7%)		

Insignificant difference using two-tailed χ^2 test at $P>0.05$.

for juice which showed a significant difference as 1 (25%) of the participants consuming juice had BPA level<1.3 ng/ml and 3(75%) of the participants had BPA≥1.3 ng/ml while 103(85.1%) of the non-consumers have BPA level <1.3 ng/ml and 18 (14.9%) had BPA≥1.3 ng/ml ($P<0.05$).

Table 4 shows the relationship between urinary BPA levels and different food storage behaviors as well as different sources of water and the different ways of water storage, where there were insignificant differences.

Discussion

Exposure of children to BPA is of concern nowadays as its hormonal effect may be harmful to children. This agent is found in several types of food and is also affected by food packaging.

We investigated the influence of certain types of food and food packaging on increasing secretion of urinary BPA levels.

In this study, higher BPA levels were detected in the older group of patients (≥12 years), and that was statistically significant. This may be explained by higher consumption of adolescents of fast food and canned food. Conflicting with our results, Zota *et al.* [28], found that there is insignificant difference between BPA and age. This discrepancy is because in that study, all participants were less than six years old, so they used different age group from our study. Moreover, we found no significance on comparing with gender. This is in accord also with Zota *et al.* [28], who found no significant difference between BPA and sex of patients. Similarly, Rudel *et al.* [29] found that sex had no significant effect on BPA secretion.

In our study, there was no statistically significant difference between urinary BPA levels and different drinks consumption (milk and soft drinks) while there was a significant difference in juice consumption. This may be explained by presence of BPA in the lining of juice boxes. A study by Khan *et al.* [30], stated that fruit juice is a considerable dietary source of BPA, however, exposure was observed to be lower than the values set by the regulatory agencies. Also, it depended on type of packaging material. Also, Geens *et al.* [31], stated that juice samples packed in retort pouch contained higher BPA levels than tetrapak samples.

Further studies on a larger scale are needed to investigate this finding as there aren't many studies showing the effect of juice consumption on urinary BPA, including difference in packaging and different additives. Regarding food consumption, our study found no significant difference with urinary BPA levels, This was contradicted by Mitsuru Yoshida *et al.* [32], who found that; among crude enzyme

solutions of fruits and vegetables, the crude enzyme prepared from potato (Solanum tuberosum) had the highest oxidative activity on BPA; as in chips manufacture. The monoquinone derivative of bisphenol A was the chief product obtained by enzymatic oxygenation, accompanied by a small amount of the bisquinone derivative. They concluded that the oxidation reactions found in the study would help to develop procedures for eradication of phenolic endocrine disrupters from the environment.

On the other hand, processed meat, eggs, animal protein, and carbohydrate consumption had no significant impact on urinary BPA levels. Similarly, Geens *et al*. [4] found no significant association between total fast food consumption and urinary BPA levels. Another study done in Canada by Quiros-Alcala *et al*. [33], reported low levels of BPA in fast food composite samples, except for that in Hamburger. On the contrary, Zota *et al*. [28] found significant association between fast food meat consumption and BPA levels. Furthermore, they also reported that low egg intake was significantly correlated with BPA levels.

In conflict with our study, Mervish *et al*. [34] found that increased fish, poultry consumption, and flour in dry mixes (including rice and oatmeal) were positively associated with BPA urinary levels. This discrepancy may be because our participants mostly ate fresh proteins as fish and poultry, but in that study, participants ate canned and processed protein. Canned fish accounts for 30% of fish consumption [32]; different food behavior may be the cause of this discrepancy. Furthermore, an Egyptian study performed by Nahar *et al*. [35] examined the connection between canned food consumption and unadjusted log-BPA concentrations, and it was not statistically significant. Siddique *et al*. [7] stated that canned meat products considerably contribute to total BPA exposure. This is explained by passage of BPA during processing from the can coating materials to the solid parts of meat.

Our study also investigated the relationship between urinary BPA levels and different food storage behaviors (plastic boxes and plastic jars) which was found non-significant. This is in agreement with a study performed by Mervish *et al*. [34], who found no association of BPA urinary levels and intake of food or beverages in plastic packaging. Unlikely to our study Rudel *et al*. [29], reported reduction in BPA concentration with limited food packaging. Also, the Egyptian study by Nahar *et al*. [35], found a significant correlation between log-BPA concentrations and stored food in plastic containers.

Our study also found no statistically significant difference between BPA levels and different sources of water (whether tap or bottled water) or the way of water storage (whether reused water bottles or water tanks or plastic containers). This is in agreement with Rudel *et al*. [29] who reported a higher concentration of BPA in spite of limited use of his participants for water bottles. They added that canned food and beverages and restaurants meals were the most probable sources of BPA. Ginter-Kramarczyk *et al*. [36], verified that bisphenol A can pass from the bottle packaging into water. Trace amounts of BPA were identified in each analyzed bottled water exposed to a certain temperature which confirmed their results.

In Egypt, using canned food is of limited use, so we cannot estimate accurately its influence on BPA levels. Lastly, Diet is not the sole source of BPA levels in urine. Many factors influence BPA levels in urine as air pollution, manufacture of food, food covering, and food storage. That must be considered with evaluation of BPA levels. Thus, we need further studies to assess this substance well and to correlate its concentration with other factors that may play a role in its production.

Conclusions

This study detected higher BPA levels in the older group of patients. Food consumption had no obvious effect on BPA levels except for juice consumption which has a significant influence on BPA secretion. Higher juice consumers had significantly increased levels of BPA in urine. Also, food storage and packaging had no significant role in BPA levels.

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Conflicts of interest

There are no conflicts of interest.

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