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Conference on 'Understanding the role of sex and gender in nutrition research'
Symposium one: Influence of sex and gender in nutrition research

Research priorities and considerations for nutrition research: methods of sex and gender analysis for biomedical and nutrition research

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For some 20 years, science funding bodies have been asking for the integration of sex- and gender-related factors into the content of research and innovation. The rationale for those requirements has been the accumulated evidence that sex and gender are important determinants of health and disease. The European Commission (EC) has been the first, since 2002, to seriously ask for the integration of sex and gender into research and innovation in the context of their multi-annual framework programmes. When introduced, this condition was not immediately applauded by the research community, who perhaps lacked training in methods for the integration of sex- and gender-related factors. The EC Expert Group on Gendered Innovations sought to fill this gap. This review describes the work of this international collaborative project which has resulted in the development of general and field-specific methods for sex and gender analysis and 38 case studies for various research domains (science, health and medicine, environment, engineering) to illustrate how, by applying methods of sex and gender analysis, new knowledge could be created. Since 2010, science funding bodies in Canada, the USA and several EU member states have followed the example of the EC issuing similar conditions. Although the effects of nutritional patterns on a range of (physiological and health) outcomes may differ for men and women, sex and gender analyses are rarely conducted in nutrition research. In this review, we provide examples of how gender is connected to dietary intake, and how advancing gender analysis may inform gender-sensitive policies and dietary recommendations.

Key words: Sex and gender analysis: nutrition research: science funding

Introducing sex and gender into research as determinants of health

The introduction in the 80s of the new concept of gender, stemming from the humanities, as relevant for biomedical research did not proceed without a struggle. Large efforts were needed, and partly still are, to provide a proper description – next to sex – of the concept of gender and an illustration of how to understand their respective influences on health outcomes. For biomedical, including

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nutrition, research it is crucial to make the conceptual distinction between sex (referring to biological characteristics) and gender (referring to socio-cultural attitudes, behaviours and identities of humans). Important as well is to acknowledge how sex and gender *interact* to determine a certain health outcome. A groundbreaking example of this interaction was given in 2003 by the epidemiologist Nancy Krieger illustrating how both sex and gender can influence a health outcome. A well-known example in this respect is the underdiagnosis of heart disease in women; next to the sex-related differences of age and non-traditional symptoms in women, gender norms can be seen as a determinant of physician likelihood of referral for diagnostic and therapeutic interventions resulting in women less likely to be referred, especially at younger ages[1].

Yet for the biomedical research community, gender was a new concept and initially not well understood. It often resulted in the neglect or a discrediting of the concept of gender as identical with women or only pertaining to women's health and therefore not of interest to the health of men. As a result, biomedical researchers missed out on the innovative potential of considering sex differences beyond reproduction and on the gender-related influences on the health of men. Moreover, early articles in the medical literature by those who did take an interest in differences between women and men often reported their findings as gender differences, although it turned out they had only studied biological sex differences. But for biomedical research, the conceptual distinction between sex and gender is a guiding principle because it provides different starting points for treatment and interventions, either in the biological or in the socio-cultural domain. And so a two-fold innovation for biomedicine emerged: (1) that sex differences, beyond reproduction, are relevant and should be considered and (2) that gender-related differences are also important for a meaningful understanding of differences between women and men.

Emerging policies of science funders

By the early years of the 21st century, a wealth of evidence was available on the lack of attention to sex and gender aspects in research[2,3].

A groundbreaking initiative was launched by the European Commission (EC) in 2000: they commissioned a Gender Impact Analysis (GIA) of their Fifth Framework Programme (FP5) to assess the attention to sex and gender in the content of research and innovation. It was the moment when the EU gender equality policy, enshrined in successive treaties since the 1950s, became translated into research. And so, after the GIA had demonstrated that there was ample room for improvement the EC started to require the integration of sex and gender in research and innovation where relevant[4]. For FP6 that ran from 2002 to 2006, a new term was launched: applicants (for several major funding instruments) had to consider Women's Participation (WP) and the Gender Dimension in the content of research (GD). Both parts were brought together in the EU's formula for Gender Equality (GE): GE = WP + GD.

The new concept of the gender dimension desperately needed a further clarification because for the biomedical and health sciences it was obvious that the term comprises attention to both sex and gender-related influences, whereas in other areas of research, sex-related influences might not be that relevant. However, for many researchers in Europe, this was a top-down policy requirement that few researchers understood in the way it was intended. A large majority interpreted the gender dimension as gender balance or WP issues, and the implementation of this policy lagged behind. What was lacking and became addressed in later projects were practical tools for researchers to incorporate sex- and gender-related aspects into research.

Evidence and tools needed to further support researchers with integrating the gender dimension when applying for EU funding were created by several groundbreaking projects. *GenderBasic* aimed to provide practical tools, relevant examples and best practices. The project resulted in a collection of *reviews* on methodological, technical (such as breeding of female laboratory animals), ethical and financial aspects of incorporating sex and gender analysis into basic, translational, clinical and public health research, and provided state-of-the-art reviews of relevant sex and gender aspects of six important major conditions (anxiety disorders, asthma, metabolic syndrome, nutrigenomics, osteoporosis and work-related health)[5].

The meta-analysis of 30 years (1980–2010), gender and science literature, was another milestone in summarizing all available evidence on the relevance of sex and gender for biomedical research[6].

Gender as a multidimensional concept

By 2010 the concept of gender was elaborated as referring to sociocultural norms, identities, and relations that: (1) structure societies and organizations and (2) shape behaviours, products, technologies, environments and knowledge. Gender attitudes and behaviours are complex and change across time and place. Importantly, gender is *multidimensional* and intersects with other social categories, such as sex, age, socioeconomic status, sexual orientation and ethnicity. Gender is distinct from sex and comprises three dimensions: gender norms, gender identities and gender relations.

Gender norms are produced through social institutions (such as families, schools, workplaces, laboratories, universities or boardrooms), social interactions (such as between romantic partners, work colleagues or family members) and wider cultural products (such as textbooks, literature, film and video games).

Gender identities refer to how individuals or groups perceive and present themselves in relation to gender norms. Gender identities may be context-specific and interact with other identities, such as ethnicity, class or cultural heritage.

Gender relations refer to how we interact with people and institutions in the world around us, based on our sex and our gender identity. Gender relations encompass how gender shapes social interactions in families, schools,

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workplaces and public settings, for instance, the power relation between a man patient and woman physician[7].

These descriptions make it clear that gender is a pervasive concept deeply engrained in any society and affects roles and behaviours of women and men alike. The challenge ahead was to provide biomedical researchers at large with practical methods of analysis. These skills were lacking because they had not been included in their training.

Reinforcement of EU policy on the gender dimension

The EU GE policy became reinforced when preparations were made for the next Framework Programme Horizon 2020. The GE policy by then had been elaborated into three objectives:

- To increase women's participation at all levels
- To stimulate gender balance in decision making
- To integrate the gender dimension in research and innovation content

The EU – as a science funding body – had made their intentions clear: 'Integrating the gender dimension in research and innovation is an added value in terms of excellence, creativity, and business opportunities. It helps researchers question gender norms and stereotypes, to rethink standards and reference models. It leads to an in-depth understanding of both genders' needs, behaviours and attitudes. It enhances the societal relevance of the knowledge, technologies and innovations produced. It also contributes to the production of goods and services better suited to potential markets'[8].

The EC had acknowledged the need of researchers for innovative methods of analysis and so in 2011, they convened the Expert Group 'Innovation through Gender' to help develop the gender dimension in EU Research.

The goal of the Expert Group was to provide scientists and engineers with practical methods for sex and gender analysis and to develop case studies as concrete illustrations of how sex and gender analysis leads to new ideas and excellence in research. Gendered Innovations (GI) as a project was initiated by Londa Schiebinger at Stanford University in 2008, and the EC joined by co-financing the project from 2011 to 2013. GI aimed to fill in the needs of researchers. Underlying principle was to trigger the interest of researchers to engage with the new methods rather than retelling the story of gender biases of the past. It aimed to offer hands-on materials directly relevant to their own research.

The first edition (GI 1) (2011–2013) was realized by a group of more than 60 experts from Europe and the USA through 7 workshops held in over 2 years; peer-reviewed case studies were developed that illustrated how – by applying methods of sex and gender analysis – new knowledge could be developed. The project aimed to provide:

- Clear definition of terms,
- methods of sex and gender analysis and
- case studies to illustrate how the application of methods of sex and gender analysis sparks creativity and leads to new knowledge.

The Report *Gendered Innovations: How gender analysis contributes to research* was published in 2013 and launched in a special session of the European Parliament[9]. The report was accompanied by a website with additional portals summarizing relevant policies developed by important science funding bodies and by journals[10].

The 23 case studies that GI 1 produced were categorized into four domains: (1) science, (2) health & medicine, (3) engineering, and (4) environment. Some examples from the health and medicine domain are nutrigenomics that examines the epidemic of non-communicable diseases (NCDs) such as heart disease, diabetes, and cancers and osteoporosis research in men as a counterexample to heart disease in women; in this field, men are the neglected sex. All case studies follow a given format; they start by formulating the challenge, followed by the new knowledge that can be developed by applying the new methods of sex and gender analysis to the problem at hand. A case study ends with conclusions and next steps.

Case study: Understanding sex and gender-related variations in NCDs risk factors

According to the WHO, NCDs such as CVD, cancers, and diabetes, are the leading cause of death in the world today and that modifiable risk factors, such as unhealthy diet, physical inactivity and tobacco use, are responsible for the majority of NCDs[11]. The prevalence of these risk factors, however, varies between country income groups, with the pattern of variation differing between risk factors and with gender[12]. The bases for this variability are multiple and still poorly defined.

Focus of the GI case study is on understanding sex- and gender-related variables in NCD risk factors (Fig. 1). The relative influences of sex- and gender-related factors determining a person's disease risk over her, or his lifetime are reviewed. Importantly, gender-related behavioural factors (such as obesity, lack of exercise, etc.) interact with sex-related biological factors (such as genetic predispositions, birth weight and hormones) to determine how a person ages. For instance, to understand differences in women's and men's obesity rates, we need to analyse gender differences in lifestyle. Perhaps gender norms in society lead men to exercise more than women and could in part explain the higher disease among women. Or perhaps gender norms in society lead men to eat less healthy food than women. This gendered behaviour could lead to greater disease among men[13].

More clarity in understanding risk factors can come from analysing sex in nutrient responses, pointing to sex-specific responses. Figure 2 illustrates a three-way interaction between gender-related factors, sex-specific biology and various mechanisms involved in human food intake and processing (Fig. 2). A gender-related food intake, which is a critical part of an individual's environment and life history, can be translated into different sex-specific base metabolisms, gene expression, and dietary responses. The expectation is that information about an individual's genetic makeup can be combined with knowledge about the biological impacts of the environmental context to better assess the personal physical vulnerability to diet-related disease[14]. An early study considered this relationship and

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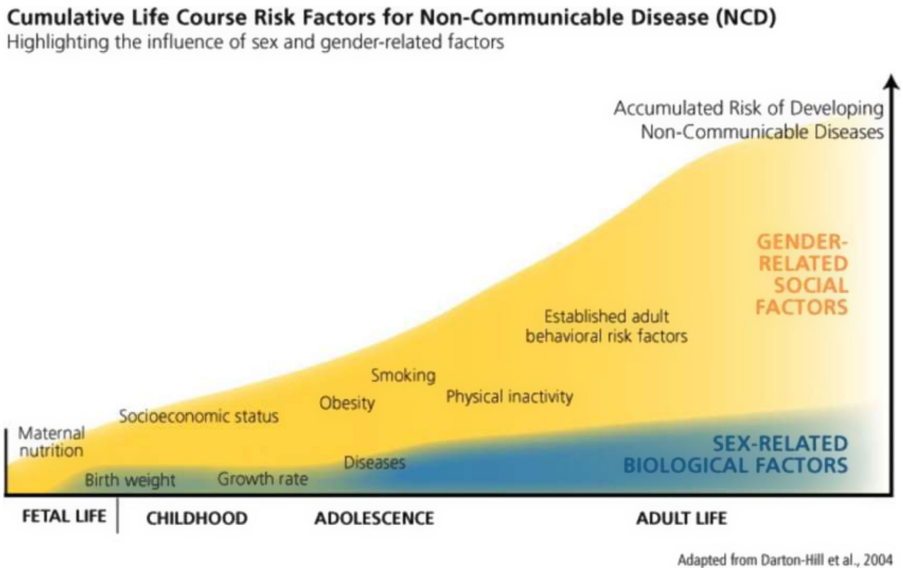

Fig. 1. Understanding sex- and gender-related variations in NCD risk factors. From a life course perspective, the relative influences of sex- and gender-related factors will determine an individual's functional capacity when aging. It is important to consider that both gender-related social factors and sex-related biological factors interact from early life onwards in the various stages of life. The resulting individual functional capacity is the product of both influences, and therefore it is hard to identify the respective influences of each factor independently. *Source*: Gendered Innovations website

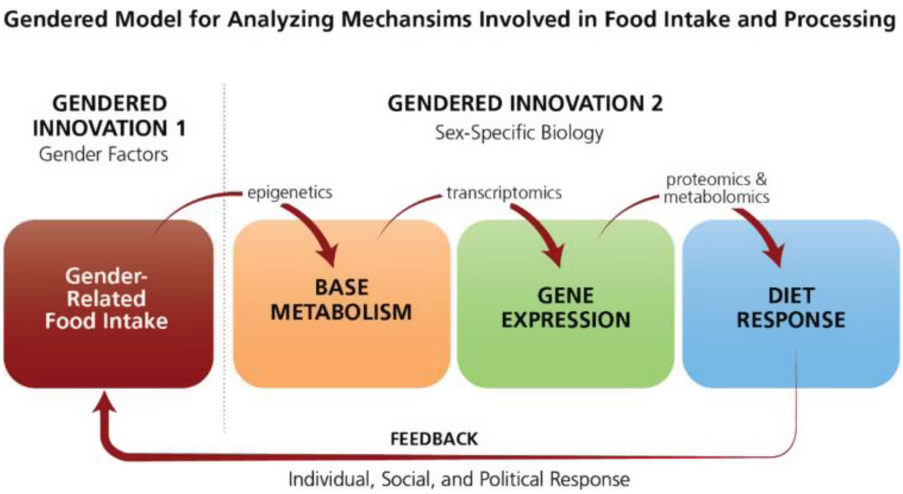

Fig. 2. Sex-specific nutrient responses. The diagram illustrates how researchers might analyse a three-way interaction between gender-related factors, sex-specific biology and various biological mechanisms involved in human food intake and processing. Gender-related food intake is translated into different sex-specific base metabolisms, gene expressions and dietary responses. *Source*: Gendered Innovations website.

examined the interplay between inflammation-related genes and vitamin E. Data from a study of 500 elderly nursing home residents were used to examine vitamin E-gene interactions affecting the incidence of respiratory tract infections (RIs). The main finding suggested that the effect of vitamin E on reducing RIs depended on sex. Further research evaluating the effect of vitamin E on RIs should consider both genetic factors and sex, because both were found to have a significant (and interactive) bearing on the efficacy of vitamin E[15].

The case study concludes that by integrating sex and gender analysis into a life course approach, researchers can explore the influence of sex-specific biological factors and gender-related social factors in determining the risk for NCDs. Specifically, analysis of high-risk behaviours indicates that gender attitudes and behaviours promote different patterns of healthy or unhealthy lifestyles among women and men. In addition, recent studies in nutrigenomics document that females and males respond differently to specific diets at the genetic, molecular, and cellular levels. Studies designed to incorporate both sex and gender analysis can provide rich data for designing interventions for healthy living – for researchers, policy-makers, and the general public.

Case study: osteoporosis research in men

Osteoporosis has been considered primarily a disease of postmenopausal women, an assumption that has shaped

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its screening, practice, diagnosis and treatment[16]. This perception may exist because osteoporosis manifests about 10 years earlier in women than in men and because women of all ages have higher risks of fracture than age-matched men. The problem is that men account for a third of osteoporosis-related hip fractures after age 75 – and when they break their hips, they die more often than women.

The case study focuses on osteoporosis as a disease with both sex and gender components: bones are formed by biology but also influenced by gender norms, such as exercise rates, nutrition, and general lifestyle. Biologist Anne Fausto-Sterling has described how environment and experience can 'shape the very bones that support us.' Osteoporosis is a complex disease that emerges over the lifecycle as a response to 'specific lived lives'[17]. Gender role*s* interact with sex in determining bone strength: in Europe and the USA, adolescent girls may exercise less than boys. Along with biological factors, these gendered behaviours result in girls laying down less bone than boys in their teens. In addition, occupational divisions of labour mean that men are more likely than women to do heavy physical work, such as construction[18]. And older women are generally less physically active than their male counterparts; inactivity may contribute to bone loss and increase fracture risk.

In summary, osteoporosis has been reconceptualized to highlight that this disease is affecting both women and men. This gendered innovation led to the development of male reference populations, allowing for better evaluation of fracture risk in men. Bone mineral density (BMD) alone, however, is not a good predictor of fracture in women or men. New diagnostics should take factors intersecting with sex and gender into account[19,20].

The materials of the Gendered Innovations project have been spread to many countries in the world and translations into German, Swedish, Korean, Spanish and Taiwanese have been produced[21].

Horizon 2020 (2014–2020) and preparing for Horizon Europe (2021–2017)

Horizon 2020 was characterized by a reinforced emphasis on the gender dimension. Applicants were supported by the GI 1 materials and particular topics of the work programmes were 'gender flagged', indicating topics for which sex and gender were relevant. An analysis of Horizon 2020 did reveal that the number of flagged topics had increased over the consecutive work programmes. Numbers of flagged topics increased from 16 % (19/610 topics) for the work programme 2014–15, to 19 % (108/508 topics) for the work programme 2016–17 and to 23 % (110/473 topics) for the work programme 2018–20[22]. Yet there was room for improvement[23].

Therefore, the Commission convened *a second Expert Group to deliver Gendered Innovations 2* (GI 2)(2018–2020), to prepare for Horizon Europe, the next framework programme starting from 2021 onwards. The Report 'Gendered Innovations 2: How inclusive analysis contributes to Research and Innovation' has refined the methods and now comprises five general methods and nine field-specific methods[24].

The methods analysing sex and analysing gender were further elaborated into a stepwise guidance through the respective phases of a research project (identify problem, design research, collect data, analysis of data, reporting, dissemination) (Figs 3 and 4)

GI 2 method Intersectional approaches features as a new method describing intersectionality as overlapping or intersecting categories such as gender, sex, ethnicity, age, socioeconomic status, sexual orientation and geographical location that combine to inform individuals' identities and experiences. The relevance of intersectional approaches is reflected in the title of the GI 2 policy review; 'How inclusive analysis contributes to research and innovation'.

The 15 new case studies cover more comprehensively all research domains funded by the EC; and addressed (1) health, (2) climate change, energy and agriculture, (3) urban planning and transport, (4) information and communication technology (artificial intelligence, machine learning, robotics) and (5) finance, taxation and economics. In early Spring 2020, an ad hoc case study on the coronavirus pandemic was created. 'The impact of sex and gender in the COVID-19 pandemic'[25].

For the Health Cluster, three new case studies were developed: 'Prescription drugs: analysing sex and gender'; 'Systems Biology: collecting sex and gender specific data' and 'Chronic Pain; analysing how sex and gender interact'.

The GI 2 Policy review was launched by the EC in November 2020. It contained tailored recommendations for the six Clusters of Horizon Europe. It was accompanied by dissemination of factsheets and a media campaign on Twitter by Commission representatives.

When the agreement on Horizon Europe was finalised in February 2021, two new conditions for funding were required : (1) the integration of the gender dimension into research and innovation content is a requirement by default, an award criterion evaluated under the excellence criterion, unless the topic description explicitly specifies otherwise; (2) having a GE Plan (GEP) in place becomes an eligibility criterion for certain categories of legal entities from EU countries and associated[26].

Comparing research policy initiatives of international science funding bodies

Policies similar to the EU GE policy to support the research community at incorporating attention to sex and gender into research were launched in 2010 by the Canadian Institutes for Health Research (CIHR) with the Institute for Gender & Health (IGH) as the main driver, when adopting their Sex- and Gender-Based Analysis plus policy (SGBA+)[27] and in 2016 by the US National Institutes of Health's Office of Women's Health Research (NIH/ OWHR) with their Sex As Biological Variable policy (SABV)[28]. Both IGH and NIH/OWHR have developed online trainings in recent years. For the field of health research, the IGH training materials, easily available online, inspired many researchers : 'Every cell is sexed and every person is gendered'[29]. NIH/OWHR recently launched on online training 'From bench to bedside' on SABV[30].

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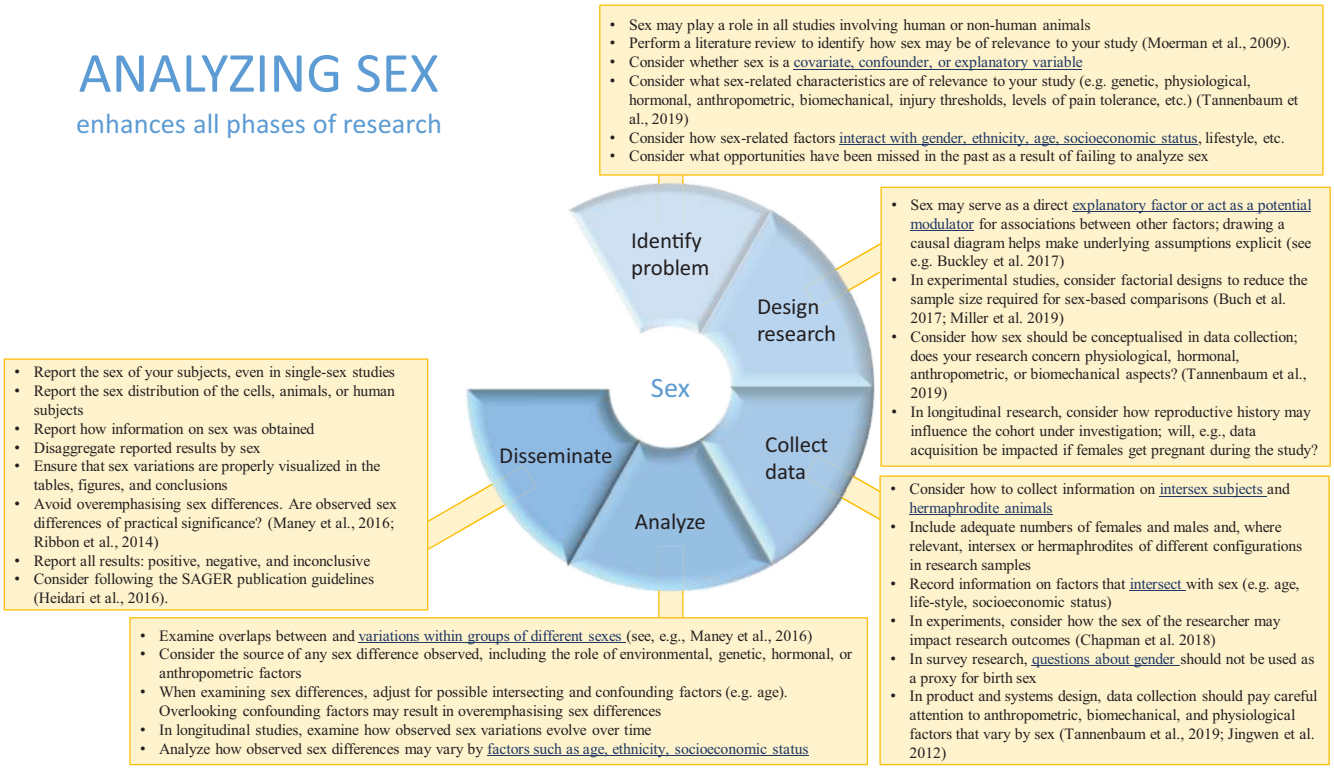

Fig. 3. Analysing sex enhances all phases of research. *Source*: Gendered Innovations website.

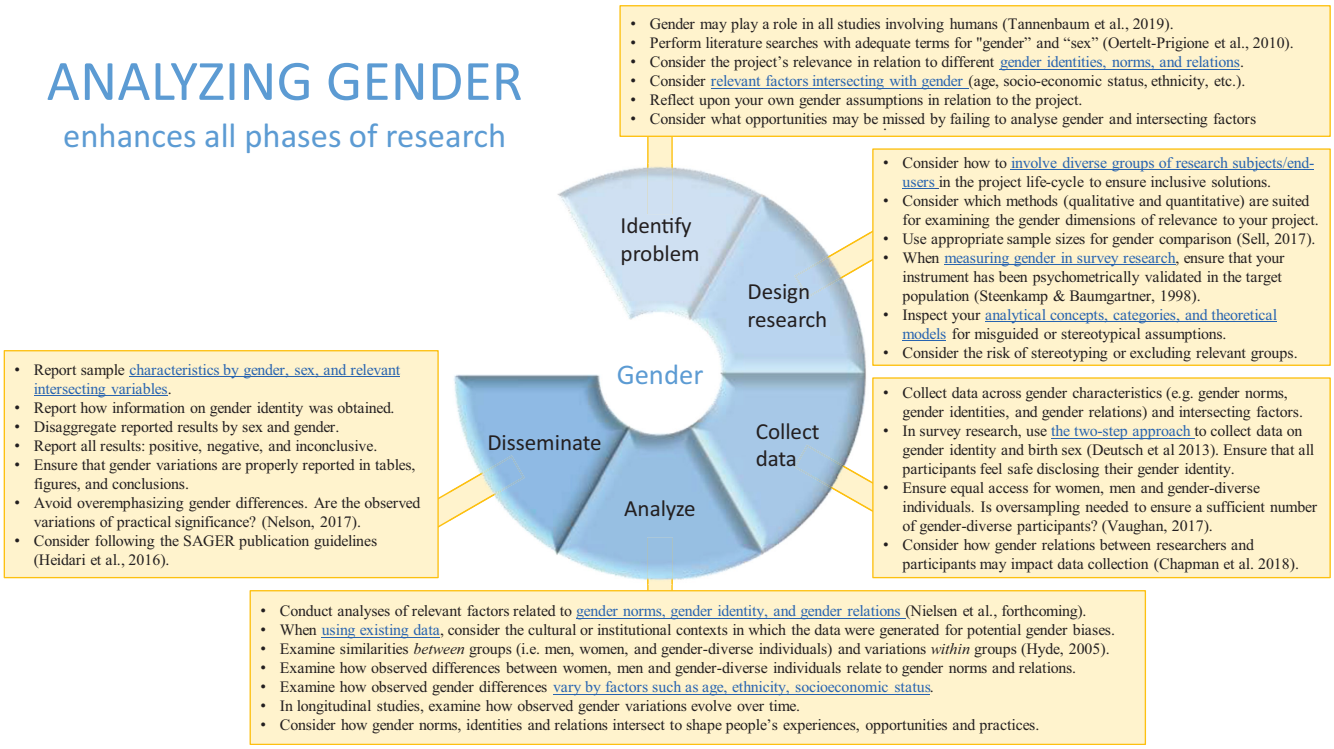

Fig. 4. Analysing gender enhances all phases of research. *Source*: Gendered Innovations website.

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A shared notion among these influential research funding bodies is that a clear definition of both sex and gender is essential for a proper guidance or instruction on how to incorporate a sex and gender analysis into the design of a research. It is beyond the scope of this review to summarise the details of similarities and differences between the policies of the various science funding bodies. The article titled 'The integration of sex and gender analysis into biomedical research: Lessons from international funding agencies' compares initiatives of major science funding bodies (CIHR/IGH, NIH/OWHR and EC) and highlights the various 'carrots and sticks', that is offering an incentive or imposing negative consequences[31].

The conditions for funding set by science funding bodies in Canada, the USA and Europe, have been accompanied by training courses in particular for early researchers at member state/national level. A good practice is the International Gender in Research Course for early researchers organised by the Netherlands Organisation for Health Research and Development (ZonMw). Fellowships were available for attending the course and covering travel costs. Forty-two applicants from six continents were selected and attended the course in Summer 2019. The second and third editions took place in May/June 2021 and 2022. Experts and guest speakers from a multitude of disciplines jointly teach and share their knowledge and research expertise with the next generation of researchers from all over the world. Participants have the opportunity to build a community with fellow talented early-career researchers from around the world and work in diverse teams on a prize-winning competition within the course[32]

Implications for sex and gender analysis in nutrition research

Despite the urges and tools from science funding bodies to support gendered innovations, gender analyses in nutritional research are still in their infancy. This is remarkable as it is very likely that causes and consequences of nutritional patterns may differ for men and women. Sex and gender are often measured in the research, but rarely is sex or gender included as a factor of interest that is worthwhile studying on its own. Instead, it is typically treated as a confounding variable: a factor that disturbs the relation between other variables; a variable that needs to be accounted for in order to exclude the influence of sex or gender. A recent review illustrated through human studies and animal models how biological sex differences influence nutrient intake, metabolism, responses to dietary restriction, and interactions with gut microbiome[33]. They observed that sex differences received scarce research attention so far, and they argued there is a clear research need to understand sex differences in order to ultimately develop dietary recommendations that are tailored to optimize men's and women's health[33]. Indeed, dietary guidelines rarely differ for men and women, which is likely to reflect a reproduction of lacking sex and gender-analysis research. This type of research is a prerequisite for generating the accumulating evidence that underpins national dietary guidelines. In a similar vein, interventions and strategies to support people to adhere to these dietary recommendations often take a one-size-fits-all approach assuming that such interventions are equally appreciated by men and women and produce equal adherence to recommendations. There is some evidence that points to the contrary, and gender-sensitive policies, treatments and interventions have been called for[33–36]. In order to design such effective gender-sensitive interventions to promote dietary change, the determinants of dietary intake need to be targeted. A first step towards gender-sensitive interventions is thus to gain an understanding of the role of gender in these determinants. Although past research on the role of gender in dietary intake was limited, past research allows for identifying gender-related aspects in determinants of dietary intake.

Gender and sex-specific determinants of dietary intake

Various scholarly fields seek to gain understanding of eating behaviour and food choice, such as public health nutrition, health promotion, consumption sociology, health psychology and consumer science. What we eat and how much we eat, is the result of a complex interplay of determinants at different micro (personal), meso (social) and macro (economic) socio-ecological levels. Gender is woven through every level and determines dietary intake in complex interactions with other variables. In the following, we will provide some examples how the role of gender plays out for the separate levels. It is not meant to be an exhaustive analysis but serves to illustrate what a gender lens could add to the current practice in nutrition research.

Role of gender at the person level. At the person level, factors such as taste preferences, self-regulation processes and eating styles, hunger and satiety mechanism, and more cognitive indicators such as beliefs, attitude and intentions are influencing individual eating behaviours. When putting on a gender lens, the most striking finding in this 'psychology of eating' field is the apparent overrepresentation of women. Experimental psychological research often invites college students for participation in laboratory studies, and (young) women register more often for these studies, especially those women concerned about their eating habits. This has led to situations where generic insights on eating behaviour processes largely stem from samples of young higher educated women with a healthy body weight[37]. Although this has not been systematically scrutinized, warranting careful interpretation, the overrepresentation of young women seems particularly apparent when studies concern emotion-regulation processes. For instance, a meta-analysis on the role of stress in eating behaviours included 54 studies and found no indications for a moderating role of gender[38]. Their analysis, however, included 30 studies with females only compared to nine studies among males only. In a meta-analysis of emotion regulation and eating pathology, including 96 studies, it was found that the percentage of females was a significant moderator of the role between specific emotion regulation and eating pathology[39]. Yet, 62 studies exclusively included women, and a total of 77 studies included more than 75 % of female participants.

An overrepresentation of healthy college-aged women in eating regulation studies can also be observed in studies

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in naturalistic settings. For instance, an ecological momentary assessment study on self-control strategies and food intake, only included college-aged women[40]. The rationale for excluding men was '....to avoid the confound of sex-related effects on eating behaviors among college-aged men and women',[41] p.756). Indeed, starting college has been associated with changes in eating behavior, and a more than average weight gain in the first year of college compared to average (US) adults[41]. Interestingly, these patterns of weight gain in college freshman have been shown to differ for men and women, depending on their relationships with their parents. Women having positive relationships with their parents gained more weight when entering college, whereas for men troublesome parent relationships predicted weight gain[41]. This points to the importance of looking into the role of gender in social dynamics influencing dietary intake: the social level.

Role of gender at the social level. At the social level, factors such as social norms, identities, and status, peer influence and parenting styles can be connected to dietary intake. In each of these variables, gender plays a role. Specific parental behaviors (e.g. modelling, rulemaking, rewarding and praise, pressure to eat) have been shown to influence healthy and unhealthy food consumption behaviors in children across different age groups[42]. Although it is widely acknowledged that fathers and mothers serve different roles in raising boys and girls, there is limited research on parenting differences between fathers and mothers and the differential effects on boys or girls in the realm of diet and eating. Studies tend to focus on the role of mothers, very likely representing standard gender roles where mothers are considered gatekeepers in the household for food and feeding and are more engaged with family meals. Nowadays, along with shifts in task and labor divisions in the household, fathers gain more responsibility for household food and feeding, and it has been implicitly assumed that results from studies on mothers will generally extend to fathers. This may not always hold true. For example, restrictive feeding has been shown to negatively impact young children's self-regulation of eating for mothers but not for fathers[43]. Among adolescents, however, youth gender mattered more than parent gender in understanding the relation between parenting practices and adolescents' dietary behaviors. Irrespective of the parent's gender, specific parenting practices influenced boys only[44]. A more fine-grained analyses on the relation between parenting and adolescent food intake suggests that parenting differently impacts boys and girls, depending on the specific consumptive behavior (fruit and vegetable intake *v.* sugar sweetened beverage consumption) and is influenced by the gender stereotypes that adolescents hold[45].

Such gender norms and identities in relation to eating are not only persistent in adolescents but in adults as well. A clear example can be found in research on meat consumption. Given the substantial public health and environmental impacts of animal-based consumption, a shift towards adopting a larger proportion of plant-based consumption in our diets has been urged. Meat consumption, however, is strongly associated with masculinity, whereas healthy diets (with more plant-based foods) are associated with femininity[46]. Eating according to these judgements can be regarded as a means to 'impression management' (i.e. conscious or unconscious act to influence other people's perceptions of oneself) in order to gain or maintain one's social position[47]. Such normative processes provide barriers towards changing dietary behaviors for public and planetary health.

Role of gender at the economic level. The processes studied at the individual (micro) and social (meso) take place in a wider context where also more structural socio-economic factors influence gender differences in dietary intake. The food environment has a strong influence on what foods are available (e.g. supermarket, fast food outlets) and what is financially accessible given that healthy diets are generally more expensive[48]. Food insecurity (i.e. insufficient, or inadequate access to safe, healthy, and nutritious food) has been shown to affect women more than men. In general, but also within households, food insecurity is not equally distributed between men and women, where women are more susceptible to food insecurity[49]. Also compared to food-insecure men, food-insecure women are less likely to meet dietary recommendations and display worse scores on health indicators[50]. Taken into account, gender disparities in the economic determinants of diets are increasingly relevant, as food prices are rising, and women may be particularly at risk given their generally lower income.

In summary, these examples illustrate how gender is relevant to understanding determinants of dietary intake and how micro-, meso- and macro-level processes are interacting. Moreover, sex and gender bears consequences for the entire chain of nutritional research from to understanding the complex interplay of personal, social and economic determinants of dietary intake to understanding the biomedical and physiological consequences of dietary practices. Advancing this understanding of the role of gender, may inform gender-sensitive interventions and policies, such as gender-specific lifestyle interventions for obesity and diabetes management or gender-specific dietary recommendations. In line with the suggestions earlier made in this review, gender analysis in nutritional research should include all genders, and not equate gender with the focus on women only as for certain types of nutritional research men are underrepresented.

Conclusions: the science ecosystem

Journals may act as gatekeepers in advancing sex and gender analysis in research. The SAGER guidelines developed over a 3-year period by a multidisciplinary group of academics, scientists and journal editors by means of literature reviews, expert feedback and public consultations at conferences, provide researchers and authors with a tool to standardize sex and gender reporting in scientific publications[51]. The GI website has listed the journals that have issued guidelines for reporting on sex and gender analysis; the efforts of Elsevier are particularly interesting covering the over 2300 journals in their portfolio[52].

University curricula have begun to integrate courses on sex and gender analysis although there is room for improvement also in curricula related to diet and nutrition. Of course, the expectation is that established

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researchers see these developments as a matter of scientific excellence. For early-career researchers, the field of sex and gender science offers wide opportunities for innovative research, also for nutrition research.

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Conflicts of interest

The author(s) declare none.

Authorship

I.K. designed the overall manuscript outline and wrote a draft of the manuscript; E.V. wrote the part on 'Implications for sex and gender analysis in nutrition research'. Both authors reviewed the entire manuscript and revised accordingly.

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