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REVIEW

The effect of sodium restriction on iodine prophylaxis: a review

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Abstract

Purpose Sodium is essential to life. However, its dietary excess is detrimental to the cardiovascular system, and sodium restriction is a crucial step in cardiovascular prevention. Iodine deficiency has been fought worldwide for decades, and substantial success has been achieved introducing the use of iodine-enriched salt. Nevertheless, areas of iodine deficiency persist around the world, both in developing and industrialized countries, and a major concern affecting dietary sodium reduction programs is represented by a possible iodine intake deficiency. There are substantial differences in the source of alimentary iodine among countries, such as iodized salt added, household tap water, seafood, or salt employed in packaged food. It is clear that a sodium-restricted diet can induce differences in terms of iodine intake, depending on the country considered. Moreover, iodine status has undergone relevant changes in many countries in the last years.
Methods Systematic review of literature evidence about the possible effects of sodium restriction on population iodine status.
Results To date, the available results are conflicting, depending on country, salt iodization policy, as well as time frame of data collection. However, to ensure an optimal iodine supply by salt fortification, without exceeding the current recommendation by World Health Organization for salt intake, seems to be an achievable goal.
Conclusion A balanced approach may be obtained by an adequate iodine concentration in fortified salt and by promoting the availability of iodized salt for household consumption and food industry use. In this scenario, updated prospective studies are strongly needed.

Keywords Iodine · Salt · Sodium · Iodine deficiency · Sodium restriction

Introduction

Dietary sodium restriction represents the standard non-pharmacological approach to hypertension [1–5]. Sodium, the main source of which is table salt, is a primary nutrient essential to life. However, its excess is detrimental to the cardiovascular system [6–8], and high salt consumption is associated with hypertension, as well as increased prevalence of cardiovascular diseases [5]. On the other hand, sodium reduction is crucial for cardiovascular prevention [1–4].

Nevertheless, the effectiveness and the safety of dietary sodium reduction in the general population are still debated [9–12]. Iodine deficiency, in contrast, is a definite basic trouble for humans since millions of years [13]. Iodine is essential to the thyroid function. Furthermore, iodine deficiency not only affects the thyroid physiology itself, but also causes growth and neurodevelopment retardation, as well as neurologic and cognitive deficits in children. Since the beginning of the last century, first in the US [14], iodine supplementation has been undertaken by law, with the addition of sodium iodide to table salt. In the following decades, iodine deficiency has been fought relentlessly worldwide, and substantial success has been achieved [15]. Nevertheless, iodine deficiency still persists around the world, in both developed and developing countries [16]. Despite the first law dates to the middle 1920s, being approximately one-hundred-year old, a nation-wide salt iodization program in Italy has been implemented only at the beginning of the

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twenty-first century [17]. Noteworthy, iodine sufficiency (IS) appears worldwide a fragile condition [18]: the main concern affecting dietary sodium restriction programs is indeed represented by a possible iodine intake deficiency [19]. The evaluation of iodine status did not show homogeneous data in hypertensive patients under low sodium diet [20, 21]. Urinary iodine excretion (UIE), based on 24-h urinary collections, iodine/creatinine excretion ratio, or spot morning urine sampling, is the most widely used biomarker to assess the IS, but it is worth underlining that it reflects the recent dietary intake of iodine, as it can change depending upon daily iodine intake [22]. In order to overcome the inter- and intra-individual variation of urine iodine concentration, it is crucial to manage large sample size in order to estimate the real iodine status [23–29].

Areas of iodine deficiency are still present around the world, both in developed economies and in low- and middle-income countries [30]. The main difference among geographical regions relies on the source of alimentary iodine, such as fortified salt added during cooking or at the table, household tap water, seafood, or salt employed by the food industry [31]. It seems clear that a low sodium diet, involving a restriction of added salt, or preserved and packaged foods, can induce large differences in terms of iodine intake, depending on the country observed.

The present review aims to evaluate by literature search the available evidence about the possible impairment of iodine prophylaxis programs due to dietary salt reduction in the population.

Materials and methods

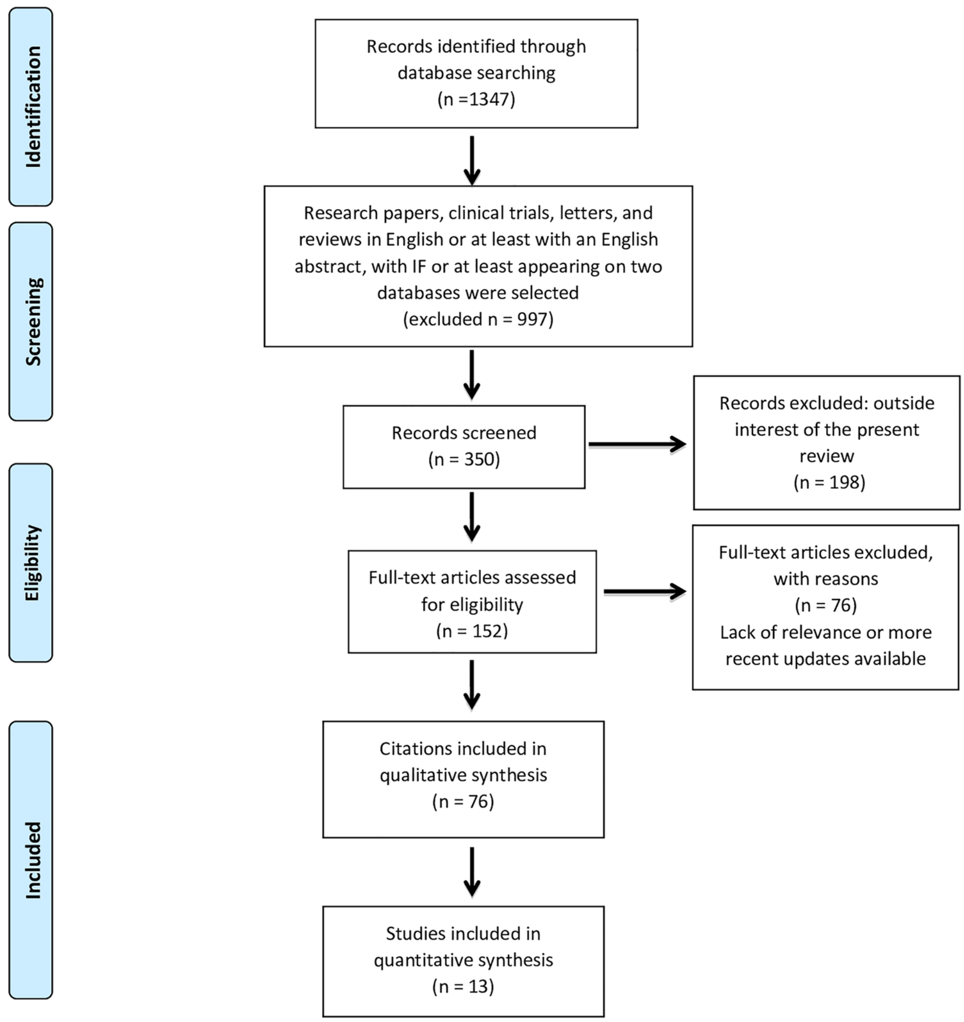
A systematic review of the literature on Web of Knowledge (ISI, Clarivate™), PubMed/Medline (NIH/NLM), and Scopus (©2021 Elsevier) databases was performed with the keywords “diet or intake”, “restriction or reduction”, “iodine status”, “iodine sufficiency or deficiency”, and “sodium or salt”. Usual Boolean operators linked the terms employed. Search results ranged from 1928 to November 2021. The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) Statement guidelines were followed [32] and 1347 results were analyzed. Research papers, clinical trials, letters, and reviews in English language or at least with an abstract in English language published in journals with a certified impact factor (IF), or at least appearing in two different databases were selected. Furthermore, duplicates, anecdotal reports, and, where possible, editorials, as well as personal opinions were discarded. After the initial restrictions were applied, 350 papers were screened and, among these, 198 manuscripts were excluded because they were outside the scope of this review. Overall, 152 full-text articles were assessed for eligibility and were analyzed independently by two author teams. A third author discussed and resolved the controversies and only the papers selected by both teams were considered for the present review. A total of 76 citations were finally selected, the oldest dating to 1928. Selection criteria included manuscripts concerning dietary advice/education/habit, food analysis, iodine intake, iodine excretion, iodine status, salt consumption, sodium excretion, and dietary sodium restriction/reduction. Then, a quantitative analysis was performed, and 13 papers [20, 27, 33–43] (7 population studies [20, 34, 35, 38, 41–43], 3 studies based on a simulation model [33, 36, 37], 2 randomized controlled trials (RCTs) [27, 40], 1 cohort study [39]) presented both inclusion criteria and relevant results to be discussed considering the aim of the present review. In detail, studies involving highly selected categories such as pregnant women (at higher risk of both iodine deficiency and hypertension), and articles not dealing with iodized salt or made in countries not using it (for example, South Korea), were not considered. Reports with inconsistencies in the description of the study design and/or their results were also excluded. Furthermore, studies based on populations undergoing special diets were not recorded, except for one analysis dealing with a Paleolithic-type diet [13] (included in the discussion but not in the results). In addition to the selected papers, publications by the World Health Organization (WHO), by the Iodine Global Network (IGN) websites, and guideline citations have been included. Finally, the website of the Italian Ministry of Health has been cited, as well. The flow diagram reporting study identification, screening and inclusion is depicted in Fig. 1.

Results

The main characteristics of the 13 studies that have been analyzed in detail (i.e., country, time of data collection, iodine content of iodized salt) are summarized in Table 1. As shown, these studies have been performed in distinct epidemiological settings and in countries applying different programs in terms of both lowering sodium consumption and promoting iodine supplementation among the population. Moreover, data have been recorded over a large time span. In each country, the beginning of initiatives undertaken to promote salt iodization, without increasing salt consumption, should be taken into account. Specifically, the time of data collection (from 1997 to nowadays) rather than the publication years has been considered.

As shown in Table 1, out of the 13 papers selected, 7 were population-based studies, 3 simulation studies, 2 RCTs and 1 a cohort study. Based on the study design and the number of subjects involved, 3 population studies [20, 42, 43], 2 simulation studies [33, 36] and one RCT [27] may be classified as high-quality studies in the present review.

Fig. 1 Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2009 flow diagram selection of the literature search from PubMed. The papers were sorted on the basis of the inclusion and exclusion criteria detailed in the manuscript. Modified from Moher D, Liberati A, Tetzlaff J, Altman DG, The PRISMA Group (2009) Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement. PLoS Med 6(7): e1000097. https://doi.org/10.1371/journal.pmed.1000097



Out of 13 studies assessed, 12 aimed to directly evaluate whether a low sodium dietary intake could affect the iodine status. With all the above-mentioned limitations affecting a direct comparison of the different studies, 3 manuscripts identified a possible link between a lower sodium intake and an increased prevalence of iodine deficiency. In detail, this connection was observed in Italian children and adolescents [41] and in the population of North European regions [33, 42]. Conversely, 9 studies did not find a worsening in the iodine status in the setting of low sodium intake. These results were obtained in the US population [20], in Italian adults [36, 39], in a post hoc analysis of a Dutch study [40], in adults and children living in Northern China [27], in Australia (especially in Native Australians) [35, 37], and among South African and Ghanaian adults [34, 43]. In one manuscript evaluating young women in Samoa [38], no relationship was found between urinary sodium and iodine excretion, but it has to be highlighted that in the Pacific region the level of salt consumption (iodized and non-iodized) is largely unknown, and data on iodine nutrition are sparse. It is worth noting that in the three studies [33, 41, 42] in which lower sodium intake resulted in inadequate iodine supply, iodine status at the baseline was suboptimal. Moreover, in two of these studies, iodine concentration in table salt was as low as 20 mg iodine/kg salt.

Discussion

Iodine deficiency is as old as the humankind [13]. Nowadays areas of iodine deficiency still persist around the world, despite many nationwide supplementation programs [14–17].

Iodine consumption is generally assessed by urinary iodine concentration, especially with spot urine samples (due to the greater feasibility), with 24-h urinary collection, or using the iodine/creatinine ratio. More heavily than sodium, iodine intake shows a high daily inter- and intra-variability, therefore it is crucial to collect large sample size in population studies to estimate the real iodine status [23–29].

Table 1 Detailed characteristics of the 13 studies included in the quantitative synthesis evaluating the effect of sodium restriction on iodine prophylaxis

	Type of work	Data collection (years, range)	Iodine sufficiency or deficiency at the time of the study	N. of subjects	Country	Current iodine content of iodized table salt*	Summary	Lower sodium intake results in iodine deficiency
Tayie et al. [20]	Study population	Subsamples from the NHANES 2001–2004	Iodine sufficiency	996 (M) 960 (F)	USA	77	Salt restriction in men was not significantly associated with iodine deficiency. Women restricting dietary salt had significantly lower mean UIC, though above 100 mcg/L, and were more likely to have iodine deficiency compared to women not restricting dietary salt	No
He et al. [27]	Randomized controlled trial	2013–2014	Iodine sufficiency	279 (children) 553 (adults)	China	30	With a 25% reduction in salt intake, there was a significant reduction in iodine consumption in northern China (where salt is iodized). Despite this finding, iodine intake was still adequate, being above the estimated average requirement	No

Table 1 (continued)

	Type of work	Data collection (years, range)	Iodine sufficiency or deficiency at the time of the study	N. of subjects	Country	Current iodine content of iodized table salt*	Summary	Lower sodium intake results in iodine deficiency
Verkaik-Kloosterman et al. [33]	Simulation study (Data derived from the Dutch National Food Consumption Survey-3)	1997–1998	Not applicable	6250 (aged 1–97 years)	The Netherlands	20	Common iodine and salt intakes were simulated for scenarios of salt reduction, and compared with no salt restriction. Simulating a 12%, 25% and 50% salt reduction in industrially processed foods, the iodine intake remained adequate. Considering a 50% reduction in both industrially and discretionary added salt, iodine intake might become inadequate in up to 10% of the Dutch population. An increase of industrially processed foods using iodized salt, or a small increase in iodine salt content, could solve this issue	Yes

Table 1 (continued)

	Type of work	Data collection (years, range)	Iodine sufficiency or deficiency at the time of the study	N. of subjects	Country	Current iodine content of iodized table salt*	Summary	Lower sodium intake results in iodine deficiency
Charlton et al. [34]	Study population	Not reported	Iodine sufficiency	262 (adults)	South Africa (Cape Town)	35–65	No association between urinary iodine and mean 24-h urinary sodium concentration was found, and UIC status did not differ according to urinary sodium categories. Where universal salt iodization is mandatory, consumers with salt intake within the recommended range (<5 g/day) are iodine replete, and median UIC does not differ across categories of salt intake	No
Charlton et al. [35]	Study population (Research Letter)	2008	Mild iodine deficiency	78 (F, aged 19–56 years)	Australia (Wollongong)	Not reported	Urinary iodine concentrations did not differ between individuals with high and low urinary sodium excretion values (salt consumption $>$ or <6 g/day, respectively)	No

Table 1 (continued)

	Type of work	Data collection (years, range)	Iodine sufficiency or deficiency at the time of the study	N. of subjects	Country	Current iodine content of iodized table salt*	Summary	Lower sodium intake results in iodine deficiency
Pastorelli et al. [36]	Simulation study (data derived from population surveillance)	Not reported	Not applicable	All age groups	Italy	30	The total daily iodine intake owing to food and non-iodized salt consumption resulted lower than the daily requirement in all age groups. With a daily consumption of 5 g of iodized salt, the estimated daily iodine intake resulted within the range of optimal iodine intake in all age groups. In children, the recommended iodine intake is achieved with a daily consumption of 3 g of iodized salt. The recommended quantities of salt, if iodized at 30 mg/kg, are sufficient to achieve the adequate daily iodine intake both in adults and children	No

Table 1 (continued)

	Type of work	Data collection (years, range)	Iodine sufficiency or deficiency at the time of the study	N. of subjects	Country	Current iodine content of iodized table salt*	Summary	Lower sodium intake results in iodine deficiency
McMahon et al. [37]	Simulation study	2012–2014	Not applicable	8300 (adults)	Australia Northern Territory)	44	Salt intake of the native Australian population exceeded the population-weighted upper limit, contributing to the high prevalence of hypertension and cardiovascular mortality. Estimated average iodine intake was within recommended values. Three scenarios enabled modeling of the estimated average salt intake within recommendations (67% reduction in sodium content of bread and discretionary salt intake; 38% reduction in sodium content of all processed foods; and 30% reduction in sodium content of all processed foods and discretionary salt intake). In all scenarios, simulated average iodine intake remained within recommendations	No

Table 1 (continued)

	Type of work	Data collection (years, range)	Iodine sufficiency or deficiency at the time of the study	N. of subjects	Country	Current iodine content of iodized table salt*	Summary	Lower sodium intake results in iodine deficiency
Land et al. [38]	Study population (Data derived from a cross-sectional survey)	2013	Not known	2975 (F, aged 18–45 years)	Samoa	Not known	No association was found between median UIC and salt excretion. Iodine status appears to be insufficient in this population and may be suggestive of iodine deficiency disorders in Samoan women. The level of salt consumption (iodized and non-iodized) is largely unknown and data on iodine nutrition are sparse	Not addressed
Musso et al. [39]	Cohort study	2017	Iodine sufficiency	157 (adults)	Italy (Liguria)	30	A low-sodium approach which primarily limits the salty foods seems safe in terms of iodine intake and does not worsen the iodine status. The number of iodine-deficient patients (UIE below 100 µg/24 h) did not change from the basal observation to the final visit after the low-sodium approach	No

Table 1 (continued)

	Type of work	Data collection (years, range)	Iodine sufficiency or deficiency at the time of the study	N. of subjects	Country	Current iodine content of iodized table salt*	Summary	Lower sodium intake results in iodine deficiency
Binnenmars et al. [40]	Randomized controlled trial (Data from a Dutch multi-center, randomized, placebo-controlled, cross-over trial. Post-hoc analysis)	2009–2012	Iodine sufficiency	45 (adults with DKD)	The Netherlands	25	Post-hoc analysis of a multicenter randomized trial in patients with diabetic kidney disease. Mean iodine excretion did not change significantly if sodium restriction and hydrochlorothiazide treatment were applied separately. Combining sodium restriction and hydrochlorothiazide resulted in decrease of mean urinary iodine excretion, although it remained above the levels of iodine sufficiency	No

Table 1 (continued)

	Type of work	Data collection (years, range)	Iodine sufficiency or deficiency at the time of the study	N. of subjects	Country	Current iodine content of iodized table salt*	Summary	Lower sodium intake results in iodine deficiency
Iacone et al. [41]	Study population	2012	Iodine deficiency	1270 (children and adolescents)	Italy	30	The iodine intake was linked to salt consumption independently of sex, age, and body weight. Median iodine intake met the European Food Safety Authority adequacy level only in teenagers with the highest salt consumption (> 10.2 g/day). Approximately 65–73% of the total iodine intake seemed to derive from food, and 27–35% from iodized salt. Among teenagers, iodized salt was only 20% of the total salt intake, insufficient to ensure an adequate iodine intake	Yes

Table 1 (continued)

	Type of work	Data collection (years, range)	Iodine sufficiency or deficiency at the time of the study	N. of subjects	Country	Current iodine content of iodized table salt*	Summary	Lower sodium intake results in iodine deficiency
Esche et al. Ref. 42]	Study population	2008–2011	Mild iodine deficiency in Germany. Iodine deficiency in Switzerland	7115 (adults)	Germany	20	In Germany, the contribution of iodized salt to the overall iodine intake and the proportion of iodized salt to total salt are lower than in Switzerland, where iodine fortification of table salt has been recently increased. Considering salt reduction campaigns, an increase of iodine content in iodized salt is necessary to prevent the growing risk of iodine deficiency, if general salt intake drops	Yes

Table 1 (continued)

	Type of work	Data collection (years, range)	Iodine sufficiency or deficiency at the time of the study	N. of subjects	Country	Current iodine content of iodized table salt*	Summary	Lower sodium intake results in iodine deficiency
Menyanu et al. [43]	Study population	2018–2019	Iodine sufficiency	5756 (adults)	Africa (South Africa and Ghana)	50	In Ghana, median sodium excretion was suggestive for a salt intake of 10.7 g/day, with a median UIE of 182.4 mg/L. In South Africa (SA), both values were lower: median salt = 5.6 g/day, median UIE = 100.2 mg/L. Considering these results, with a salt consumption within the values recommended by WHO (< 5 g/day), in SA iodine sufficiency is reached thanks to the use of iodized salt	No

N. number; *Current iodine contents of iodized table salt expressed as: mg iodine/kg salt; *F* females, *M* males, *24-UIC* 24-h urinary iodine concentration, *24-UIE* 24-h urinary iodine excretion, *DKD* diabetic kidney disease, *NHANES* United States National Health and Nutrition Examination Survey, *WHO* World Health Organization

Dietary sodium restriction is nowadays recommended by most guidelines in order to reduce the overall cardiovascular risk [1–4]. Furthermore, in the last years, many countries have pushed population-based initiatives highlighting the importance of salt reduction. Despite these recommendations, currently salt intake often exceeds the advised salt consumption due the misleading connection between salt preference and salt need [5]. Sodium is the primary component of table salt: sodium and salt are not interchangeable concepts, even if confusion still exists in the literature. Salt is sodium chloride, and its weight is approximately 2.54 times the weight of sodium alone. Sodium reduction, as suggested by International Guidelines [1–4], does not seem to induce iodine deficiency when the iodine status of the population evaluated is within the normal range (urinary concentration: 100–199 µg/L; 24-h UIE = 150 to 300 µg/day) [23]. Bearing in mind this background, whether a low sodium diet can induce iodine deficiency is matter of debate. To date, only few studies in the literature have focused on the topic concerning dietary sodium restriction, as recommended by International Organizations, and the possible interaction with the iodine status. A number of different reasons have led to the heterogeneity in the results reported and summarized in Table 1.

Firstly, studies have been carried out in both developing and developed countries, characterized by major differences in iodine status and sodium supply. Moreover, data have been recorded in a large span of time, while the iodine status is rapidly evolving in different ways in the various countries worldwide. These differences depend in a significant part upon prevention strategies, namely iodine content of iodized salt, universal use of iodized table salt, as well as the use of iodized salt in food industry and in bread-making process. Notably, the policies for universal iodized salt prophylaxis vary considerably in each country. Furthermore, the introduction of salt iodization policies does not necessarily imply a successfully operating iodized salt program. In detail, considering Europe, few countries have introduced compulsory enforcement of iodized salt and in 2018 the "Krakow Declaration on Iodine" endorsed the importance of stronger legislations to improve iodine status in Europe through mandatory iodization of table salt [44]. Concerning different scenarios outside Europe, in the US the great majority of dietary sodium derives from salt added in processed food and restaurants, overcoming the recommended sodium intake. Iodized salt was introduced in 1924 and subsequently the US Food and Drug Administration strained the importance of domestic iodized salt containing about 77 µg of iodine at the production level [20], as shown in Table 1. In China universal salt iodization program was started in 1995 [27]. Conversely, for the Pacific region, less clear information is available concerning the level of salt consumption (iodized vs non-iodized) and the data on iodine nutrition.

Furthermore, the design of the different studies is widely heterogeneous, and it is worth highlighting that in the present analysis, we included 3 reports based on a simulation model [33, 36, 37].

Other aspects that make the results hard to compare are the different characteristics of the study groups. Among the studies assessed, children, adolescents, and adults were evaluated: it has been underlined that the choice of a specific target age group is critical, and other variables, such as the body mass index (BMI), may also play a role [45, 46]. As mentioned above, epidemiological surveys dealing with highly selected categories (including pregnant women) were not considered in the present analysis. Considering people undergoing special diets, it is worth citing the Paleolithic-type diet, characterized by the exclusion of grains, legumes, dairy products, refined sugar, processed oils, and overall salt. This is a type of alimentary regimen linked with a higher risk of developing iodine deficiency [13] and iodine supplementation should be considered when on it.

Overall, the main issues affecting the interpretation of the results obtained from the various studies are both salt (and therefore sodium) and iodine dietary sources, which are deeply different around the world. In this context, the salt employed in the food industry represents a further important issue. Main iodine sources are "natural" food and water, as well as iodine-supplemented food and salt [47]. In some countries, iodine status seems to be sufficient, while in others, it is not [15, 31]. Of note, iodine excess can be also found, mostly due to high iodine content in tap water [48–51]. In many countries (Continental Europe, the UK and the US), the primary sources of iodine are dairy products and fortified table salt [52–57]. Elsewhere, especially in the Middle East, dietary iodine mainly comes from fortified flour and salt [58]. The single most important source of iodine is represented by fortified table salt in several areas, mainly Africa and Asia–Pacific Region [59–67]. In these latter regions, particularly in the developing countries, the availability and the use of fortified salt are strongly recommended, even if the availability itself may represent a major issue.

Dietary sources of sodium are variable, as well. Dietary sodium is usually higher than ideal and multiple dietary sources of sodium are available worldwide [68, 69]. It is worth distinguishing the discretionary and non-discretionary salt intake. Indeed, we can identify countries primarily characterized by the habit of adding salt to the food while cooking or at table (discretionary salt), others by a daily and heavily consumption of packaged foods (a great amount of non-discretionary salt other than that naturally present in food), and those where the two quotes of salt intake are fairly balanced. In this scenario, a crucial point is the use of iodized salt by the food processing industry and by the catering sector. Indeed, when the industry employs fortified salt for preserved foods, and these products are one of the primary sources of sodium, the restrictions of table salt will not lead to iodine deficiency. Conversely, when the industry avoids the use of fortified salt in the preparation of packaged foods, a low sodium diet might be linked with a reduction of iodine intake in the population. Therefore, the use of iodized salt by the food industry and by the public catering sector (such as restaurants, children care centers and canteens) has been implemented over the last decade, with the aim of achieving an adequate iodine intake, even in the context of a reduction of discretionary salt.

Overall, there is an obvious relationship between salt consumption and iodine intake via iodized salt. The question arises as whether salt restriction may result in a lack of iodine supply, or not. It is conceivable that, when iodine deficiency is eradicated, iodine content of iodized salt is adequate, and iodized salt consumption is widespread, salt restriction does not impact at all the iodine status in general population. This point of view has been very recently emphasized in an "opinion" authored on behalf of various scientific societies [70]. Indeed, this position is supported by the results of the present systematic review, since we found that salt restriction favored iodine deficiency only in those countries where a stable condition of adequate iodine supply was not achieved [42]. Indeed, salt restriction resulted in less-than-adequate iodine supply in countries where iodine content of fortified salt was relatively low (< 30 parts per million) [33, 42].

In any case, more attention is required for special at-risk groups, with marked reference to pregnant women, newborns, and children. Overall, programs aimed to achieve both salt intake reduction and increased salt iodization should go hand in hand, with a set monitoring to ensure a sufficient iodine intake [71].

Due to the primary relevance of optimal sodium intake, as well as iodine supply, further updated prospective studies on the effects of salt restriction on iodine status are required. Anyhow, there is no doubt that a proper monitoring of iodoprophylaxis is mandatory, to ensure a sustained adequate iodine supply, and to avoid iodine excess, a possible risk of uncontrolled iodine prophylaxis, that may result in an increased incidence of thyroid autoimmunity [71–73].

As a final joke, it is possible to recall the fundamental advice of some Italian scientific societies, when they recommend eating "poco sale, ma iodato" (only a bit of salt, but iodized) [74].

Conclusion

Since UNICEF has defined iodine deficiency "the single greatest cause of preventable mental retardation" and set the goal of virtual elimination of iodine deficiency disorders, it is worth underling the importance of iodized salt [75]. At the same time, excessive salt intake is a cause of chronic diseases, such as hypertension and cardiovascular diseases [76]. In this scenario, it is crucial to ensure a balance between iodine salt fortification without exceeding the current recommendation by WHO for a salt intake of < 5 g/day. This may be achieved by promoting worldwide a generalized availability of iodized salt for household consumption and food industry use, and by ensuring an adequate iodine concentration in fortified salt. However, considering both the strength to reach iodine sufficiency worldwide and the endorsed importance of a low sodium intake recommended by international institutions in the last years, it appears reasonable to call for a cooperation among countries to design prospective studies with a view to reaching comparable results and a definitive conclusion on this public health issue.

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Declarations

Conflict of interest Diego Ferone has been a speaker for and participated on advisory boards and received research grants from Novartis, Ipsen and Pfizer. Diego Ferone is a member of the Editorial Board of Journal of Endocrinological Investigation. Federico Gatto has been a speaker for Novartis and has participated on advisory boards of Novartis, AMCo Ltd, and IONIS Pharmaceuticals. Diego Ferone and Manuela Albertelli are members of the Editorial Board of the Journal of Endocrinological Investigation. The other Authors have no conflicts of interest to declare.

Ethical approval This article does not contain any study with human participants and animals performed by any of the authors.

Informed consent As the present study is a review article no informed consent is required.

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