THESIS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY (PHD)

Nutrition and dietary profile of the Roma population living in segregated colonies

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CONTENTS

LIST OF ABBREVIATIONS

ABBREVIATION	EXPLANATION
ANOVA	*Analysis of Variance*
BDNF	*Brain-derived neurotrophic factor*
BMI	*Body mass index*
BP	*Blood pressure*
CI	*Confidence interval*
COVID-19	*Corona virus disease 2019*
CRP	*C-reactive protein*
DASH	*Dietary Approaches to Stop Hypertension*
DII	*Dietary Inflammatory Index*
DNA	*Deoxyribonucleic acid*
EHIS	*European Health Interview Survey*
FAO	*Food and Agriculture Organization of the United Nations*
FTO	*Fat mass and obesity-associated protein*
GNPDA2	*Glucosamine-6-phosphate deaminase 2*
GP	*General practitioner*
GPMSSP	*General practitioners' morbidity sentinel stations program*
HDI	*Healthy Diet Indicator*
HDL-C	*High density lipoprotein cholesterol*
HG	*Hungarian general population*
HR	*Hungarian Roma population*
IDF	*International Diabetes Federation*
IDF_{EURO}	*International Diabetes Federation, criteria for Europeans*
IQR	*Interquartile range*
LDL-C	*Low density lipoprotein cholesterol*
MHO	*Metabolically healthy obesity*
MUFA	*Monounsaturated fatty acids*
NB-EAT	*Nutrient-based EAT index*
NCD	*Noncommunicable diseases*
NEGR1	*Neuronal growth regulator 1*
NPY	*Neuropeptide Y*
OECD	*Organization for Economic Co-operation and Development*
PBF	*Percentage of body fatness*
PHC	*Primary health care*
PPAR-γ	*Peroxisome proliferator-activated receptor gamma*
PUFA	*Polyunsaturated fatty acids*
RMSE	*Root mean square error*
SFA	*Saturated fatty acids*
SNP	*Single-nucleotide polymorphism*
STROBE	*Strengthening the Reporting of Observational studies in Epidemiology*
T2DM	*Type 2 diabetes mellitus*
TMEM18	*Transmembrane protein 18*
UCP	*Mitochondrial uncoupling proteins*
WC	*Waist circumference*
WHO	*World Health Organization*
WtHR	*Weight to height ratio*

INTRODUCTION

The Roma population represents the largest ethnic minority group in Europe, which has been estimated to be 10 to 12 million people [1]. In past decades, they have been a major focus of medical and health research [2, 3]. Their historical mobility has led to a dispersion over continental Europe [4-6], as well as has subjected them often to unfavorable living conditions, food insecurity, high-risk health behaviors, as well as stigmatization, discrimination and difficulties accessing healthcare services [7-11].

These exposures have directly and indirectly contributed to a characteristically substandard health status, marked by a higher risk for chronic disease morbidity compared to host populations, particularly with regards to diet-related non-communicable diseases (NCDs) [12-17]. In addition, their estimated life expectancy appears to be on average a decade less, compared to the general population in Europe, regardless of the country where they reside [16, 18-20].

Surveys from different European countries have attempted to explore and examine dietary aspects of Roma communities and have found unfavorable dietary habits and food choices, linked to the increased risk for developing diet-related NCDs. Specifically their dietary habits and behaviors are characterized by an inadequate and relatively low consumption of fruits, vegetables [21-33] and dairy products [25, 27-29, 34], excessively frequent consumption of fast-foods [35-38], large quantities of animal-based fats [30, 33, 38, 39], high frequency of sugar-sweetened beverages [24, 25, 30, 37], as well as confectionery [30]. Although there are studies and efforts that have attempted to characterize and describe food choices and eating habits, several questions on dietary intake profile and patterns have remain still unanswered.

Efforts to qualify dietary intake of Roma [31] have been made, but food intake and dietary patterns data for Roma are not available yet – in Hungary or elsewhere. Such information would be very useful, not only in identify how their diet may be related to their health, but also in determining which specific aspect(s) of their diet or nutrient(s) should be targeted, when designing and/or implementing preventive interventions among Roma, i.e. identifying effective ways of intervening to reduce health inequalities.

Along with the growing burden of diet-related NCDs [40], there is a renewed and growing interest in characterizing, its association with dietary and nutrient patterns, particularly among disadvantaged minority population groups, such as Roma.

Eating behavior is a complex nutritional trait, which can be influenced by a plethora of factors, including environmental factors (social, cultural, and community factors) and (epi-) genetic factors. Information on their intake and dietary patterns, in combination with nutritional status measures, will improve our current understanding on their nutritional situation. It can provide us a proxy of their metabolic health and aspects that need to be addressed, as well as sustainability considerations for future nutrition interventions.

Moreover, what we are consuming and the way we are producing, processing and eating food are exerting not only health and nutritional concerns, but huge environmental pressures as well [41]. Diet has emerged as one of the most important and most promising levers to improve health and environmental sustainability, particularly on the demand side of the challenge [42].

It has been now established and well-demonstrated that health-promoting dietary patterns can drastically diminish the environmental footprint of our diet, suggesting that dietary shifts that can decrease the risk for NCDs, have an invaluable potential to also aid attainment of global and local environmental sustainability targets [43, 44].

In order to address and quantify the needs emerging from a growing global population, hence a growing global food demand, a healthy diet from sustainable food systems was defined by the EAT-*Lancet* report – a universal reference diet, which aims to promote both human and planetary health [44]. It is reasonable to suppose that diversity and inclusion is key to unlocking sustainability and in creating the kind of development which meets the needs of current generations, without compromising the ability of future generations to meet their own needs. Therefore such efforts require estimates of adherence to such dietary patterns and guidelines, so that proxies of the dietary patterns' environmental potential in various populations around the world can be obtained and progress can tracked.

In Hungary, dietary profile and intake has been investigated and characterized for the general adult population. According to the most relevant research results, the dietary profile of the Hungarian general adult population is largely characterized by relatively immoderate quantities of fats, meats (predominantly processed), salt and sugar [45, 46]. However, to the best of our knowledge, dietary intake and nutrient patterns among Hungarian Roma (HR) adults (nor Roma adults in other countries) has not been quantified or described to date.

Therefore, it is timely and reasonably relevant to address malnutrition, in all its forms, and its potential implications, not only with regards to nutrition and health, but environmental sustainability implications as well.

With that in mind, this report examines the dietary profile and nutritional status of Roma population living in segregated colonies, while exploring how their nutrition is associated with dietary guidelines and patterns known to influence health (i.e., Healthy Diet indicator (HDI) and Dietary Inflammatory Index (DII)) and environmental sustainability (i.e., Dietary Approaches to Stop Hypertension (DASH) and EAT-Lancet), while considering HG population as benchmark.

To the best of our knowledge, this is the first study of this kind and depth among Roma, addressing the relevance of diet for human and planetary health. It is also the first instance in the scientific literature that quantified, extensive dietary intake data and comprehensive nutritional status estimates are provided for Roma adults, benchmarked against the general adult population of Hungary as reference, as well as internationally established guidelines/recommendations for healthy and sustainable nutrition as well.

Literature review – Roma in Hungary

In this literature review important data and information on the characteristics of HR relevant to their health status are summarized. Based on the available information, selected major risks factors that possibly contribute to the critical health disparities documented between HR and Hungarian general (HG) populations are examined, such as the life expectancy gap and inequalities in cardiometabolic disturbances burden. Eventually an overview and the importance of nutrition and dietary profile of HR is provided, as well as the relevance of conducting and understanding inclusive nutritional epidemiology research for developing clear and effective strategies for improving HR health and reducing inequalities. The dietary profile and nutritional status of the Roma communities in other countries is out of the scope of this literature review.

Nevertheless, we have mentioned some relevant information in the 'Introduction' part (above), as well as in the 'Discussion' section of this thesis, related to nutritional status and dietary profile of Roma elsewhere and how our results compare with them. It should be noted that there are scarce and fragmented data on specific indicators for HR, while most of the information is scattered and exists predominantly in the form of grey literature, generic reports and often not appropriately referenced sources. On the other hand, the scientific evidence on HR, comes from studies conducted mainly by the University of Debrecen, where extensive research has been conducted with regards to determinants of Roma health for many years.

Hungarian Roma in numbers

Roma are the largest minority in Hungary, comprised of at least three main distinct subgroups: Hungarian Roma, the Vlach Roma and the Beás people. It is believed that the Roma have arrived in Hungary, in the first migration wave, as early as the 1400s, and the Vlach Roma are have come more recently (i.e. 19th century) [47]. Following the social, political and economic changes in the late 1980s, a new wave of Roma migration within Europe, instigated new research activities about the origin and demographic phenomena of this minority. Recent genetic studies investigating the origin of Roma have suggested as source of their South Asian ancestry the Northwest region of India [48-50]. However, the ancestral group or geographic region within South Asia that is most closely related to the ancestral population of the Roma is still a subject of speculation [51]. Additional data from a largescale ancient DNA study on genomic history of South-eastern Europe [52], suggest that this region has served as a genetic contact zone over thousands of years, something which hints the route of migration and at the same time indicates that major genetic distinctions may have been lost over time due to interaction of population genetics, shaped by adaptive evolution. A study on refining the origin of Roma suggests that their genetic background is closer to European genetic architecture than to Asian ones, concerning the fact that the average shared IBD (identity by descent) segment length of Roma with Central European populations was 0.355 Mb, while it was only 0.132 Mb with Northwest Indian, and the extent of IBD share between Roma and Pakistani populations was only 0.066 Mb [50]. In the 2011 Hungarian census [53], there were 308,957 persons declaring themselves Roma, while in the previous 2001 census this number was almost three times lower (i.e. 190,000) [54]. Recent surveys have estimated that there may be between 450,000 and 1,000,000 Roma living in Hungary [55-58] and the most recent estimate showed that approximately 876.000 Roma people lived in Hungary in 2010-2013 [55]. In this work when we use the word “Roma” in the text we are referring to Hungarian Roma living in segregated colonies, if otherwise not indicated.

Living conditions, health and determinants of health among Hungarian Roma

Official governmental reports reveal that the majority (i.e. more than 60%) of HR in Hungary live in rural areas, mostly in segregated colonies, with relatively poor living conditions [59].

Their historical migration and exclusion has led to dispersion over many European countries [5, 60, 61] and they have been subject to disadvantaged living conditions, food insecurity, high-risk health-related behaviors, as well as discrimination, stigmatization and barriers to accessing health and other services [62, 63]. In Hungary, over 70% of the Roma population live in such spatially segregated settlements, surrounded with only or mostly Roma neighbors and a quarter of them live in settlements with basic or no infrastructure [64]. The lack of sewage system, garbage deposits, waterlogged soil and water mains are among the most frequent environmental challenges, present in the segregated settlements of HR [47, 65]. Such living conditions have been are believed to contribute to perceived and actual social and health inequalities that HR are faced with. In a 2009 survey, 62% of HR participants reported experiencing discrimination in many aspects, namely :19% when searching for work or at work, 10% by housing agency or landlord, 22% by healthcare personnel, 18% by social service personnel, 20% by school personnel and 48% by private services [66]. In the same survey, 90% of HR respondents also reported that they felt that this ethnic-based discrimination may be widespread in the country, while in a 2020 survey only 62% of respondents claimed to have witnessed discrimination against a Roma citizen [67]. Whether people are healthy or not is partially determined by their circumstances and environment.

The World Health Organization defines health risk factors from built environments, genetics, income and education levels, and relationships with friends and family. All these factors can have considerable impacts on health, while other more commonly considered factors, such as access and use of health care services, often have less of an impact [68]. The above-mentioned conditions of social and living conditions of HR, appear to have taken a toll on their health and have resulted in a particularly higher burden of chronic morbidity, especially NCDs [20, 64, 69, 70]. Although ethnicity-based death recording and consequently proper estimates on life expectancies are not available, it is supposed that Roma life expectancy is almost 10 to 15 years less than the general population [71-73]. Sex wise, HR men have been consistently shown to have a life expectancy of ten years less than non-Roma men in Hungary [74], while for women this gap extends to a staggering 18 years [72, 74]. A recent study, indicates that Roma ethnicity may be a distinct risk factor for NCDs (i.e. 1.16% of NCDs can be attributed to the Roma ethnicity in the whole population), independently of sociodemographic status [75]. A major indicator of the growing burden of NCDs is metabolic syndrome, which has been shown to be prevalent and strongly contributes to the development of the poor health status of the HR population [20].

The life expectancy gap among HR and HG, can be partially explained by the environmental factors such as the substandard living conditions and the systemic socio-economic disparities [2, 13]. For instance, employment rate among HR compared to HG is less than half and unemployment rates are 3-5 times higher among HR [76]. Employment rate for HR men was less than 20% in 2011, while among Roma women was roughly 10% [77]. However, in 2013 it was shown that HR women had improved and better rate of labor market participation, estimated at 32%, compared with men of the same ethnicity, which had a rate of 26% [78]. Education appears to be another challenge for HR. Education level of HR population aged above 15 years was below the national average and in 2012, 77.7% of the HR Roma did not have a higher level of education than elementary school, while this figure was 24.6% for the HG population [76]. From available data at the national level, 31.3% of HG had high school education in 2011, while for HR this proportion was just 4.6% [76].

Although Hungary was active during the Decade of Roma Inclusion, demonstrating progress in employment and educational status of Roma, much needs to be done to create a thriving environment and standard of living for HR [3], as well as an improved evidence base to trace and document the progress. To date, there is still no convincing evidence showing that the life expectancy gap between HR and HG has been sufficiently addressed. On the other hand, there has been tremendous progress in the recent years, with regards to inclusion of HR communities in research programs. Despite this progress, a growing body of evidence indicates that factors influencing the life-expectancy gap and HR's unfavorable health status may go beyond the lower educational and socio-economic status [34, 79-85]. For instance, although the Hungarian primary health care (PHC) system may be underutilized with regards to cardio-metabolic preventive services, recent research has suggested that PHC is not a considerable source of health inequalities with regards to socio-economic characteristics, such as the level of education [86]. Research findings also indicate that socio-economic level can explain HR's worse health status, but it partially influences their health-related behaviors [87]. Thus research focus has been turned towards genetic and life style factors aiming to understand their contribution to health inequalities, as well as their potential to reduce these inequalities [84, 88-91]. Recent genetic research has elucidated some of the genetic influences of HR's health, with particular focus on lipid profile and anthropometric status (e.g. BMI, waist size, etc.) – major factors which in cardiometabolic health and instrumental in estimating the risk of the earlier onset of disease, as well as for risk-stratification in the context of preventive interventions.

Extensive research on lipid profile has been generated recently and it has been demonstrated how the prevalence of low high density lipoproteins cholesterol (HDL-C) levels among HR is consistently linked to genetic causes [92-94]. On the other hand, genetic research has also demonstrated the differences in genetic predisposition to obesity between the HG and HR populations. A study on genetic susceptibility to obesity among HR and HG, reported significantly higher risk allele frequencies for single nucleotide polymorphisms (SNPs) in *NEGR1* (rs2815752), *TMEM18* (i.e. rs2867125 and rs6548238), *BDNF* (rs925946 and rs6265), and *UCP* (rs660339) genes, but significantly lower risk allele frequencies for variants in *GNPDA2* (rs10938397), *NPY* (rs16139), *PPAR*γ (rs1801282), and *FTO* (i.e. rs6499640 and rs1558902) genes in HR compared with the HG population [89]. Comparison of the distribution of investigated risk allele variants could not confirm increased genetic predisposition to obesity among HR. However, in our previous study, while investigating the applicability of data on selected obesity-related SNPs, obtained from HG population of European origin, on the HR population, we found that out of 20 SNPs, four located in the FTO gene (i.e. rs1121980, rs1558902, rs9939609 and rs9941349) showed strong association with BMI and waist circumference (WC) as continuous variables in both samples [88].

Computations based on ATPIII and IDF's European and Asian criteria showed rs9941349 in the FTO gene to be linked with WC among both (HR and HG) populations and two SNPs (i.e. rs2867125,rs6548238) in the *TMEM18* gene associated with WC only in HG population. Substantial difference (*both with regards to directionality and magnitude of the effect*) was detected only for rs1801282 SNP in PPARγ gene on WC as continuous outcome.

Collectively, these findings indicate that genetic risk scores based on counting SNPs with relatively high effect sizes, defined on European ancestry populations, can sufficiently allow estimation of genetic susceptibility among Hungarian Roma. While further research should clarify the role of SNP (s) with protective and/or risk effect (s), findings exemplify the potential utility of public health genomics in genetic risk stratification, for the early identification of high risk for prevention of later onset of disease among HR. In parallel, there has been a renewed research attention on lifestyle and other modifiable factors such as smoking [95], blood pressure [96], physical inactivity, type 2 diabetes [97], blood cholesterol [94] and body weight/shape [88, 89]. Heavy smoking has been shown to be 1.5 times more prevalent among HR, compared to the lowest income quartile of the HG population [9], while a similar pattern has been documented for HR adolescents [98].

In 2003, 60% of HR women older than 25 years were smokers, of which 62% smoked during pregnancy, while the proportion of women smokers among HG was 26%, with only a quarter of them reported smoking during pregnancy [76]. A 2021 study confirms the fact that the prevalence of factors driving major diet-related NCDs, such as cardiovascular diseases, are higher among HR [90]. In particular, there was a significantly higher prevalence of smoking observed among HR compared to HG, regardless of sex and age, something which may be partially attributed to the fact that smoking has been described as a part of the Roma lifestyle in the literature [82, 99]. For alcohol consumption data show a nuanced picture. Among the HG population, 14% of adults over 18 years old drink alcohol regularly, but among the HR population it is only 4%, while among HR women this proportion is negligible (i.e. 1%) [76]. On the other hand, the prevalence of abstainers has been shown to be significantly higher among HR, compared to HG population in 2007 [9] and daily alcohol consumption, as well as drunkenness was more common among HR adolescents [100].

Moreover, a study involving HR and HG adolescents has suggested that Roma ethnicity may be associated with lifetime prevalence of alcohol intoxication [98]. A recent detailed analysis of two surveys (one in 2003 and the other in 2014) involving HG and HR population, showed negative changes in alcohol consumption [3]. In this analysis, despite of the proportion of older women (i.e. 45–64 years) who were abstinent was shown to be relatively high, there was a significant decrease. On the other hand, there was no meaningful change noted in rates of abstinence among women at other ages and among men of all ages. Nevertheless, among men, there was a shift from moderate to heavy drinking at all ages, especially among those who were younger and middle aged. More recent data are not available, warranting further research in this area.

Nutrition and dietary profile

Among the abovementioned lifestyle factors, to the best of our knowledge, dietary intake and patterns have not been quantified or characterized previously. Nevertheless, there have been attempts to describe dietary habits of HR. For instance, the use of vegetable oil and the low daily frequency of fruits/vegetable consumption was reported in a survey in 2003 [9] and a report of national study on the same year, confirms the low daily frequency consumption of fruits and vegetables among HR, compared to the lowest income quartile of the HG population [101].

In 2019, a study involving HR and non-HR children, reported a higher consumption frequency of sweets and soft drinks among HR children, but with no differences in fruit/vegetable consumption frequency and BMI between the two populations [102]. Nutritional status has also been described and the recent survey results show a dramatic and significant increase in the prevalence of obesity among Roma youth (regardless of sex) over a very short period of less than 10 years [3]. Obesity appears to disproportionally affect HR and the prevalence of obesity among young HR females (i.e. aged 18-29 years) has almost quadrupled, compared to the analogues age group in the HG population [3]. Roma ethnicity has also been independently correlated with lower birth-weight among at term neonates, in a comparative study of HR and HG neonates (37-42 weeks) [34]. Updated information on HR nutritional status would be crucial for assessing their health situation and trajectory, particularly in the context that Hungary was ranked the fourth most obese country among Organization for Economic Co-operation and Development (OECD) countries in 2017, with more than 30% of adults suffering from obesity [103].

In addition, Hungary was evaluated as '*off course*' for meeting all of the global nutrition targets for which there was sufficient data to assess progress, according to the Global Nutrition Report of 2020 [104]. The same report showed that Hungary has shown limited progress towards achieving the diet-related NCDs targets, with no progress towards achieving the target for obesity, with an estimated 24.6% of adult (aged 18 years and over) women and 28.2% of adult men living with obesity. The most recent data show an obesity prevalence higher than the regional average of 23.3% for women and 22.2% for men [104]. At the same time, type 2 diabetes is estimated to affect 6.7% of adult women and 8.9% of adult men, and there is a significantly higher prevalence of prediabetes and known type 2 diabetes among HR compared with the HG population [20, 105]. On top of this, in 2019, age-standardized proportion of all-cause mortality attributable to dietary risks among Hungarian adults, was estimated to be 27.5% (95%CI: 25.7%-29.4%) at the national level - almost a third of all deaths in the country [106]. Poor diet has been established as a major risk factor for poor health, while dietary risks are not evenly distributed within populations [107]. Socioeconomic gradients in diet quality have been consistently reported among high-income countries, but the available data poorly represent the situation of ethnic minorities [108, 109]. Similarly, dietary patterns and intake of HG population has been documented and described previously and it appears to be characterized by high amount of fats, meat (mainly processed), salt and sugar – all prerequisites for a raising burden of diet-related NCDs [110, 111].

Moreover, prevalence of NCDs is often higher in ethnic minority groups, and socioeconomic position is on average lower [112], a pattern that we also observe in the case of HR in Hungary. Hence, in principle poorer diet quality among these groups may be expected. Additionally, dietary patterns and dietary behaviors differ between ethnic groups [113, 114], which could contribute to ethnic differences in diet quality, and could also modify the relationship between socioeconomic position and diet [115]. These relationships warrant further research, as interventions and policies aiming to improve HR diet quality and reduce dietary inequalities should take subgroup differences into consideration. Besides health and nutritional concerns, what and how we are eating is also having considerable impacts on climate and biodiversity [41]. At the same time, diet has emerged as one of the most promising levers to address not only health, but environmental sustainability as well [42]. It has been now demonstrated that health-promoting dietary patterns often have lower environmental impacts, suggesting that dietary transitions that might lower the risk of NCDs might also support the attainment of environmental sustainability targets [43].

Healthy and sustainable dietary patterns, aimed at promoting both human health and environmental sustainability have been defined, and this provides an opportunity to nurture a growing population in a healthy and sustainable manner. However, information on the state of the diet for HR or HG in relation to such dietary patterns has never been described. Such information would be valuable in addressing the pressing and actual issues of climate change and malnutrition (in all its forms) at the same time, as well as the potential that diet has on transforming health and sustainability. We have not been able to retrieve additional data or studies on nutritional status and dietary intake or patterns among HR in the published literature or grey literature, during the writing of this document. We are not aware also of any other study among Roma adults in Hungary that has quantified and/or characterized dietary intake to date, despite of diet being the leading lifestyle factor of mortality globally [106] and the cornerstone of cardiometabolic health [116-119]. Thus, it is reasonable within the current context, to assume the need to elucidate dietary intake and patterns, as well comprehensive measures of nutritional status of HR. Diet is among the leading causes of preventable morbidity and mortality and there is virtually no information on HR's dietary patterns. While we acknowledge that fact that improving diets may require population-based, multi-sectoral and culturally relevant approaches, it is crucial to build the evidence base that can inform interventions targeting HR. Eventually, while nutrition and diet is a piece of the puzzle for healthier HR, it is not the puzzle. HR should live in environments conducive to health and such environments are supported by healthy public policies that reduce exposure to risks.

RESEARCH QUESTION AND AIM

AIMS AND OBJECTIVES

The main aim of this work was to investigate and elucidate the state of diet, nutritional status and dietary profiles of the Roma population living in segregated colonies in North East Hungary, while considering HG population as reference. We draw attention to the nutritional challenges among HR, but at the same time provide up-to-date data on the dietary situation of HG population. There were two broad objectives of this research:

- To determine the current dietary profile and nutritional status and
- To assess the dietary patterns shown to strongly influence health and environmental sustainability, of Roma population living in segregated colonies.

However, our work tackles the following specific objectives:

- Assess dietary intake and patterns among HR, while comparing them with HG population;
- Explore sex and ethnic differences with regards to intake of major nutrients;
- Identify HR' dietary patterns with regards to established healthy and sustainable nutrition guidelines and benchmark the results against HG population results
- Enhance knowledge on HR's dietary profile and nutritional status in Hungary
- Provide updated and quantified estimates of dietary intake and nutritional status among HR and a basis for future dietary intake studies

RESEARCH QUESTIONS

The main research questions that guided this study were:

1. What is the diet composition of HR and how it compares with HG population?
2. Is there a difference between HR and HG in terms of energy and nutrient intake?
3. How does nutritional status of HR compare to that of the general population?
4. How do dietary patterns shown to strongly influence health and environmental sustainability of Roma population living in segregated colonies compare to that of the general population?

MATERIALS AND METHODS

STUDY DESIGN AND SAMPLING

All data used in this work were obtained in a cross-sectional survey carried out between May-August 2018, as a three-pillar (i.e. questionnaire-based, physical examination and laboratory examination) complex (i.e. health behavior and examination) survey [120]. In this survey, individuals aged 20-64 years, were selected randomly, to be representative of the adult HR population living in segregated colonies of North-East Hungary (Hajdú-Bihar and Szabolcs-Szatmár-Bereg counties), where a great proportion of HR population resides [55], as well as that of the HG population living in the same counties. In a recent analysis [55], the spatial characteristics of the HR population and its changes during the last three decades was elaborately described, based on the population census datasets of 1990 and 2011, that relies on self-declaration, and other two surveys (the CIKOBI survey from 1984-87 and the survey of the University of Debrecen from 2010-13), the latter representing external ethnic assessment.

This work demonstrated the rapid growth in the HR population and its regional disparities, reinforcing the already known regional characteristics of the Roma population. In the reviewed period weakening spatial backwardness was typical, the share of HR population living in towns was shown to be increasing. However, the rapid growth of the HR population is especially visible in the case of some districts, where their proportion was already high in the1980s (that has doubled since then). This process is quite concentrated affecting mostly districts in the underdeveloped areas of the country.

PILLAR I. QUESTIONNAIRE-BASED INTERVIEWS

The questionnaire was adopted from the European Health Interview Survey (EHIS) wave 2 questionnaire [121] (EHIS 2 for 2013–2015, previously used in the Hungarian survey of 2014). This comprehensive questionnaire consists of four main parts: (a) health status, (b) health care use, (c) health determinants, and (d) socio-economic variables. In these modules, the following topics are covered: (a) self-perceived health, chronic diseases and mental health, (b) utilization of health care services, including hospitalizations, consultations, preventive services, medications, and unmet needs, and (c) smoking, alcohol consumption, physical activity, dietary habits and socio-economic characteristics such as sex, age, living conditions, education, income, and employment.

PILLAR II. PHYSICAL EXAMINATIONS

Anthropometric data (i.e. weight, height and waist circumference) were obtained on site and blood pressure (BP) measurements were performed for each participant, based on the protocol of the European Health Examination Survey [122]. All corporal measurements, were used to estimate body composition indicators, such as percentage of body fatness, eight-to-height ratio, central obesity, etc. Physical examination was supplemented with visual acuity and physical/cardiovascular fitness checks.

PILLAR III. LABORATORY EXAMINATIONS

Native (5 mL) and ethylene diamine tetra acetic acid (EDTA)-anticoagulated whole blood samples (2 × 3 mL) were collected for laboratory analysis and DNA extraction. Serum and plasma samples were separated by centrifugation at 3000 rpm for 10 min and used immediately or kept at −80 °C until biochemical analysis and investigation. DNA preparation was carried out from EDTA-anticoagulated blood samples on the day of sample collection.

Total cholesterol (C), HDL-C, LDL-C, triglycerides, glucose, creatinine, uric acid, C-reactive protein, apolipoprotein A1, apolipoprotein B100 concentrations, alanine aminotransferase, aspartate aminotransferase, gamma-glutamyl-transferase, alkaline phosphatase activities, folic acid, hemoglobin A1c, and insulin concentrations were analyzed and determined in the Department of Laboratory Medicine of the University of Debrecen.

DATABASE CREATION

All validation rules (i.e. skip, range, and consistency checks) provided previously to the EHIS 2 by Eurostat were strictly followed and processed [121]. All data obtained from interviewer-assisted questionnaires, as well as from physical and laboratory examinations were input into a designated database and participants' identification was anonymized.

Data for the identification, characterization and determination of components of metabolic syndrome were extracted from the abovementioned database of the complex health survey. Specifically, data on waist circumference, blood pressure, fasting triglycerides, HDL-C, glucose, and insulin concentrations, as well as antihypertensive, antidiabetic therapies, and specific treatments for lipid abnormalities were sorted and classified with standard procedures.

DATA USED FOR THE CURRENT THESIS

In addition to the above-mentioned socio-demographic, anthropometric, health-related behaviors, physical and laboratory examination data collection in the survey, we also collected two 24-hour (h) dietary recalls in order to characterize and quantify dietary intake and patterns. The original sampling plan was to include at least 500 participants in both study arms.

However, the final study sample, with full recall data, included a total of 797 participants, of which 410 subjects were in the HG arm and 387 in the HR arm.

HUNGARIAN ROMA SAMPLE

Segregated colonies with more than 100 inhabitants were previously identified by Roma field workers and ethnicity of the colony population was determined by self-declaration. Previously, a comprehensive environmental survey of all settlements in Hungary (n = 3145) was carried out, which employed HR field workers in order to locate and characterize segregated parts (colonies) of human habitats [65].

Based on the collected data on environmental conditions and aggregate population numbers of the colonies, ranking of colonies and maps on their characteristics were prepared for all counties of Hungary. Our current research has built upon the findings of this work, with regards to identifying HR settlements and households.

Further, HR subjects were enrolled based on a stratified multistep-sampling method in two counties of Northeast Hungary (i.e. Hajdú-Bihar and Szabolcs-Szatmár-Bereg), where the majority of Roma colonies reside. In this stratified sampling approach, data objects are grouped into homogeneous strata, according to one certain property (i.e. ethnicity), and then a representative set is selected from each stratum.

Multiple-step stratification sampling helps determine the sample size needed and afterwards the sample set is drawn from each stratum. After verification of an established database, twenty colonies were randomly chosen, and twenty-five households were randomly drawn from each colony.

Individuals aged 20 to 64 years were identified in each household and eventually one person was selected by random table. These persons were interviewed face-to-face at the respondent’s household by Roma university students with the support of the local Roma self-government under the supervision of public health coordinators.

Hungarian general reference sample

The Hungarian adult sample, used as reference, was derived from General Practitioners' Morbidity Sentinel Stations Program (GPMSSP). This program is a population-based registry designed to identify and monitor those suffering from NCDs of high public health importance and it is operational in in Hungary since 1998 [123]. The GPMSSP was a joint initiative of the Hungarian School of Public Health and the National Public Health Service, created as a network of sentinel stations based in primary care facilities and involves eleven Hungarian counties for today. This program provides valid data and comprehensive information on important aspects of the Hungarian population's health, with relevance to health policy and health service planning.

Within this program, individuals, between the ages of 20 and 64 years, who were living in private households and were registered by their GPs in the same abovementioned counties at the time of the investigation, were randomly selected, using as sampling frame the GPMSSP registry. The sampling intention during the process of study design, was to involve 25 randomly selected individuals from 20 GP practices among these counties. However, two GPs refused to participate in the study and were excluded. Therefore, the final sample was reduced to 450 participants from the practices of a total of 18 GPs. In the present analysis, only individuals with full dietary recall data were included from both groups and subjects with implausibly low or high intake data were not included.

Socio-demographic data collection

Data on socio-demographic characteristics of participants included age, sex, educational level (i.e. '*elementary*', '*secondary*', '*vocational training*' and '*university degree*'), self-reported perceived financial status (i.e *on a Likert scale*: '*very good*', '*good*', '*fair*', '*challenging*' and '*very challenging*') and economic activity (i.e. '*full-time employment*', '*part-time employment*', '*student*', '*unemployed*', '*retired*' and '*ill-health retirement*' - the latter including subjects that were unable to work due to illness or disability).

Dietary and anthropometric data collection and quality appraisal

Dietary intake data were obtained using a double (i.e. one weekday and one weekend day nonconsecutively), interviewer-assisted multiple-pass, 24-hour dietary recall protocol, which was designed, developed and validated in our previous study [124], using data from Albanian young adults.

In our previous work, the 24-hour dietary recall was conducted using a standardized wording methodology to make recall of all possible foods as accurate as possible. This procedure allowed generation of more reliable data and identification of possible biases related to data collection. The protocol and instructions on recording intake were administered *step-by-step*, as described in the protocol, and all aspects of qualification/quantification were elaborated. The entire procedure was aided by the internally developed and validated, illustrated accompanying booklet and coding procedure (for more details and in-depth explanations see section '*Dietary data'* in ***Appendix***.)

In brief, the consecutive steps used to determine food intake were the following: (i) listing of foods consumed by the respondent during a 24-hour period, including one weekday and one weekend day, before the interview, (ii) additional recall of nine categories of foods that are often forgotten, such as non-alcoholic and alcoholic beverages, sweets, savory snacks, fruits, vegetables, cheeses, bread and rolls, etc., (iii) assessment of meal time and occasion, (iv) detailed description of each item reported, and (v) a final opportunity to amend or recall any other unreported item.

All subjects were eligible to report their intake if the weekday and the weekend day were considered '*typical*', which meant that: (i) intake represented what they usually consume, (ii) there was no special event (birthday, party, etc.) on the day assessed, (iii) no disease was diagnosed prior or during the days recorded, (iv) nutritional supplements of any kind were taken and (v) a diet regime of any kind was applied. If one of these conditions was not satisfied, subjects were not eligible and hence the recall was not recorded. The two dietary recalls were administered to all survey participants.

Generalized obesity and obesity classes were estimated based on body mass index (BMI) according to WHO's criteria (i.e. obesity class I (30.0–34.9 kg/m^2), class II (35.0–39.9 kg/m^2) and class III (above 40 kg/m^2) [125]. Abdominal obesity was determined using waist circumference (WC) standards defined for females and males by the International Diabetes Federation (IDF) for European (IDF_{EURO}) population [126]. The waist-to-height ratio (WHtR) index [127] was also calculated, as it has received attention in the scientific literature for being strongly associated with metabolic syndrome and several related NCDs [128-130] regardless of sex, age, or ethnic group [131]. In addition, anthropometric indices that estimate percentage of body fat (PBF) were defined, using four different anthropometric equations for estimating PBF [132-135]. These equations were considered suitable and potential alternatives in estimating whole-body fat percentage in subjects 20 years of age and older, independently of the ethnic background and sex [136].

Eventually, the proportion of those with metabolically healthy obesity (MHO) was determined among subjects suffering from obesity (i.e., BMI≥30 kg/m^2). Since, there is no universally accepted standard for defining MHO, and there are more than 30 different definitions in the literature [137], MHO was defined in our study if participants fulfilled the following criteria: (1) no diagnosed pre-existing cardiometabolic diseases, (2) a healthy cardiometabolic blood profile (i.e. fasting triglycerides <1.07 mmol/L, HDL-C ≥ 1.04 mmol/L (men) and ≥ 1.29 mmol/L (women) and fasting glucose < 5.55 mmol/L) and (3) normal BP (i.e. blood pressure < 130/85 mmHg). After applying these criteria, we used four different approaches to further determine proportion of MHO among participants suffering from obesity [138-141]. Although we admit, that such data are indicative, our findings support the need for further rigorous research on MHO among HR and HG, which we believe can identify the factor(s) involved in protecting some people with obesity from the adverse metabolic effects of excess adiposity.

DIETARY PATTERNS INDEXES

In the dietary pattern analysis part, we employed four different dietary quality indexes: HDI, DII, the EAT-*Lancet* and DASH. In the scientific literature, EAT-*Lancet* and DASH are considered to be environmentally sustainable dietary regimes, in addition to being beneficial to health [142]. The World Health Organization (WHO) guidelines for the prevention of chronic diseases [143] and the 2020 updated healthy diet fact sheet [144] were used to construct a modified version of the HDI originally introduced by Huijbregts *et al.* [145]. Our HDI was computed using seven nutrient standards and a dichotomous variable was generated for each nutrient according to Table S5 (see ***Appendix***) coding criteria.

Further, individual scores were summed and participants received a maximum HDI score of 7 points, if all HDI targets were met and a minimum of 0 points if none was met. Categories of adherence were created based on the total score (i.e., very low HDI [0-1 points], low HDI [2-3], moderate HDI [4-5], high HDI [6-7]). DASH diet index, used previously by Mellen *et al*. [146], was an entirely nutrient-based version, constructed on the basis of target nutrient values from the DASH diet used in 2 clinical trials [147, 148]. The nine nutrients were those expected to be higher (protein, fiber, magnesium, calcium, and potassium) or lower (total fat, saturated fatty acids (SFAs), sodium, and cholesterol). Individual dietary data were compared against each of the nine dietary component goals.

Meeting a dietary component goal received 1 point, while meeting an intermediate goal (defined as the midpoint between the DASH diet goal and the nutrient content of the DASH control diet [147]) received 0.5 point, and meeting neither goal received 0 points. The total score was generated by summing all nine nutrient targets score for a minimum of 0 and a maximum of 9 points (see Table S6 in ***Appendix***). Further, a categorical outcome was evaluated to estimate the number of individuals achieving modest accordance with the DASH dietary approach. Individuals meeting at least half of the DASH targets (DASH score ≥4.5) were considered DASH accordant and the rest, DASH non-accordant. In 2019, the EAT-*Lancet* Commission on Healthy diets from the sustainable food systems report defined a universal reference diet to promote human and environmental health [44].

To evaluate the adherence of our subjects to this diet, we constructed a novel, nutrient-based EAT index (NB-EAT), based on the nutrient composition of the original EAT-*Lancet* reference diet. Our NB-EAT included twelve nutrient reference intakes (i.e. α-linolenic acid, carbohydrates, cholesterol, dietary fibers, (mono- and poly-) unsaturated fats, proteins, saturated fats, total fat, calcium, added sugar, magnesium and potassium) [44].

The individual NB-EAT score was calculated as the sum of nutrient targets met: a value of 1 was given if the participant achieved an EAT-*Lancet* target for a nutrient and a value of zero was given if target was not met (with a score range from 0 to 12). Categories of adherence were coded based on the achieved score and three categories were created, i.e., low (0-4), moderate (5-8) and high (>8) adherence (see Table S7 in Appendix). Calculations of DII were based on a protocol described by Shivappa *et al*. [149] and consideration methodological aspects of its use and utility [150]. Briefly, nutrient data obtained by 2-day 24-h dietary recall were first linked to the regionally representative world database that was created at the University of South Carolina and provided a robust estimate of a mean and SD for each parameter [149].

These became the multipliers used to express an individual's exposure, relative to the "standard global mean" as a z-score. This was achieved by subtracting the "standard mean" from the amount reported and then dividing this value by the "standard deviation". To minimize the effect of "right skewing", this value was converted to a centered percentile score. The centered percentile score for each food parameter was then multiplied by the respective food parameter effect score. This was derived from the structured review and scoring of 1943 qualifying research articles, to obtain a food parameter–specific DII score for the individual. All of the food parameter–specific DII scores were then summed to create the overall DII score for every participant in the study [149].

Out of 45 possible parameters, a total of 27 nutrients were available to calculate the DII for our study populations. The overall index obtained by summing the 27 dietary parameters (total energy, carbohydrate, protein, total fat, alcohol, fiber, cholesterol, saturated fatty acids (SFAs), caffeine, monounsaturated fatty acids (MUFAs), polyunsaturated fatty acids (PUFAs), omega-3 and omega-6 fatty acids, niacin, thiamine, riboflavin, vitamin B12, vitamin B6, iron, magnesium, zinc, vitamin A, vitamin C, vitamin D, vitamin E, folic acid, and beta-carotene), ranged from a minimum of −4.60 (most anti-inflammatory) to a maximum of 3.12 points, with a median value of − 1.33.

DATA ANALYSIS

All the collected dietary intake data were processed with *NutriComp Étrend ver. 3.03* (https://www.nutricomp.hu/) software which has been used in *Hungarian Diet and Nutritional Status* surveys [45, 46], as it contains detailed food composition information on 1328 food items and 1823 recipes. Additional recipes were created or existing ones were modified, if a food item was missing or had additional/less ingredients accordingly. The software converts inputs of food and drinks intakes, into quantified macro- and micro-nutrient intakes and creates a mean of the two dietary recalls. Comparisons of characteristics between study groups were made using chi-square (χ^2) test for categorical variables and t-test or ANOVA for continuous variables, as appropriate.

Data were presented as means accompanied by 95% confidence intervals (95% CI), where relevant, or as percentages. All assumptions for normality were checked. Multiple linear regression analyses were performed for exploring the associations between Roma ethnicity and nutrient intakes. Regression coefficients were adjusted for the respondent's age, sex, and education, marital and perceived financial status. Beta coefficients (β) and their corresponding 95% CI were calculated for explanatory parameters. In linear regression analyses, outcome variables with a non-normal distribution were normalized by Box–Cox transformation [151].

Further, binary outcomes were created based on international nutrient intake recommendations and a multiple logistic regression was used to compute the odds of achieving nutrient intake recommendations for the HR sample, with HG group as a reference, while adjusting for all relevant covariates (i.e., age, sex, and education, marital and perceived financial status). Results were presented as forest plots and an estimated overall quantitative value for the combined odds was shown for both fixed and random effect models [152].

Recommended intake values were obtained from WHO's official guidelines on diet, nutrition and the prevention of chronic diseases [143], as well as joint WHO/FAO's guidelines on fats and fatty acids [153], vitamins and minerals [154], sodium [155] and potassium [156]. In addition, recommended intake targets derived from the DASH [146], the EAT-Lancet reference diet [44] and European Food Safety Authority dietary reference values [157] were considered for benchmarking. Comparisons of intakes with recommended/reference intakes have been made. Univariate analysis with chi-square tests were used to evaluate the association between DASH, HDI, DII and NB-EAT scores, as well as socio-demographic and anthropometric factors such as age, sex, and BMI.

To appraise the differences between the HG and HR populations, negative binomial and Poisson regressions were considered if the data showed over-dispersion negative binomial regression would be chosen for the better fit. All sociodemographic and nutritional covariates (age, sex, education, marital status, perceived financial situation, economic activity, BMI and energy intake) were included in the models by a stepwise manner to determine the Roma ethnicity effect independently from sociodemographic and anthropometric data.

Initially, the regression models were fit with DASH, HDI, DII and NB-EAT scores as outcome variables and Roma ethnicity controlled for anthropometric data.

Secondly, demographic variables were added to each model. Finally, the regression models were fitted with demographic, anthropometric and socioeconomic factors together. Complete regression analysis results and models are provided in Tables S8-S11 (***Appendix***).

Statistical analyses were performed with IBM SPSS Statistics for Windows, Version 21.0 (IBM Corp., Armonk, NY, USA) and R Statistics (RStudio, Boston, MA, USA).

Results were reported in accordance with STROBE (***ST****rengthening the* ***R****eporting of* ***OB****servational studies in* ***E****pidemiology*) extension for nutrition and dietary assessment [158].

RESEARCH ETHICS

Approval for the research protocols and methodology implemented in this work was provided by the Ethical Committee of the Hungarian Scientific Council on Health (61327-2017/EKU).

Participants gave their written informed consent in each study population in accordance with the Declaration of Helsinki and the Science Ethics Code of The Hungarian Academy of Sciences.

RESULTS

In the complex health survey, as described above, the final study sample size was 797 participants, i.e. 410 in the HG and 387 in the HR population (response rates of 91.0% and 77.4%, respectively). However, for the current analysis cut-off values for implausibly low or high estimated caloric intake (<800 or >4500 kcal/day for males, <700 or >3500 kcal/day for females [124, 159, 160]), were applied. Those subjects, whose intake was out of the filtering ranges were excluded. Specifically, in the HG group 51 subjects were excluded (i.e. 4 and 47 for implausibly low intake and high intake, respectively) and in the HR group 43 participants were excluded (i.e. 4 and 39 for implausibly low intake and high intake, respectively). Therefore the final analysis contains the results for only 703 participants aged 20 to 64 years (i.e. 359 HG and 344 HR). Implausible intake reporting, particularly underreporting, is a widely recognized limitation of dietary assessment methods regardless of the type and it is often influenced by age, sex, and other individual characteristics, including BMI.

People suffering from obesity tend to underestimate their total energy intakes and under-report intakes of foods that are deemed unhealthy or socially undesirable, such as foods that are high in fat and refined carbohydrates. It is important to show after exclusion that, the characteristics of those who had implausibly low intake has not affected our benchmarking (i.e. comparison of intakes of HR subjects with those of HG population).

This information has particularly higher importance in case of the HR population, as it would be assumed that the proportion of HR excluded because of implausibly lower intake, would be higher. This would create a bias and would mask any possible nutrition security challenges. However, this is not the case, as the proportion of those excluded for implausibly lower intake is higher among HG population, compared to HR.

A detailed description and characteristics of excluded subjects are presented in Tables S1-S2 in the ***Appendix***.

SOCIODEMOGRAPHIC AND ANTHROPOMETRIC CHARACTERISTICS OF PARTICIPANTS

Both populations had a higher representation of females and HR status was associated with lower education, higher unemployment levels and more perceived financial difficulties (Table 1).

All these associations were statistically significant.

Table 1. Socio-demographic characteristics of participants

Variable	Hungarian General (n=359)	Hungarian Roma (n=344)	*P* [a]
Age group (*years*)	44.2 ± 12.2*	42.9 ± 12.1	>0.05
20-34	93 (25.9%) †	103 (29.9%)	
35-44	92 (25.6%)	85 (24.7%)	
45-54	100 (27.9%)	93 (27.1%)	
55-64	74 (20.6%)	63 (18.3%)	
Sex (*females*)	188 (52.4%)	248 (72.1%)	<0.01
Educational level			
Elementary	76 (21.2%)	292 (84.9%)	<0.01
Secondary	118 (32.9%)	17 (4.9%)	
Vocational training	112 (31.2%)	35 (10.2%)	
University degree	53 (14.7%)	0 (0.0%)	
Perceived financial status			
Very good	18 (5.2%)	5 (1.5%)	<0.01
Good	97 (27.6%)	46 (13.5%)	
Fair	190 (54.1%)	186 (54.7%)	
Challenging	40 (11.4%)	85 (25.0%)	
Very challenging	6 (1.7%)	18 (5.3%)	
Economic activity			
Full-time employment	267 (74.4%)	233 (67.7%)	<0.01
Part-time employment	29 (8.1%)	23 (6.7%)	
Student	8 (2.2%)	0 (0.0%)	
Retired	22 (6.1%)	22 (6.4%)	
Ill-health retirement	18 (5.0%)	10 (2.9%)	
Unemployed	15 (4.2%)	56 (16.3%)	

*[a] Student t-test was used to test differences and chi-square for associations. * Mean ± standard deviation. †*
Values are given as number (percentage).
Note that for 'Perceived financial status' 8 and 4 responses were missing for HG and HR respondents, respectively.

Average WC and BMI values were not significantly different between the two groups (they fell within the range of overweight status in both populations), but the distribution of BMI categories showed significant difference. Abdominal obesity, based on IDF_{EURO}, was significantly associated with ethnicity only among men (*Table 2)*.

Both underweight and obesity were more prevalent among HR. WH*t*R was significantly higher among HR, while females, in both groups, had significantly higher PBF compared to males, regardless of ethnicity.

Table 2. Anthropometric characteristics of the study populations

Variable	**Hungarian General** (n=359)	**Hungarian Roma** (n=344)	***P*** [a]
Height (*cm*) - mean (*95% CI*) [†]	169.1 (168.1-170.1)	161.4 (160.4-162.4)	<0.01
Males	175.6 (174.4-176.8)	170.7 (169.1-172.4)	<0.01
Females	163.1 (162.1-164.1)	157.8 (156.9-158.7)	<0.01
Weight (*kg*) - mean (*95% CI*)	78.0 (76.3-79.8)	72.2 (70.2-74.2)	<0.01
Males	85.0 (82.6-87.3)	81.5 (77.8-85.3)	>0.05
Females	71.8 (69.5-74.0)	68.6 (66.4-70.9)	>0.05
BMI (*kg/m²*) - mean (*95% CI*)	27.3 (26.7-27.8)	27.7 (26.9-28.4)	>0.05
Males	27.5 (26.8-28.2)	28.0 (26.7-29.3)	>0.05
Females	27.0 (26.1-27.9)	27.5 (26.7-28.4)	>0.05
Underweight	10 (2.8%)	22 (6.4%)	<0.01
Normal weight	116 (32.3%)	109 (31.7%)	
Overweight	129 (35.9%)	84 (24.4%)	
Obese (total)	104 (29.0%)	129 (37.5 %)	
Obese class I	73 (20.3%)	83 (24.1%)	>0.05
Obese class II	22 (6.1%)	31 (9.0%)	
Obese class III	9 (2.5%)	15 (4.4%)	
MHO - % (*95%CI*) [*]			
Lynch et al. criteria [138]	15.6 (12.0-19.8)	14.8 (11.2-19.0)	>0.05
Meigs et al. criteria [141]	33.7 (28.8-38.9)	25.6 (21.1-30.5)	>0.05
Karelis et al. criteria [139]	18.9 (15.0-23.4)	18.6 (14.6-23.1)	>0.05
Wildman et al. criteria [140]	21.2 (17.1-25.8)	16.9 (13.1-21.2)	>0.05
Waist circumference (*cm*) mean (*95% CI*)	95.9 (94.4-97.5)	95.1 (93.3-96.9)	>0.05
WHtR	♂0.56; ♀0.58	♂0.58; ♀0.60	<0.05
Abdominal/central obesity IDF$_{EURO}$[1] – *n (%)*	♂66 (38.6%);	♂42 (43.8%);	<0.05
	♀122 (64.9%)	♀161 (64.9%)	>0.05

Variable	Hungarian General (n=359)	Hungarian Roma (n=344)	*P* [a]
Estimated percentage of body fat - % (*95% CI*)			
Gomez-Ambrozi et al. [161]	32.7 (31.7-33.6)	35.1 (34.1-36.2)	<0.01
Deurenberg et al. [134]	30.7 (29.7-31.7)	33.2 (32.1-34.3)	<0.01
Woolcott et al. [132]	22.2 (21.4-23.1)	25.6 (24.6-26.6)	<0.01
Gallagher et al. [135]	29.6 (28.7-30.5)	31.9 (30.9-32.9)	<0.01

[a] Student t-test was used to test differences and chi-square for associations. Significant statistical comparisons are highlighted in grey.

[*] Proportion of subjects that suffer from obesity (BMI≥30 kg/m²) but are metabolically healthy according to different published criteria. Values are given as proportion and 95% confidence interval for the proportion.

[†] Values are given as means (95% confidence interval of the mean).

[1]International Diabetes Federation, 2006: criteria for Europeans (WC♂ ≥ 102 cm and WC♀≥ 88 cm). WHtR: waist-to-height ratio; PBF: percentage of body fat estimations by different equations; ♂: males; ♀: females.

Note: Criteria for determining metabolically healthy obesity (MHO) were based on three different criteria as follows:

- *Meigs et al. criteria (0 of the following): (1) HOMA-IR≥75th percentile in study population;*
- *Lynch et al. criteria (0 of the following): (1) blood pressure (mmHg)>130/85, (2) blood pressure medications, (3) lipid medications, (4) fasting TG/HDL-cholesterol ratio >1.65 in men or >1.32 in women, (4) fasting glucose (mmol/L)>5.55, and (5) diabetes medications;*
- *Karelis et al. criteria (≤1 of the following): (1) fasting TG (mmol/L) ≥1.69, (2) total cholesterol (mmol/L) ≥5.18, (3) LDL-cholesterol (mmol/L) ≥3.37, (3) HDL-cholesterol (mmol/L)<1.29 in men and women, and (4) HOMA-IR>1.9;*
- *Wildman et al. criteria (≤1 of the following): (1) blood pressure (mmHg) ≥130/85, (2) blood pressure medications, (3) fasting TG (mmol/L) ≥1.69, (4) HDL-cholesterol (mmol/L) <1.04 in men or <1.29 in women, (5) lipid medications, (6) fasting glucose (mmol/L) ≥5.55, (7) diabetes medications, (8) HOMA-IR>5.13 (i.e., ≥90th percentile in study population), and (9) C-reactive protein (mg/L) ≥90th percentile in study population.*

Estimations of percentage of body fatness were based on different equations as follows:

- *Gomez-Ambrosi et al. equation: $PBF = -44.988 + 0.503 \times age + 10.689 \times sex + 3.172 \times BMI - 0.026 \times BMI^2 + 0.181 \times BMI \times sex - 0.02 \times BMI \times age - 0.005 \times BMI^2 \times sex + 0.00021 \times BMI^2 \times age$ (Sex: Males = 0, Females = 1; $R^2 = 0.79$, Root Mean Square Error (RMSE) = 4.7%);*
- *Deurenberg et al. equation: $PBF = -11.4 \times sex + 0.20 \times age + 1.294 \times BMI - 8.0$ ($R^2 = 0.88$, RMSE = 2.5%);*
- *Woolcot et al. equation: $PBF = 64 - (20 \times (height/waist)) + (12 \times sex)$ ($R^2 = 0.84$, RMSE = 3.5%); and*
- *Gallagher et al. equation: $PBF = 64.5 - 848 \times (1 / BMI) + 0.079 \times age - 16.4 \times sex + 0.05 \times sex \times age + 39.0 \times sex \times (1/BMI)$ ($R^2 = 0.86$, RMSE = 4.98%)*

There were significant differences between the two groups on PBF – regardless of the method used to estimate it – with HR having consistently higher estimates of PBF than HG. The representation of MHO subjects was consistently, but not significantly, lower in the HR group compared to HG, regardless of the classifying criteria applied. Less than a third of all participants suffering from obesity were metabolically healthy.

Energy intake estimation was found to be not significantly different between HG and HR. Males had higher energy intake compared to females, regardless of ethnicity (*Table 3*), but this difference was found statistically not significant.

Table 3. Total average daily energy intake (*kcal*) by sex and ethnicity

	Hungarian General (n=359)		Hungarian Roma (n=344)		*P**
	Mean	*95% CI*	*Mean*	*95% CI*	
Both sexes	**2188.3**	2111.2-2265.3	**2114.1**	2042.3-2185.8	0.166
Males	**2270.9**	2148.9-2392.8	**2212.5**	2064.2-2360.8	0.559
Females	**2113.1**	2016.5-2209.7	**2076.0**	1994.5-2157.5	0.561

* *Student t-test was used to test differences between groups. 95% CI: 95% confidence interval of the mean.*

Energy intakes and contributions of energy-yielding nutrient, estimated by the MPM 24-h recall method, using country-specific food composition tables, allowed comparisons between the two groups at nutrient level.

The energy content of a food and drinks consumed by our participants was calculated as the sum of the factored contributions from standardized protein, carbohydrates, fat and alcohol using the Atwater factors in kJ 17, 17, 37 and 29 (in kcal 4, 4, 9 and 7) per gram of protein, carbohydrate, fat and alcohol, respectively. Disaggregation of dietary composition allowed quantification of various dietary components, with regards to macro- and micro-nutrients, both as absolute values and adjusted (e.g. expressed as percentage of total energy, as quantity per 1000 kcal, etc.).

Therefore, with regards to macronutrients total carbohydrate daily intake, as energy percentage, was significantly higher among HR, but still significantly lower than the recommended range in both groups (*Table 4*).

Sugar intake did not differ significantly between HR and HG, but it was significantly higher than the recommended daily intake of 10% of total energy intake (10%E), and even higher than the 5%E intake recommended by WHO for additional health benefits.

Total dietary fiber intake, both as absolute intake and adjusted quantity for 1000 calories, was much lower than the recommended daily amount for both groups.

Table 4. Macronutrient intakes among Hungarian Roma and general populations

Macronutrients	Recommendation [*Ref.*]	Hungarian General (n=359)	Hungarian Roma (n=344)	β [95% CI] †
Carbohydrates (%E)	**55-75 %E [143]**	46.2 [45.3;47.1]	48.2 [47.2;49.2]	**2.8 [0.9;4.8]***
Sugar (*g*)	**≤ 31 g [44]**	96.27 [89.03;103.5]	101.5[94.1;108.8]	**3.7 [1.8;5.6]***
Sugar (*%E*)	**≤10 %E (≤5%E) [143]**	17.0 [16.0;18.0]	18.8[17.7;19.8]	**0.03 [0.01;0.05]***
Fiber (*g*)	**≥ 24 g [143]; ≥ 42.9 g[44]**	20.3 [19.3;21.3]	20.4 [19.1;21.6]	-2.35 [-4.7;0.01]
Fiber (*g/1000 kcal*)	**14.8 g/1000 kcal [146]**	9.7 [9.2;10.1]	9.9 [9.4;10.4]	-0.75 [-1.7;0.2]
Proteins (%E)	**10-15 %E [143]**	15.5 [15.2-15.9]	15.1 [14.7;15.4]	-0.59 [-1.3;0.1]
Animal-based proteins (*% tot. proteins*)	**-**	59.3 [57.5;61.0]	60.6 [58.9;62.4]	-1.07 [-2.63;0.49]
Plant-based protein (*% tot. proteins*)	**-**	40.7 [39.0;42.5]	39.4 [37.6;41.1]	0.98 [-0.58;2.54]
Animal/plant protein ratio		1.8 [1.7;1.9]	1.6 [1.5;1.72]	**0.19 [0.04;0.34]***
Amino acids (*g*)	**-**	76.8 [73.9;79.7]	71.1 [68.5;73.7]	**-2.02 [-3.6;-0.4]***
Essential amino acids (*g*)	**-**	28.7 [27.6;29.8]	26.4 [25.4;27.4]	**-0.8 [-1.5;-0.2]***
Fats (%E)	**15-30 %E [143]**	37.1 [36.3;38.0]	36.1 [35.2-37.0]	-1.6 [-3.4;0.2]
Animal-based fats *(% of total fats*)	**-**	59.3 [57.5;61.0]	60.6 [58.9;62.4]	1.69 [-1.77;5.15]
Plant-based fats *(% of total fats*)	**-**	40.7 [39.0;42.5]	39.4 [37.6;41.1]	-3.34 [-6.80;0.12]
SFA (*%E*)	**≤10 %E [143]**	10.7 [10.3;11.1]	10.7 [10.3;11.0]	-0.2 [-0.9;0.6]
MUFA (*%E*)	**-**	11.9 [11.5;12.3]	11.4 [11.0;11.8]	-0.5 [-1.4;0.3]
PUFA (*%E*)	**6-10 %E [143]**	9.0 [8.7;9.3]	8.2 [7.9;8.5]	**-1.0 [-1.6;-0.4]***
UFA (*%E*)	**-**	20.9 [20.3;21.4]	19.6 [19.1;20.2[	**-1.5 [-2.6;-0.4]***
Cholesterol (*mg/1000 kcal*)	**71.4 mg/1000 kcal [146]**	172.9 [164.7;181.0]	159.5 [152.2;166.8]	**-18.8 [-34.4;-3.2]***
Cholesterol (*mg*)	**<300 mg[143]; ≤ 125.2[44]**	369.2 [350.7;387.7]	339.7 [320.3;359.2]	**-41.27 [-80.18;-2.36]***
ω-3 fatty acids (*%E*)	**1-2 % [143]**	0.31 [0.29;0.32]	0.27 [0.26;0.28]	**-0.06 [-0.11;-0.01]***
ω-6 fatty acids (*%E*)	**5-8 % [143]**	8.7 [8.4;9.0]	8.0 [7.7;8.3]	**-0.99 [-1.60;-0.38]***
α-linolenic acid (*%E*)	**0.5-2 %E [153]**	0.27 [0.26;0.28]	0.25 [0.24;0.26]	**-0.03 [-0.05;0.002]***

**p<0.05; Intake that is significantly different compared to internationally established recommendations are highlighted in grey and significant differences in intake levels between groups are bolded. † β: regression coefficient (regression coefficient was controlled for the respondent's age, sex, education, marital and perceived financial status, with Hungarian general population as reference and the β coefficient is associated with HR ethnicity). Notes: Every value is given as mean and 95% confidence interval of the mean. 95% CI: 95% confidence interval of the mean; [Ref.]: Reference – source of the recommended range; MUFAs: monounsaturated fatty acids; PUFA: polyunsaturated fatty acids; SFA: saturated fatty acids; UFA: unsaturated fatty acids; (%E): intake as percentage of total energy.*

Total dietary protein intake was significantly higher compared against recommended intake ranges among HG, but not among HR. Neither animal-based nor plant-based protein intake were significantly different between groups. Total and essential amino acid consumption was significantly lower in the HR sample compared to the HG group.

There were no significant differences by type and source of fat between the two groups, but there were significantly higher intakes (in both groups) compared to the established dietary recommendations. PUFAs' intake was significantly lower among HR, but still within the recommended range and both groups were characterized by an excessive intake of SFAs.

Cholesterol intake was very high compared to the reference limit in both groups, both as absolute intake and as adjusted value (i.e. mg/1000 kcal); while intake of beneficial fatty acids, such omega-3 fatty acids and alpha-linolenic acid, were very low, particularly among HR. Omega-6 intake was higher than the upper value of the recommended range among HG and significantly lower, but at the upper value among HR.

Minerals are inorganic substances required by the body in small amounts for a variety of different functions. Minerals are involved in the formation of bones and teeth; they are essential constituents of body fluids and tissues; they are components of enzyme systems and they are involved in normal nerve function. The body requires different amounts of each mineral; people have different requirements, according to their age, sex, physiological state (e.g. pregnancy) and sometimes their state of health.

In case of minerals and trace elements, sodium intake in both groups was exceedingly higher compared to established international dietary recommendations (*Table 5*), while potassium and magnesium intakes were below the recommended intake, independently of the criteria used. Intake values were not significantly different between the two groups.

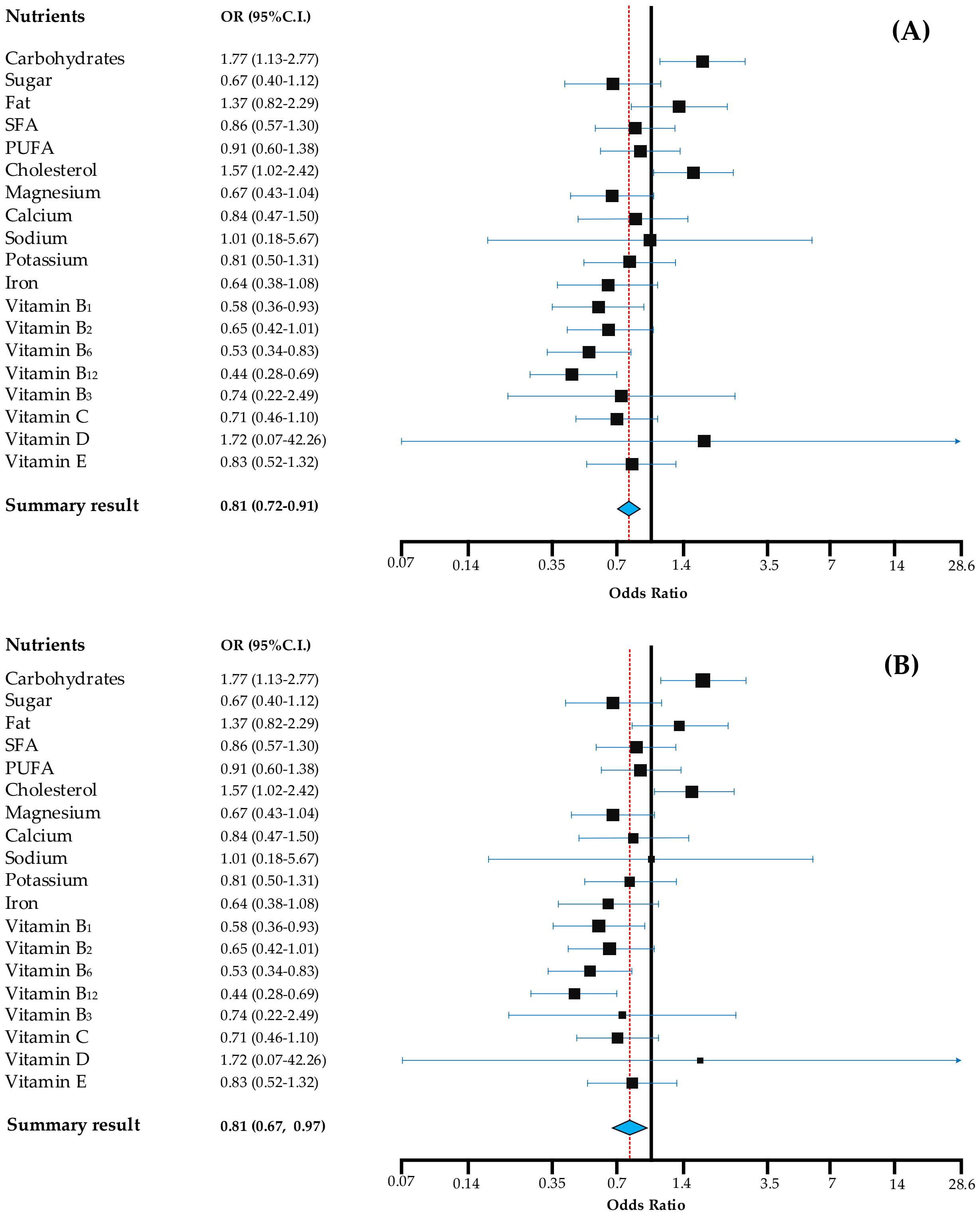
HR had consistently lower vitamin intake – particularly B vitamins - compared to recommendations. For more in-depth comparisons of nutrient intakes between males and females see Tables S3-S4 in the ***Appendix***. When examining the odds of the HR participants achieving the recommended daily nutrient intake ranges/values, compared to HG population as a reference, results showed that HR was less likely to achieve recommended intake targets, compared to HG (Figure 1).

Table 5. Micronutrient intakes among Hungarian Roma and general populations

Micronutrients	Recommendation [Ref.]	Hungarian General (n=359)	Hungarian Roma (n=344)	β [95% CI] †
Minerals and trace elements				
Magnesium (*mg/1000 kcal*)	**≥238 mg/ 1000 kcal [146]**	188.7 [164.7;212.6]	180.0 [172.6;187.3]	-32.2 [-73.1;8.7]
Calcium (*mg/1000 kcal*)	**≥590 mg/ 1000 kcal [146]**	246.9 [232.5;261.4]	245.9 [233.3;258.4]	1.0 [-27.7;29.7]
Sodium (*mg/1000 kcal*)	**≤1143 mg/1000 kcal [146]**	2605.1 [2508.7;2701.5]	2434.9 [2348.7;2521.2]	**-282.8 [-480.7;-84.9]***
Sodium (*mg*)	**≤2000 mg [155]**	5644.0 [5351.9;5936.0]	5094.4 [4866.0;5322.8]	**-765.0 [-1304.5;-225.5]***
Potassium (*mg/1000 kcal*)	**≥2238 mg/ 1000kcal [146]**	1371.8 [1297.4;1446.1]	1426.8 [1345.8;1507.7]	-105.9 [-267.6;55.8]
Potassium (*mg*)	**≥3510 mg [156]**	2981.8 [2752.2;3211.4]	2971.6 [2778.2;3165.1]	-432.3 [-870.4;5.9]
Iron (*mg/1000 kcal*)	**-**	5.2 [5.0;5.5]	5.2 [4.9;5.5]	**-0.6 [-1.2;-0.1]***
Iron (*mg*)	**1.05 mg [154]**	11.2 [10.6;11.8]	11.1 [10.2;11.9]	**-1.6 [-3.1;-0.1]***
Vitamins				
Vitamin A (*µg/1000 kcal*)	**-**	140.9 [124.9;156.8]	166.4 [129.1;203.8]	-19.0 [-81.6;43.6]
Vitamin A (*µg RE*)	**500 µg RE [154]**	294.89[260.9;328.9]	393.1 [279.6;506.69]	-78.86 [-245.64;87.92]
Beta-carotene (*mg/1000 kcal*)	**-**	1.2 [1.1;1.3]	1.36 [1.19;1.53]	-0.13 [-0.44;0.17]
Vitamin B_1 (*µg/1000 kcal*)	**-**	465.4 [448.8;482.1]	457.1 [439.2;474.9]	-32.9 [-68.4;2.5]
Vitamin B_1 (*µg*)	**≥1100 µg [154]**	1023.1 [973.3;1073.0]	960.5 [912.3;1008.8]	**-109.9 [-207.9;-11.9]***
Vitamin B_2 (*µg/1000 kcal*)	**-**	567.7 [512.4;622.9]	539.1 [514.0;564.1]	-68.51 [-164.6;27.6]
Vitamin B_2 (*µg*)	**≥1100 µg [154]**	1290.3 [1041.7;1538.9]	1135.4 [1068.1;1202.7]	-355.36 [-728.62;17.89]
Vitamin B_6 (*µg/1000 kcal*)	**-**	813.2 [785.2;841.2]	771.8 [741.7;802.0]	**-103.8 [-162.4;-45.3]***
Vitamin B_6 (*µg*)	**≥1300 µg [154]**	1761.7 [1689.0;1834.4]	1591.8 [1518.4;1665.1]	**-270.7 [-415.9;-125.6]***
Vitamin B_{12} (*µg/1000 kcal*)	**-**	1.6 [0.7;2.5]	1.3 [0.9;1.8]	**-2.3 [-3.9;-0.6]***
Vitamin B_{12} (*µg*)	**≥2.4 µg [154]**	3.7 [1.4;6.1]	3.0 [1.8;4.1]	-5.58 [-9.30;-1.87]*
Vitamin B_3 (*mg NE/1000 kcal*)	**≥6.6 mg NE/1000 kcal [157]**	9.7 [8.1;11.3]	8.4 [8.0;8.8]	**-3.7 [-6.4;-1.0]***
Vitamin B_3 (*mg NE*)	**≥14 mg NE [154]**	22.9 [15.7;30.2]	17.7 [16.6;18.7]	**-12.8 [-23.3;-2.3]***
Vitamin C (*mg/1000 kcal*)	**-**	37.3 [33.9;40.7]	40.08 [35.56;44.6]	**-8.7 [-16.7;-0.6]***
Vitamin C (*mg*)	**≥45 mg [154]**	78.8 [71.7;86.0]	79.4 [71.3;87.5]	**-18.98 [-34.26;-3.7]***
Vitamin D (*mg/1000 kcal*)	**-**	0.8 [0.7;0.9]	0.8 [0.6;0.9]	-0.1 [-0.3;0.2]
Vitamin D (*µg*)	**≥10 µg [154]**	1.7 [1.5;1.9]	1.7 [1.4;2.0]	-0.23 [-0.72;0.27]

**p<0.05; Intake that is significantly different compared to internationally established recommendations are highlighted in grey and significant differences in intake levels between groups are bolded. † β: regression coefficient (regression coefficient was controlled for the respondent's age, sex, education, marital and perceived financial status, with Hungarian general population as reference and the β coefficient is associated with HR ethnicity). Notes: Every value is given as mean and 95% confidence interval of the mean. 95% CI: 95% confidence interval of the mean; [Ref.]: Reference – source of the recommended range; (%E): intake and as percentage of total energy; NE: niacin equivalents; RE: retinol equivalents.*

Figure 1. Odds for achieving recommendations of Hungarian Roma compared to Hungarian general population*



*Note: In the fixed effects model (A) the summary result provides the best estimate of an assumed same effect of all nutrients in achieving recommendations and in the random effects model (B) the summary result gives the average from the distribution of random effects across nutrients. Calculations are based on age and sex-specific nutrient recommendations according to WHO, where applicable. OR (odds ratio) estimates are adjusted for age, sex, education, marital and perceived financial status, with HG as reference. *95% CI: 95% confidence interval of the mean; PUFA: polyunsaturated fatty acids; SFA: saturated fatty acids.*

The odds were significantly lower for HR in general, regardless of the model accounted for (*fixed and random effects*). Vitamin D had a wide 95% CI range, as there was a very limited number of participants that achieved recommended intake for this micronutrient.

DIETARY PATTERN SCORES AND QUALITY

Further, when accounting for dietary patterns quality, results showed a high representation of participants with poorer adherence levels for DASH, HDI and NB-EAT, independently of the dietary index used, ethnicity or sex (Table 6). Table 6 presents the distribution of the scores and adherence categories for the selected dietary indicators among HG and HR, disaggregated by sex. It can be noted that, DII tertile and score distribution show a considerable representation in the two upper tertiles. Additionally, there was no observed statistical association between sex and/or ethnicity and the selected dietary indexes, with regards to score differences.

Table 6. Distribution of the dietary indicators among HG and HR, by sex

Dietary indicator		Hungarian General (n=359)			Hungarian Roma (n=344)		
		Both sexes	Females	Males	Both sexes	Females	Males
HDI	Very low	27 (7.5)	13 (6.9)	14 (8.2)	23 (6.7)	18 (7.3)	5 (5.2)
	Low	172 (47.9)	91 (48.6)	81 (47.4)	152 (44.2)	113 (45.6)	39 (40.6)
	Moderate	140 (39.0)	75 (39.9)	65 (37.0)	158 (45.9)	111 (44.7)	47 (48.9)
	High	20 (5.6)	9 (4.6)	11 (6.4)	11 (3.2)	6 (2.4)	5 (5.2)
DASH	Non-accordant	341 (95.0)	177 (94.1)	164 (95.9)	330 (95.9)	240 (96.8)	90 (93.8)
	Accordant	18 (5.0)	11 (5.9)	7 (4.1)	14 (4.1)	8 (3.2)	6 (6.2)
NB-EAT	Low	324 (90.3)	171 (91.0)	153 (89.5)	305 (88.7)	223 (89.9)	82 (85.4)
	Moderate	35 (9.7)	17 (9.0)	18 (10.5)	39 (11.3)	25 (10.1)	14 (14.6)
	High	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
DII	Tertile 1	119 (33.1)	66 (35.1)	53 (31.0)	115 (33.5)	84 (33.9)	31 (32.3)
	Tertile 2	109 (30.4)	50 (26.6)	59 (34.5)	126 (36.6)	90 (36.3)	36 (37.5)
	Tertile 3	131 (36.5)	72 (38.3)	59 (34.5)	103 (29.9)	74 (29.8)	29 (30.2)
DASH score (0-9): median (IQR)		1.5 (1.5;2.0)	1.5 (1.5;2.0)	1.5 (1.5;2.0)	1.5 (1.5;2.0)	1.5 (1.5;2.0)	1.5 (1.5; 2.0)
NB-EAT score (0-12): median (IQR)		2.0 (2.0;3.0)	2.0 (2.0;3.0)	2.0 (2.0;3.0)	2.0 (2.0;3.0)	2.0 (2.0;3.0)	3.0 (3.0;4.0)
HDI score (0-7): median (IQR)		3.0 (3.0;4.0)	3.0 (3.0;4.0)	3.0 (3.0;4.0)	3.0 (3.0;4.0)	3.0 (3.0;4.0)	4.0 (4.0;5.0)
DII score (−4.60-3.12): median (IQR)		-1.26 (-1.49;-1.06)	-1.31 (-1.80;-0.92)	-1.26 (-1.45; -1.02)	-1.40 (-1.65;-1.23)	-1.34 (-1.64; -1.12)	-1.59 (-1.92; -1.27)

All data are given as n (%) unless otherwise indicated. IQR: Interquartile Range; DASH: The Dietary Approaches to Stopping Hypertension; HDI: Healthy Diet Indicator; DII: The Dietary Inflammatory Index; NB-EAT: Nutrient-based EAT-Lancet score.

Multivariable regression models (Table 7), both adjusted and unadjusted for the indicated and relevant covariates, showed no significant effect of Roma ethnicity on DASH, NB-EAT and HDI scores. On the other hand, DII score was significantly and inversely associated with Roma ethnicity in the adjusted models.

Table 7. Effect of Roma ethnicity on nutrient-based dietary patterns*

Dietary score	MODEL 1 (β [95%CI])	MODEL 2 (β [95%CI])	MODEL 3 (β [95%CI])
DASH†	-0.023 [-0.176 ; 0.129]	-0.084 [-0.286 ; 0.117]	-0.049 [-0.254 ; 0.156]
HDI†	0.038 [-0.131 ; 0.207]	-0.003 [-0.229 ; 0.223]	-0.001 [-0.231 ; 0.230]
DII‡	-0.147 [-0.344 ; 0.049]	**-0.450 [-0.709 ; -0.191]**	**-0.455 [-0.720 ; -0.191]**
NB-EAT†	0.021 [-0.073 ; 0.114]	-0.024 [-0.183 ; 0.136]	-0.017 [-0.179 ; 0.144]

*† Poisson regression model ‡Multiple linear regression model *Hungarian general population sample is taken as a reference in these models. Model 1: effect adjusted only for BMI and energy intake; Model 2: effect adjusted for BMI, age, education level, energy intake and sex; Model 3: effect adjusted for BMI, age, education level, energy intake, sex, financial status, marital status and economic activity (see Tables S8-S11 in the Appendix). Significant effect sizes are bolded. DASH: The Dietary Approaches to Stopping Hypertension; HDI:* Healthy Diet Indicator*; DII: The Dietary Inflammatory Index; NB-EAT: Nutrient-based EAT-Lancet score; β [95%CI]: beta coefficient of the regression model, accompanied by its corresponding 95% confidence interval.*

DISCUSSION

Nutrition plays a fundamental role in maintaining optimal health and preventing diet related NCDs. It is now clear that the effects of nutrition on health differ among individuals of different ethnicities, genetics, sex, etc. Recently ethnic health-related disparities have become a central focus of public health research, practice, and policy, as a growing body of evidence shows a strong association between ethnic and socio-economic disparities with healthy dietary and nutrient patterns [162-164]. Nutritional disparities play a major role in health and exist in the form of "*differences in dietary intake, dietary behaviors, and dietary patterns in different segments of the population, resulting in poorer dietary quality and inferior health outcomes for certain groups and an unequal burden in terms of disease incidence, morbidity, mortality, survival, and quality of life*" [165]. Typically, ethnic minority groups – such as Roma may experience diet-related disparities, and as a result have a tendency to have poorer dietary profiles and related behaviors, compared to majority population. Such disparities are often characterized by diets with excessive quantities and poor composition of dietary fats, low in dietary fibers from whole grains, vegetables and fruits; high in sodium and poor in beneficial micronutrients.

It is important to note that while such disparities may be often determined based on ethnicity, factors contributing to disparities may be associated more with socio-economic factors and food environment, rather than ethnicity *per se*. Since diet and nutrition are closely related to a number of NCDs, there is growing interest in characterizing the association between dietary and nutrient intake, particularly among the most disadvantaged minority population groups, such a Roma.

Nutritional epidemiology research efforts, as well as nutrition education and intervention initiatives aimed at reducing and ultimately eliminating diet-related disparities should be versatile, innovative, multi-component, and multi-faceted, and must include Roma minorities. This provides an opportunity to address and document such disparities and tailor interventions according to the identified needs, especially for those living in disadvantaged conditions.

The relatively unfavorable living conditions in which some Roma people live, frequently on the outskirts of towns and villages and in substandard settlements, allow relatively straightforward identification of locations in which Roma people are concentrated. This study has taken advantage of this aspect, by sampling HR participants in Northeastern Hungary, where the Roma population is greatest and in identified settlements, in which the population was almost exclusively Roma.

Below we discuss two themes that emerged while investigating dietary profile and nutritional status of Roma living in segregated colonies in Northeast Hungary, namely (1) dietary profile and general nutritional status and (2) adherence to healthy and sustainable dietary patterns. In addition we provide a brief outlook of the relevance of our findings to the current Corona Virus Disease 2019 (COVID-19) pandemic, which has only increased the importance of nutrition. A proper and healthy diet can ensure a robust immune system that can resist any onslaught by the virus.

A certain amount of particular nutrient saturates into cells and prevents any kind of nutritional deficiency. Individuals consuming well-balanced diets appear to be safer with better immune systems and lower incidence of chronic diseases and infections. Therefore here we make a call to overcome the current barriers towards better, more inclusive and mainstreamed nutrition education, services and research, if we aim to improve the metabolic health of Hungarian citizens. If all actors, including government, food industry, and the Hungarian public do not prioritize healthy and sustainable diets with high-impact policies, there is a serious risk of not only losing potential progress, but also a threatening increase in diet-related NCDs, which are already a major threat to Hungarian public health.

DIETARY PROFILE AND GENERAL NUTRITIONAL STATUS

To the best of our knowledge, this is the first study designed to characterize and examine selected health-relevant nutrients estimates and anthropometric parameters, as well as the dietary intake profile and patterns of the Hungarian Roma, with reference to the Hungarian general population, based on data derived from our complex health survey [3].

Overall, findings indicate poor dietary patterns for both groups, with inadequate dietary composition and anthropometric status estimates, not strongly different, but occasionally worse among HR. Dietary profile of HR participants could be characterized by lower odds for achieving established dietary recommendations, highlighting the need for additional public health initiatives to translate nutritional data into efficacious preventive interventions to lower risk of malnutrition in all its forms, as well as diet-related NCDs risk.

With regards to nutritional status, HR appear to be particularly affected by malnutrition in many forms, with less favorable estimates of body composition coupled with greater perceived financial challenges and higher unemployment rates – factors which may affect access to better nutrition and dietary quality. Although statistical differences could not be detected for some anthropometric indices, estimates of body fatness were significantly and consistently (criteria-wise) higher among HR, indicating less healthy body composition compared to HG.

Although not significantly different from HG, consistently lower MHO was showed among HR according to different classification criteria. Such results need to be confirmed via direct body composition measurements, but currently these findings are in line with results from recent analysis of two paired health surveys, where the distribution of BMI was shown to have significantly worsened among younger HR (in both sexes) between 2004 and 2015, with obesity becoming significantly more frequent [3]. In addition, Roma had higher rates of underweight compared to HG.

With regards to nutrient patterns and intake, dietary fat composition among the study participants, was substandard considering the representation of beneficial fatty acids, such as PUFAs, omega-3 fatty acids and alpha-linolenic acid, particularly among HR. SFAs and cholesterol intake were excessively high in comparison with the recommended intake, with no significant differences between groups. These results are consistent with recent WHO estimates, that show the adult population in Hungary with an estimated 11.8% of their total calorie intake coming from SFAs [166].

It is reasonable to assume that such high SFAs' intakes can be partially explained by the traditional consumption of meat and SFAs-rich products, such as lard, tallow, cold cuts and sausages among Hungarian population [167]. The current nutritional discourse and best dietary guidelines put no longer an emphasis on the reduction in total fat intake, but rather call for optimization of fat types in the diet, and specifically reduced intake of SFAs and trans-fats [168]. Therefore, given our results and the current evidence, dietary guidance should focus on optimizing dietary fat sources.

Similarly, a recent survey in South Bohemia Region (Czech Republic) [31], attempting to ascertain differences in eating habits between Roma and the majority population, based on qualification of major nutrient intake estimates, showed that Roma exceeded reference values for energy intake (as calculated in relation to sex, age and physical activity) and the proportion of fats (i.e. 34.9%E) in their diet was higher than the nutritional recommendations. Furthermore, high intake of animal-based proteins suggests a high meat and meat products consumption, supported by results of previous research on HG [169]. Higher proportion of plant-based proteins compared to animal-based proteins (regardless of type of meat: white or red meat) in diet has been shown to improve cardiometabolic profiles and reduce cardiovascular disease risk, on the basis of plasma lipid and lipoprotein effects [170]. The opposite, i.e. longitudinal higher intake of animal-based proteins, has been associated with increased risk of insulin resistance and prediabetes and type 2 diabetes mellitus (T2DM) [171]. Both groups had a greater than one animal to plant protein ratio and HG had significantly higher compared to HR. This result cannot be well interpreted, as no optimal animal to plant protein (or vice versa) ratio in the diet, has been established yet.

Sugar intake was also significantly higher evaluated against WHO recommended intake for both groups and previous data on HG adults have also shown similarly immoderate amounts of sugar intake [169]. Sugar, coming predominantly from glucose- or fructose-sweetened beverages and confectionary, is a great public health challenge in Hungary [172] and recent analyses have shown two-thirds of the adult population being overweight or obese, which has been partially linked to the excessive consumption of sugar-sweetened beverages [169, 173]. Governmental legislative initiatives have been introduced to tackle the situation, with most notably the 2011 Public Health Product Tax Act, applied to non-staple foods including sugar-sweetened beverages and pre-packaged sweets. However, given our results and the urgency to tackle the current 'sugar epidemic', measures aimed at reducing excessive sugar consumption should go beyond legal actions and additional regulatory mechanisms should be introduced, particularly targeting early exposures in childhood and adolescence.

Such mechanisms may include regulating and monitoring advertising of unhealthy foods and beverages, with special attention to child-directed food marketing. Moreover, sodium intake was observed to be exceedingly high for HR, both in terms of absolute and adjusted intake, and not significantly different from HG. It should be noted that the estimated intake in this analysis may be subject of a diluted underestimation effect, as sodium is typically under-reported when using recall methods, such as ours [174].

This means that the actual intake may be even higher. Such results strengthen the importance of existing national targets to reduce sodium intake at the population level. Another critical aspect of diet composition, in both study groups, was the inadequate fiber intake, which has been linked to higher risk of colorectal cancer [119].

This dietary aspect is highly relevant for Hungary as colorectal cancer is one of the most common causes of cancer-related death, for both males and females, in Hungary [175], making it the number one country in the world ranking list of age-standardized mortality (per 100,000) caused by colorectal cancer [176, 177]. Recent results from meta-analysis of prospective studies indicate a 10% reduction in colorectal cancer risk for each 10 g/day intake of total dietary fiber and cereal fiber, and an about 20% reduction for each three servings (90 g/day) of whole grain daily, and further reductions with higher intake [178]. Considering the current evidence on the protective effect of dietary fibers, our findings have important public health implications and provide support for public health nutrition recommendations to increase intake of fiber especially in the prevention of colorectal cancer. Fiber intake, combined with potassium estimates, can be an indication of fruits and vegetables consumption, which seems to be low and this is also reflected in the lower micronutrient intake among HR (particularly B-vitamins). Such results are supported by our recent study among HR showing that the Roma participants reported significantly less frequent consumption of fresh fruits and vegetables than the Hungarian subjects [85].

Previous research on Roma attempting to characterize eating habits and food choices during different periods of the year than the current research (April - September), as well as different locations where Roma reside, have also recorded an unfavorable dietary picture. Roma youth from Slovakia were reported to consume fruits less frequently than non-Roma individuals [21]. Roma participants (over 18 years of age) in survey from South Bohemian Region during June 2015 to March 2016, reported high consumption of sugar sweetened beverages and inadequate consumption of fruits and vegetables [24]. Another survey involving Roma and non-Roma subjects, conducted in the latter region, also reported low fruits and vegetables consumption [31].

A report from a European project involving Roma individuals from seven different European countries (i.e. Bulgaria, Czech Republic, Greece, Portugal, Romania, Slovakia, Spain) conducted in varying periods of the year (from March – June and September – December 2008) found that less than a third of Roma participants reported consuming fruits and fresh vegetables on a daily basis, while 36% reported consuming sweets and confectionery every day [26].

Research involving Roma from the county of Rimavská Sobota district of Slovakia (the survey was carried out during June 2007 – May 2008) showed that their diet was characterized by low consumption of dairy products and vegetables [27].

A cross-sectional study over a one-year period in 2010, using an instrument with questions related to the frequency of consumption for certain food groups among 400 participants from Roma communities in five districts in Albania, found infrequent consumption of fruits and milk and moderate consumption of meat and vegetables [28].

Further, estimates of the Household Budget Survey in Romania involving almost 9,000 settlements during 2004 to 2011, suggest that the Roma population has an inferior diet compared to that of non-Roma populations in terms of a lower proportion of dairy product, fruit, and vegetable intake [29].

Other studies involving Roma participants also suggest excessive consumption of fast-food, fatty meats and sweets and low consumption of vegetables and fruits [30] [25]. Eventually, findings from two paired health surveys, that we carried out in the general Hungarian and Roma populations using the same methodology before and after the Decade of Roma Inclusion were compared, and it was clearly shown that the distribution of BMI worsened significantly among younger Roma individuals (in both sexes) between 2004 and 2015, with obesity becoming significantly more frequent [3]. Such findings support the assumption that unhealthy diet is characteristic of the nutritional profile of the Hungarian Roma population, since obesity is a potential consequence of poor dietary behavior [179].

Despite the fact that all the above-mentioned studies have not quantified intake of micro- and macro-nutrients among Roma, it appears that dietary quality of Roma is less favorable than that of the host population, regardless of where their live or when the dietary survey was conducted. Our results are in line with these findings. This in turn signifies the need for public health nutrition interventions in addition to existing ones in Hungary, going beyond just legal and regulatory policies [118], while deliberately engaging minorities such as Roma, aiming at modifying current dietary patterns.

Given the complexity of nutritional behaviors and the wide range of influences on diet, such efforts require active collaboration of a variety of actors throughout the food system, along with policies targeting multiple sectors. Many populations, as in the present case, are dynamically enriched by a range of ethnic groups and such minority groups should be key targets when tackling inequalities in health. An opportunity exists, particularly within the current framework of the UN Decade of Action on Nutrition (2016-2025) global work program, which can be a successful decade also for Hungary.

Our results suggest that such actions should emphasize and reinforce the relevance of more plant-based proteins, higher fiber, fruit, vegetables, whole grains intake and substitution of detrimental fatty acids sources with beneficial fatty acids sources in energy balanced conditions. The present findings can also imply the presence of dietary risk factors, and signify elevated risk for diet-related NCDs in both groups examined. Given the importance of maintaining a healthy diet in supporting health and function, our results are of concern and require further work to be confirmed, as well as to identify the factors that drive such poor dietary patterns and thus, facilitate targeted interventions to Roma, who may need it most.

ADHERENCE TO HEALTHY AND SUSTAINABLE DIETARY PATTERNS

In relation to the nutrient-based dietary patterns, our results further confirm the substandard adherence to established healthy and sustainable dietary guidelines, as accounted by the nutrient-based dietary indexes used in this work. Ethnicity did not have a strong influence on adherence to the selected dietary guidelines. However, being Roma was associated with a lower DII score, i.e. lower dietary inflammatory potential. These findings are in line with our previous results and reinforce the fact that currently the Hungarian population is not close to meeting healthy diet targets – *regardless of ethnic background*. The cause of such a substandard quality of diet is likely to be multifactorial. A relevant contributor may be the lack of adequate dietary guidance/interventions, as nutrition services and dietary counselling have not yet been mainstreamed into the Hungarian health care system.

As a result, dietary patterns such as DASH, EAT-*Lancet* or dietary evaluation based on DII and HDI approach have not been widely promoted in Hungary. At present, provision of general preventive services in primary health care in Hungary is challenging and not based on evidence-informed dietary guidance, i.e. trained dieticians, nutritional experts, etc. [180].

General practitioners (GPs) constitute a significant workforce of the Hungarian primary healthcare system and are in regular contact with both the healthy and ailing people. According to our data and previous research, lifestyle counselling is the kind of service that patients need most and one of the leading drivers of medical litigation [181]. Coverage and quality of nutritional counselling services, within primary healthcare settings are limited and primarily focused on those suffering from diet-related NCDs, particularly among T2DM patients [182, 183].

People suffering from other diet-related NCDs (e.g. Crohn's disease, gluten sensitivity, etc.) are provided with some dietary advice, only within the context of outpatient care, with no targeted or tailored preventive dietary counselling yet. Additionally, dietary assessment is not common in the routine GP's practice and it is provided only for small proportion of patients (i.e. 24%; and mainly for hypertonic and diabetic patients), with almost no monitoring compliance or providing further counselling and/or follow-up [184].

Dietary services, currently available only in the outpatient and inpatient care, appear to target only those who are already suffering from diet-related NCDs, hence not as a preventive approach.

On the other hand, there is a limited number of private dietary and nutritional services, available only in the largest cities, relatively pricy and not clear whether they are effective or not. However, it is crucial to recognize that optimal health and well-being is a human right and not a privilege of only those who can afford to pay.

Integrating dietary services within health systems has the potential to generate substantial health gains and be highly cost-effective [185]. Another aspect of the inadequate access and/or availability of evidence-based nutritional services that merits attention, is the need to raise the profile of nutrition at national level, while aligning resource allocation accordingly. Currently, there is a demand for such services, particularly among high-income, highly-educated Hungarians [186], that seem to have recognized the value of nutritional guidance and interventions (e.g. balanced nutrition, blood glucose lowering, healthy weight control, etc.), among other lifestyle changes.

Currently, nutrition services are not widely supported by the Hungarian national health budget and are typically not delivered by qualified nutrition professionals, since other professions (e.g. personal trainers) are currently attempting to fill the demand gap [187]. The latter phenomenon has been recognized and there is data showing that such guidance is inadequate and not in line with established guidelines [187, 188].

Consequently, despite efforts to improve nutrition [189], Hungarians appear to have a limited exposure to professional and evidence-informed dietary and nutritional preventive services, something which may contribute to our “no difference” findings with regards to nutrient-based dietary patterns. Additionally, in our sample there was a considerable representation of subjects in the upper tertile of the DII, hinting an elevated inflammatory potential of the current dietary patterns. Chronic inflammation plays an important role in the development of several chronic diseases [190].

Since various nutrients and foods have been shown to modulate inflammation, dietary patterns play an important role in the regulation of chronic inflammation [191]. Although the link between diet and disease outcomes needs additional studies to further confirm the health potential of current dietary patterns, longitudinal epidemiological data have already linked poor adherence to healthy dietary patterns to many NCDs and claiming an attributable global death toll of 11 million from diet-related NCDs [106]. Therefore, there is a compelling case for urgently considering the inclusion of nutrition and dietary services as an integral component of primary healthcare [104]. The Hungarian healthcare system has for decades focused on the clinical, pharmacological-oriented model of disease that may ignore fundamental causes, such as diet and lifestyle.

The consequences of this approach can be observed in the poor dietary patterns reported here, with the potential to contribute to an elevated risk of diet-related NCDs and further supported by data showing a very high prevalence of metabolic syndrome in both HG and HR populations (i.e. 39.8% and 44.0%, respectively) with no significant difference between the two groups in either females or males [120]. Integrating and mainstreaming nutrition actions into the Hungarian health care system to promote healthier diet, and prevent and treat diet-related NCDs, has the potential to generate substantial health gains and be highly cost-effective [185]. In addition national public health program targeting the population as a whole is also missing in Hungary. The last Program for the Decade of Health [192] in which promoting healthy dietary habits and improving food safety were received particular focus ended in 2012, and it is still not renewed [193].

Furthermore, adherence to sustainable dietary patterns among our participants, can be viewed, not only as dietary marker, but as one of behavioral commitment towards addressing Climate Change as well. The vast majority of nutrient-based EAT-Lancet reference diet targets were not attained and none of the participants was in the third-upper category of adherence.

Considering the detrimental environmental impact of current food systems [194], and concerns raised about their sustainability, there is a pressing need to promote diets that are healthy and have no or low destructive impact on the environment in Hungary and globally.

The ‘Nutritional recommendations for the adult population in Hungary’ (i.e. national food-based dietary guideline [195]) released in 2004 fails to include sustainability criteria, although there is mounting evidence linking overconsumption of, in particular, red and ultra-processed meat products with detrimental human and environmental health outcomes [43, 196, 197]. Advocating for plant-based diets in Hungary is also timely.

Recommending dietary shifts towards plant-based diets may be of great importance in achieving health and sustainability goals [198]. From a food systems point of view, down-right adoption of plant-based diets has the potential to all-at-once optimize food supply, improve health, increase environmental sustainability, and advance social justice outcomes [199, 200]. Our results provide potential insights into dietary aspects that require particular focus during nutrition education aiming at improving the overall dietary quality among HR and HG as well. Apart from the established health benefits [201-203] DASH diet is also considered an environmental-friendly dietary pattern [142, 204]. Our results indicate an extremely high ‘non-accordance’ to DASH pattern (95%), independently of ethnicity.

This may be an epidemiological signature, which may signify increased risk for diet-related NCDs, as well as low potential of the current diet to contribute to climate targets. Thus our findings provide novel insights into dietary situation among HR and HG, as well as key dietary recommendations which might require special attention during nutrition/public health education. Such nutrition campaigns should strongly emphasize the importance of fiber, fruit, vegetable, and wholegrain intake and the substitution of saturated fats by mono/polyunsaturated fatty acid sources. Moreover, we advocate for nutrition education and research, to be integrated in health sciences-related academic programs, with an overarching emphasis and regular reinforcement of the importance of higher fiber, fruit, vegetable and wholegrain intake and substitution of fat sources with beneficial ones, in an energy balanced manner.

In addition to the above-mentioned challenges, the actual nutrition situation is clearly neither a mere consequence of inappropriate quantity/quality of foods in the Hungarian diet, nor as a lack of willpower from the individual [205], but a consequence of a fundamental global challenge*:* food systems that have failed in providing healthy, safe, affordable, and sustainable diets [206].

The economic, social, and environmental implications of further inaction can impact the growth and development of individuals and societies for decades to come [207, 208].

As the Lancet Series on the "Double Burden of Malnutrition" has shown, the intricate biological and social pathways of all forms of malnutrition cannot be disrupted through siloed interventions, therefore requiring society-wide and scalable behavioral shifts that can be sustained over time [209, 210]. Hence, more studies are warranted to determine the food system determinants, as well as social drivers of poor dietary intake in Hungary.

IMPLICATIONS OF FINDINGS FOR THE TRAJECTORY OF THE CURRENT PANDEMIC

Eventually, with relevance to the current COVID-19 situation, it is important to emphasize that research has showed that major risk factors for hospitalization, severity and mortality of COVID-19 include diet-related conditions, such as obesity, hypertension and T2DM [211-213]. A study of almost 7 million people with COVID-19, found a linear increase in risk of severe COVID-19 leading to admission to hospital and death at a BMI of more than 23 kg/m^2 and a linear increase in admission to an ICU across the whole BMI range, which is not attributable to excess risks of related diseases [214]. The relative risk due to increasing BMI is particularly notable people younger than 40 years and of black ethnicity. Hence, nutritional well-being for all, particularly the most vulnerable, has heightened significance in the face of COVID-19 pandemic [104]. Thus addressing malnutrition in all its forms and diet-related NCDs is crucial in preparedness and building metabolic resilience of populations for this and other potential future public health threats [215].

A streamlined response to COVID-19 in the context of nutrition and NCDs is important to optimize public health outcomes and reduce the impacts of this pandemic on individuals, vulnerable groups, minorities and societies [216]. Finally, the current COVID-19 pandemic has cast spotlight on longstanding costly and life-threatening inequities in global society. Those living in economically challenged communities, such as ethnic minorities, are bearing the heaviest burden of COVID-19 infections [217, 218]. It is now accepted that poor metabolic health is one of the most important immunity-impairing factors underlying cardiovascular disease, T2DM and obesity-related cancers, rendering many people vulnerable to COVID-19 severity and mortality [219]. However, while diet-related NCDs may increase vulnerability to the virus, limited attention has been paid in improving access to healthy and sustainable diets that can both sustain metabolic health, support a vigorous immune system and contribute to lessening the effect on the environment.

After this pandemic subsides, hopefully a lot more attention to the needs to be given to the potential of our diets have to ward off, not only future medical, economic and social calamities from whatever pathogen next comes down the pike, but to address bigger ‘pandemic’ as well climate change. As governments embark on economic recovery plans in the wake of COVID-19, a great opportunity exists, within the framework of the UN Decade of Action on Nutrition (2016-2025), to invest in a green recovery plan that can tackle the health equity and environmental crises together, to ensure the most effective response to each. Addressing these issues and building forward better starts with our ‘plates’.

STRENGTHS, LIMITATIONS AND CONSIDERATIONS FOR FUTURE RESEARCH

This report provides a comprehensive comparative dietary analysis with primary data, offering an opportunity to explore nutrition and diet among Roma in relation to a variety of measures of nutritional quality and anthropometric status.

However, even though our analysis may be the first comprehensive and detailed characterization for Roma’s nutrition, there are some limitations to our observations that should be recognized. Observations are based on a double multiple-pass 24-hour dietary recall, and even though it is a valid approach to assess dietary intake patterns in epidemiological studies, findings need to be interpreted with caution, as long-term or seasonal variation of dietary patterns, in the populations under investigation, may not be fully captured.

In our study the representation of females among HR was higher than among HG. This has also been the case in our previous surveys conducted among segregated Roma colonies in Hungary, with more female respondents [20], and also in Roma surveys in other countries [220]. We have described in our previous work [120] that one of the major limitations of the study is that females are overrepresented in the Roma sample.

This cross-sectional survey was based on randomly selected households and in many households, only women were home during the day when most visits took place, while men had travelled at least locally for public work. The Hungarian government has quadrupled the budget for public works between 2010 and 2015 for all Hungarian municipalities. This is especially relevant for villages in the North-eastern region of Hungary, where segregated Roma settlements are concentrated. Therefore, the majority of workers participating in the program have been men from deprived Roma communities.

The same challenge has been identified in a cross-sectional survey among Slovakian Roma, where females were strongly overrepresented (64.8%) in the sample [220]. Further, the Roma study population can be considered representative only of HR living in segregated colonies of Northeast Hungary, but not representative of overall Roma population living in Hungary. A common challenge in ethnicity-based studies is the accurate determination of ethnicity. In the present study, Roma ethnicity status was self-reported, which may result in losing potential participants [8]. Concerning the fact that data collection was made by Roma university students with the support of the local Roma self-government only slight – if any – loss of subjects can be assumed.

Considering that more than 8% of the Hungarian population is Roma, it is reasonable to suppose that individuals belonging to the Roma population may be present in the HG sample, which may result in a potential slight underestimation of differences between the two study groups. Roma who have been, to various degrees, assimilated with the general Hungarian population were not included due to scope of the study. Additionally, PBF estimates were based on anthropometric equations and future research should consider measuring body composition directly to confirm our results. It is remarkable though, that regardless of the equation used, there was significantly higher estimated body fatness among HR.

Another element that needs to be taken into consideration for the current results is that the *NutriComp Étrend ver. 3.03* software does not provide within-person variation corrections of dietary data. To reduce day to day variation of dietary intake, the software calculated the average of the two-day intake, allowing room for some measurement error. However, we used this software as it is the only software with nutritional data tailored specifically for the Hungarian context, containing special dishes, and food types consumed only in Hungary and their respective nutrient composition. If the results had been processed with another software, the measurement error would have been unacceptably larger compared whit this software. Eventually, comparisons of intake patterns and nutritional status between HR and HG, should consider the social context in which such differences are measured and occur, with cautious interpretations that consider the social determinants of health. Research shows that unemployment rate among HR communities exceeds not only that of the general population, but the unemployment is significantly different from even among small areas of Hungary as well [221]. Low levels of education, coupled with widespread discrimination in employment, exclude large numbers from the labor market [222]. Hence, a substantial proportion of the HR population remains economically challenged.

This is highly relevant regarding nutrition, as higher quality diets of lower-energy-density are likely to cost more [223-226] and can be not only more costly per kilocalorie, but also more likely to be consumed by individuals with higher educational level as well [223, 225]. Therefore, identifying dietary patterns that are nutrient-rich, affordable, and taste-appealing for the HR should be a public health research priority to identify and address social inequalities in nutrition and health. The current findings, even though insightful, are relatively incomplete, as linking them with health outcome data (e.g. metabolic syndrome) is crucial in order to better characterize the current situation, and link health effects of an environmentally sustainable diet and further confirm these findings. Although diet is, no doubt, an important modulator of inflammation, it is by no means the only one.

Other indexes, including physical activity and stress, should be derived using similar methods. If these could be integrated with the DII, then this could validate and confirm the inflammatory potential of the diet in the current population under investigation. It should be taken also into consideration that in our study the representation of females among HR was higher than among HG. This has also been the case in our previous surveys conducted among segregated Roma colonies in Hungary [20] and also in Roma surveys in other countries [220].

Although this is the first attempt, to the best of our knowledge, to present a nutrient-based index for healthy and sustainable diets based on the rigorous EAT-Lancet reference diet, we recognize that it may need further validation. The EAT-Lancet commission's "healthy and sustainable reference diet" provides values of nutrient composition, as well as intakes for food groups, with the latter being more informative. In our attempt to describe dietary sustainability, NB-EAT's use was chosen due to the inability to obtain dietary intake data at the level of individual food items or food group data – something which we acknowledge that can provide more tangible details on the healthiness and sustainability aspects of the diet. Nevertheless, it was shown that there is a poor adherence to healthy and sustainable dietary targets, independently of the dietary pattern and population group.

Further work on drivers of poor dietary patterns should go beyond measuring the effect of prescribed, (but often not followed) dietary guidelines on population-averaged cohorts, towards quantifying the efficiency of dietary and lifestyle advice as well. Even the best dietary advice in the world may be indistinguishable from the worst, when individuals do not or cannot adhere to it due to specific circumstances, e.g. place of residence, access to healthy foods, employment conditions, income, etc.

Despite the abovementioned challenges, our findings offer new nutritional insights on dietary aspects that require particular attention during potential interventions and monitoring their effects, when attempting to improve the overall quality of the diet among young adults in Hungary. Decision-makers and experts should approach this issue from a food system's perspective, in order to address and transform the complex web of activities involving the production, processing, transport, and consumption of unhealthy diets. Another possible limitation is the different response rates of the two study samples. The response rate of the Hungarian sample was 91%, while it was less favorable (77.4%) among the Roma population. Survey response rates of Roma surveys differ to a great extent (28-96.9 %) [9, 102, 227-230] and can be lower among Roma populations than among the majority populations included in research [102, 227, 230]. This phenomenon can be due to the lack of incentives for participation and motivation of Roma to be involved in free medical examinations and to the existing mistrust of segregated Roma towards interviewers. To address the latter issue, Roma field workers were involved in our study; however, higher response rates were not achieved. Although the response rate of Roma individuals in our study was lower than that of the reference sample, it is quite high if we compare it with the majority of Roma studies [227-229]. To design potentially effective nutrition intervention programs, it is important to identify the individual, environmental, social, cultural, and behavioral factors and their complex interplay that may have an effect on dietary intake and dietary behaviors. All the barriers need to be addressed, such as social and cultural symbolism of foods, poor taste and cost of healthy foods and lack of information [231]. Strategies to reduce diet-related disparities should include *individual-level approaches* (e.g. targeted nutrition education, dietary counseling and intervention programs; with a focus on cultural and environmental attributes, the use of innovative approaches and novel channels for delivering nutrition education and interventions; the identification of strategies for improving recruitment/retention in intervention, etc.) and *societal-level approaches* (e.g. increasing healthy food options in low-income neighborhoods, increasing healthy options in schools, creating environments to encourage physical activity, addressing other barriers to behavioral change, etc.) [232]. HR need to be provided with basic nutrition knowledge and practices, as well as be encouraged to build a healthy diet, with culturally relevant and sensitive considerations with regards to their lifestyle [231]. Addressing the problem of food accessibility among HR is essential and it is important to emphasize that further research is needed on their dietary habits, including evaluation of nutrient profile and intake of traditional Roma dishes and cooking habits, including other diet-relevant lifestyle elements.

CONCLUSION

In summary, current dietary profile, intake patterns and nutritional status of HR living in segregated colonies in Northeastern Hungary, was found to be suboptimal, with inadequate nutrient composition and anthropometric status estimates, not strongly different than HG population, but occasionally worse among HR. Ethnic-specific differences exist with regard to meeting nutrient-based dietary recommendations, with Roma being less likely to comply, compared to HG population. To date, this is the first study, to provide detailed and comparable (with the general population) data on nutrient patterns and intake, as well as extensive anthropometric indices in a relatively large sample of Roma. Such data are valuable for developing and implementing public health nutrition strategies to meet the national dietary recommendations, as well as for guiding nutrition education and intervention programs to reduce the risk malnutrition in all its forms and diet-related NCDs risk, in these high-risk population. This study also demonstrates the data gaps on intake for key nutrients among HR, highlighting the importance of establishing and integrating Roma nutrition in national surveillance and monitoring systems for key dietary risk factors. It is timely to reconsider dietary guidelines for Hungary, with incorporation of evidence on ethnicity-related issues into these recommendations.

Potential nutritional interventions in Hungary, addressing healthy and sustainable nutrition, are not only necessary among Hungarian Roma population, but on a population-wide level as well. Unhealthy nutrient-based dietary patterns appear generally indiscriminate of ethnic background according to our analyses, with both populations (HG and HR) poorly adhering to healthy and sustainable dietary patterns, with no strong mediation by any included factor in this analysis. Identifying dietary patterns that are nutrient-rich, affordable, healthy and sustainable for Hungarians should be a top public health research priority, as well as an opportunity to discern and address social inequalities in nutrition and health. Our cross-sectional analysis also indicates that current nutritional trajectory may not be in line with achieving the sustainable development goals in respect to multiple dietary targets for public health and environmental sustainability. Research and policy action therefore need to be integrated between disciplines and domains, starting with the formulation of integrated national nutrition guidelines, through a sustainability lens and an outlook of long-term challenges to the food system, as well as an agenda to achieve the relevant behavioral change. Further research is warranted to elucidate drivers and ascertain food-based dietary patterns, with sustainability considerations in mind.

SUMMARY

Background: Nutritional epidemiology studies on Roma people are scarce and, to date, no quantified dietary data has been reported on their actual intake, dietary profile or adherence to dietary patterns with regards to both health and sustainability considerations.

Aim: This report aimed to provide, for the first time, quantified dietary data and comprehensive anthropometric information, including adherence to healthy and sustainable dietary patterns.

Methods: Data were obtained from a complex comparative health survey, involving 387 and 410 subjects of HR and HG populations, respectively. Using corporal measurements, body composition indicators were constructed, while daily nutrient intakes were evaluated in comparison with internationally accepted guidelines on nutrient requirements and recommended intakes. Associations between Roma ethnicity and nutrient intakes, as well as odds of achieving dietary recommendations were explored using regression models, adjusted for relevant covariates (i.e., age, sex, education, marital status and perceived financial status). Scoring and regression models were employed, based on recommendations defined by the World Health Organization, in the Dietary Approaches to Stop Hypertension (DASH) study and the EAT-Lancet report, as well as dietary quality derived from Dietary Inflammatory Index (DII) among the Hungarian Roma (HR) population living in North East Hungary, with Hungarian general (HG) adults as reference. Poisson regressions were fit to models that included DASH, EAT, DII and Healthy Diet Indicator as dependent variables to assess the influence of ethnicity on healthy and sustainable nutrient-based patterns.

Results: Results showed occasional differences for selected nutrient intakes between the groups, with HR's intake being less favorable. Total fat intake, predominantly animal-sourced, exceeded recommendations among HR (36.1 g, 95% confidence interval (CI): 35.2–37.0) and was not dissimilar to HG group (37.1 g, 95% CI: 36.3–38.0). Sodium intake among HR was significantly lower (5094.4 mg, 95% CI: 4866.0–5322.8) compared to HG (5644.0 mg, 95% CI: 5351.9–5936.0), but significantly greater than recommended intake in both groups. HR had greater estimated body fatness (25.6–35.1%) and higher average body mass index (BMI, 27.7 kg/m2, 95% CI: 26.9–28.4), compared to HG. HR had lower odds of achieving dietary recommendations (odds ratio (OR) = 0.81, 95% CI: 0.67–0.97, $p < 0.05$).

Adjusted models controlled for all relevant covariates using the residual method indicated poor dietary quality with regards to the selected dietary patterns. These associations were not ethnicity-sensitive, except for DII, where Roma ethnicity was linked to a decrease of DII score ($\beta = -0.455$, 95%CI: -0.720; -0.191, $p < 0.05$).

Conclusions: Currently, HR dietary patterns appear to be relatively unhealthy and unsustainable, rendering them vulnerable to elevated risk of ill-health. Nevertheless, their dietary patterns did not strongly differ from HG, which may contribute to Hungarians being one of the most obese and malnourished nations in Europe.

Practical implications: Findings warrant further research, while highlighting the importance of establishing and integrating Roma nutrition into national surveillance and monitoring systems for key dietary risk factors. Evidence presented here on whole dietary patterns of HR and HG raise concerns about potential adverse health effects of the current state of nutrition and diet in Hungary. Implied shifts toward plant-based diets and away from animal-based ones and changes in food system have direct relevance to the Hungarian health agenda, as well as the Sustainable Development Goals 2030 agenda. Malnutrition, in all its forms, will have serious and lasting economic, social and clinical impacts on the health of Hungarian families if not addressed. An opportunity exists, particularly within the current framework of the UN Decade of Action on Nutrition (2016–2025) global work program, which can be a successful decade also for Hungary.

KEYWORDS

Nutrition; Roma; Hungary; Diet; Nutritional status; Dietary Intake; Health; Dietary patterns; Dietary indicators; Sustainability; Dietary recall

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AUTHOR'S DECLARATION

This thesis report is mainly based on author's published work and results:

- Llanaj, E.; Vincze, F.; Kósa, Z.; Sándor, J.; Diószegi, J.; Ádány, R. Dietary Profile and Nutritional Status of the Roma Population Living in Segregated Colonies in Northeast Hungary. *Nutrients* **2020**, *12*, 2836. https://doi.org/10.3390/nu12092836

- Llanaj E, Vincze F, Kósa Z, Bárdos H, Diószegi J, Sándor J, Ádány R. Deteriorated Dietary Patterns with Regards to Health and Environmental Sustainability among Hungarian Roma Are Not Differentiated from Those of the General Population. Nutrients. 2021; 13(3):721. https://doi.org/10.3390/nu13030721

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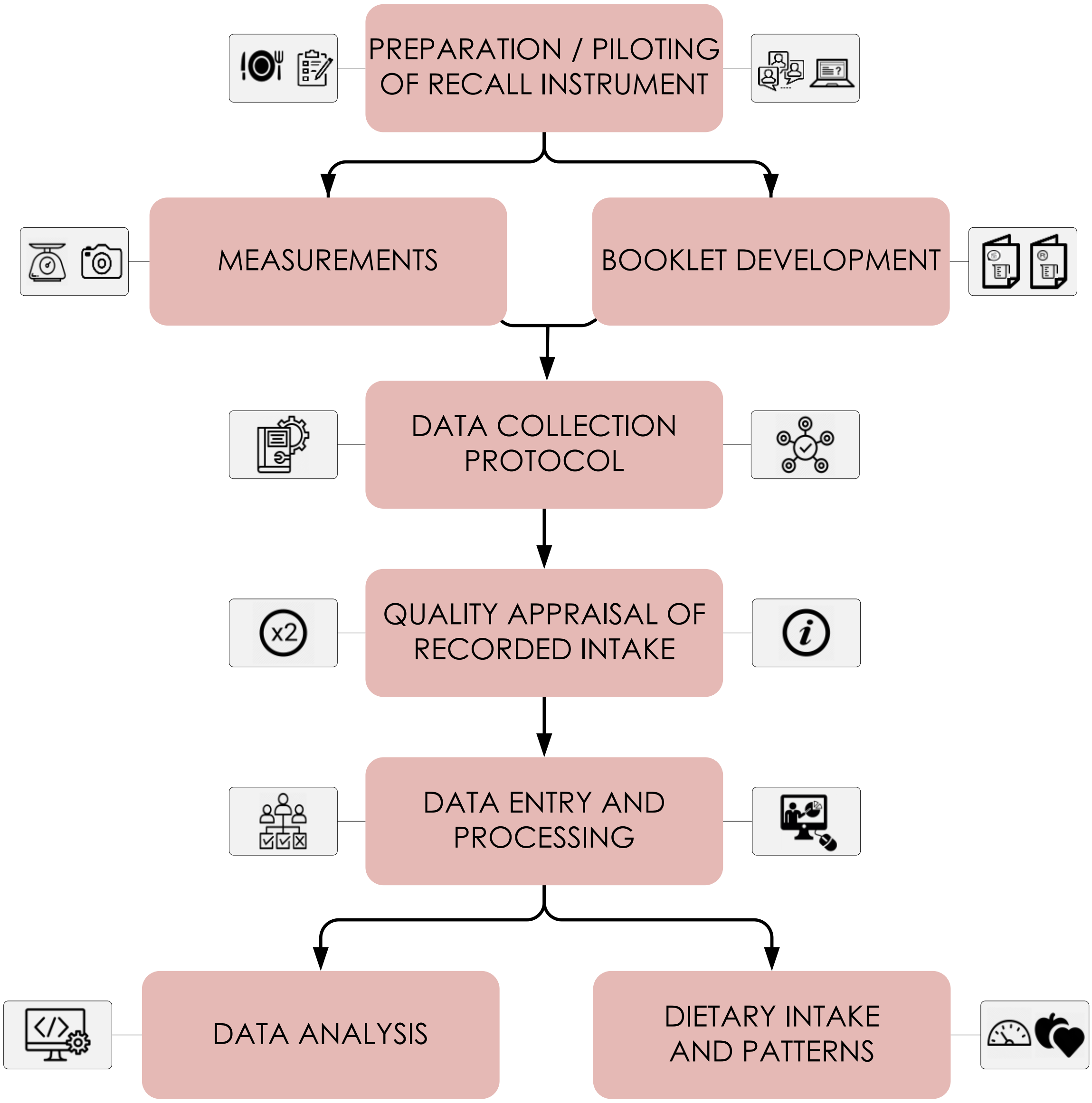
APPENDIX

DIETARY INTAKE DATA: DESIGN, PILOTING AND VALIDATION OF DIETARY DATA COLLECTION INSTRUMENT

The whole process of design, piloting and validation of dietary data collection instrument and the procedures undertaken in our work to estimate and determine dietary intake and patterns are described in Figure S1, below.

Figure S1. Flowchart of the process of design, piloting and validation of dietary data collection instrument



Specific elaboration on the dietary data intake collection and internal development of the accompanying booklet can be found in the sections below.

Dietary intake data collection

Dietary intake data were obtained through an interviewer-assisted, double multiple-pass 24-h diet recall (one weekday and one weekend day). Prior to the cross-sectional survey, two focus groups were organized with Hungarian general (HG) and Hungarian Roma (HR) subjects in two different locations (Nyíregyháza and Debrecen). A single 24-hour recall was completed, in order to pilot and compare the 24-hour multiple-pass method (MPM) recall instrument against three-day unweighted food record.

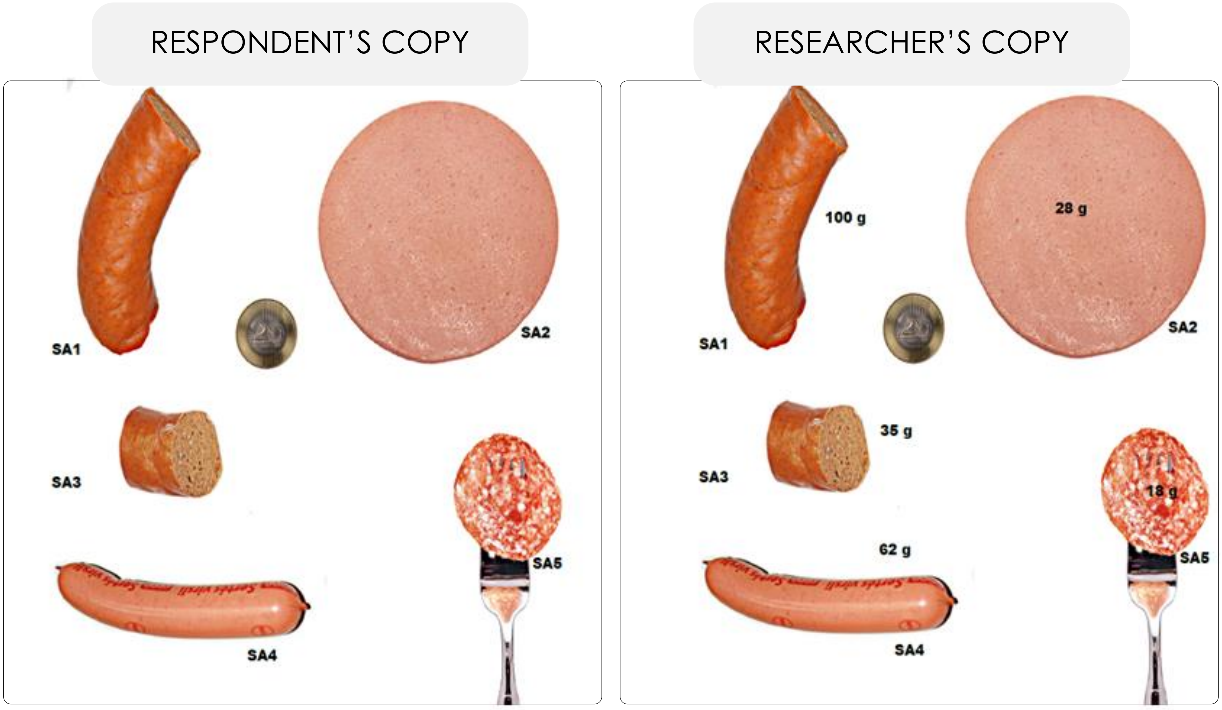
Questions concerning comprehension and interpretation of the illustrated accompanying draft food booklet, recognition and familiarity with different dishes, food items and containers, as well as potential omittable or under-reportable items were also examined. Images of canned foods commonly consumed, usual utensils and some containers widely used among subjects, not present in the initial draft booklet, were inserted in the latter version accordingly.

Booklet development

Following focus groups' findings and the results from the recall instrument, modifications were introduced to the accompanying booklet, such as representations of real-life size drawings of different containers and dishes. This was done with the intent of making it more convenient for participants to identify and estimate amounts and portion sizes of reported food and drinks, as well as to increase accuracy and ease of identification of the illustrated items. The amount of food consumed and discarded was estimated with the aid of the booklet, and the software automatically calculated energy and nutrient intake. The reliability and validity of measuring food intake increase with the aid of the accompanying booklet with reference images and aids in adults. In addition to increasing accuracy of estimates food intake, this approach has many advantages, including reduced participant burden, elimination of the complexities for subjects to estimate portion size (s), and a better understanding of population-specific dietary considerations.

Since, to date there is no standard portion size guide booklet for Hungary, further adjustments were made. A recognizable life-size picture of a 200 HUF (Hungarian Forints) coin and occasionally other recognizable items (kitchen utensils) were attached to picture models to increase accuracy of estimating portion sizes (see example in **Figure S2** below).

Figure S2. Sample quantification from the booklet used in this study



Portion sizes for fruits, vegetables and other food/drink items were established and a database with food measurements was developed with average weights of different items after sampling and weighting with a digital kitchen scale. In addition, two versions of the booklet were developed, one for the interviewers and one for participants. The purpose for creating two versions was to minimize influence on participants during portion size estimation. The interviewer's version had clear indications of exact weight of food/drink(s), but participant's version had no indication of any quantity or weight (see example in **Figure S2** above). The booklet was validated qualitatively through focus-groups and piloting before beginning the study as described above and the design process was developed from the concept used in our previous research [124].

DIETARY DATA PROCESSING

Following data collection completion, a quality appraisal protocol was applied and completed recalls would be accepted if: (1) two recalls were available (i.e. one for a weekday and one for a weekend day), (2) subject identification code was correct, (3) columns were filled according to instructions. In case of substantial error(s), interviewers should have repeated the recall procedure for the corresponding subject. After successful initial assessment, recalls were considered eligible for data entry.

Thirty-five undergraduate students of the dietetics bachelor program, at the Faculty of Public Health, University of Debrecen, were recruited and trained on the process of data entry in *NutriComp Étrend* software. The process was supervised by a registered dietitian. Data entry included three stages: firstly, data were entered in the database, based on the dietary recalls and all missing items or unusual foods/drinks were indicated. Secondly, the supervisor determined which relevant foods, drinks, ingredients or recipes could be used in these cases, and eventually, the correct information was inserted and processed.

Table S1. Socio-demographic characteristics of excluded subjects due to implausibility of intake data

Variable		Hungarian General (N=51)	Hungarian Roma (N=43)
Age – mean (std. deviation)		45 (13)	42 (12)
Sex	*Male*	9(64.3)	5(35.7)
	Female	42(52.5)	38(47.5)
Perceived financial status	*Very good*	2(100)	0(0)
	Good	10(58.8)	7(41.2)
	Fair	37(63.8)	21(36.2)
	Challenging	1(11.1)	8(88.9)
	Very challenging	1(14.3)	6(85.7)
Educational level	*Elementary*	10(22.2)	35(77.8)
	Secondary	17(89.5)	2(10.5)
	Vocational training	11(68.8)	5(31.3)
	University degree	13(92.9)	1(7.1)
Economic activity	*Full-time employment*	35(53.8)	30(46.2)
	Part-time employment	5(83.3)	1(16.7)
	Student	1(100)	0(0)
	Retired	3(50)	3(50)
	Ill-health retirement	3(60)	2(40)
	Unemployed	4(36.4)	7(63.6)

Values are presented as n (%), unless otherwise indicated. Only data for participants with full records are presented.

Table S2. Socio-demographic characteristics of excluded subjects due to implausibility of intake data, by type of implausibility (i.e. low vs. high)

		Hungarian General			Hungarian Roma		
		Implausibly Low	***Implausibly High***	**Included**	***Implausibly Low***	***Implausibly High***	**Included**
Age – mean (std. deviation)		51(11)	45(13)	44.2 (12.2)	52(12)	41(12)	42.9 (12.1)
Females		2(5)	38(95)	188 (52.4)	3(7.9)	35(92.1)	248 (72.1)
Perceived financial status	*Very good*	0(0)	2(100)	18 (5.2)	0(0)	0(0)	5 (1.5)
	Good	0(0)	10(100)	97 (27.6)	1(14.3)	6(85.7)	46 (13.5)
	Fair	4(11.1)	32(88.9)	190 (54.1)	1(4.8)	20(95.2)	186 (54.7)
	Challenging	0(0)	1(100)	40 (11.4)	0(0)	8(100)	85 (25.0)
	Very challenging	0(0)	0(0)	6 (1.7)	2(33.3)	4(66.7)	18 (5.3)
Educational level	*Elementary*	0(0)	9(100)	76 (21.2)	4(11.4)	31(88.6)	292 (84.9)
	Secondary	1(6.3)	15(93.8)	118 (32.9)	0(0)	2(100)	17 (4.9)
	Vocational training	3(27.3)	8(72.7)	112 (31.2)	0(0)	5(100)	35 (10.2)
	University degree	0(0)	13(100)	53 (14.7)	0(0)	1(100)	0 (0.0)
Economic activity	*Full-time employment*	3(8.6)	32(91.4)	267 (74.4)	3(10)	27(90)	233 (67.7)
	Part-time employment	1(25)	3(75)	29 (8.1)	0(0)	1(100)	23 (6.7)
	Student	0(0)	1(100)	8 (2.2)	0(0)	0(0)	0 (0.0)
	Retired	0(0)	3(100)	22 (6.1)	0(0)	3(100)	22 (6.4)
	Ill-health retirement	0(0)	3(100)	18 (5.0)	0(0)	2(100)	10 (2.9)
	Unemployed	0(0)	3(100)	15 (4.2)	1(14.3)	6(85.7)	56 (16.3)

Values are presented as n (%), unless otherwise indicated. Included intakes are highlighted in grey for reader's convenience and only data for participants with full records are presented.

Table S3. Macronutrient intakes among Hungarian Roma and general populations, by sex

Macronutrient	Hungarian General (n=359)		Hungarian Roma (n=344)		Recommendation [*Ref.*]
	Males	Females	Males	Females	
Carbohydrates (%E)	46.4(45;47.7)	46.1(44.8;47.4)	48.8(47;50.6)	48(46.8;49.1)	**55-75 %E [143]**
Sugar (*g*)	98(87.2;108.8)	94.7(84.9;104.5)	113.1(96.9;129.3)	96.9(88.9;104.9)	**≤ 31 g [44]**
Sugar (*%E*)	16.8(15.3;18.2)	17.3(15.9;18.7)	19.8(17.7;21.9)	18.4(17.2;19.6)	**≤10 %E (≤5%E) [143]**
Fiber (*g*)	20.8(19.3;22.3)	19.9(18.6;21.3)	19.1(17.5;20.6)	20.9(19.2;22.6)	**≥ 24 g [143]; ≥ 42.9 g[44]**
Fiber (*g/1000 kcal*)	9.5(8.9;10.1)	9.8(9.2;10.4)	8.9(8.3;9.5)	10.3(9.7;11)	**14.8 g/1000 kcal [146]**
Proteins (%E)	15.3(14.9;15.8)	15.9(15.3;16.4)	14.9(14.2;15.6)	15.1(14.7;15.5)	**10-15 %E [143]**
Animal-based proteins (*% tot. proteins*)	83.2(82.2;84.3)	82.6(81.5;83.8)	82.1(80.7;83.4)	81.7(80.7;82.6)	**-**
Plant-based protein (*% tot. proteins*)	16.8(15.7;17.8)	17.4(16.2;18.5)	17.9(16.6;19.3)	18.3(17.4;19.3)	**-**
Animal/plant protein ratio	0.77(0.68;0.86)	0.73(0.67;0.79)	0.78(0.71;0.86)	0.86(0.78;0.94)	
Amino acids (*g*)	78.3(74.1;82.5)	75.4(71.4;79.4)	72.7(68.1;77.2)	70.5(67.4;73.7)	**-**
Essential amino acids (*g*)	29.3(27.7;30.9)	28.2(26.7;29.7)	26.8(25.1;28.6)	26.2(25;27.4)	**-**
Fats	37.5(36.2;38.8)	36.9(35.7;38.1)	35.8(34;37.5)	36.3(35.2;37.3)	**15-30 %E [143]**
Animal-based fats *(% of total fats*)	60.3(57.7;62.9)	58.3(55.9;60.6)	58.3(54.8;61.8)	61.5(59.5;63.6)	**-**
Plant-based fats *(% of total fats*)	39.7(37.1;42.3)	41.7(39.4;44.1)	41.7(38.2;45.2)	38.5(36.4;40.5)	**-**
SFA (*%E*)	11.1(10.5;11.7)	10.3(9.8;10.8)	10.3(9.6;11)	10.8(10.4;11.2)	**≤10 %E [143]**
MUFA (*%E*)	12.2(11.5;12.8)	11.7(11.1;12.2)	11.2(10.4;12)	11.5(11.1;12)	**-**
PUFA (*%E*)	8.9(8.5;9.4)	9.1(8.7;9.5)	8.5(8.0;9.0)	8.1(7.7;8.5)	**6-10 %E [143]**
UFA (*%E*)	21(20.2;21.8)	20.7(20;21.5)	19.7(18.6;20.7)	19.6(19.0;20.3)	**-**
Cholesterol (*mg/1000 kcal*)	166(154.6;177.5)	179.2(167.5;190.8)	159.2(147;171.5)	159.6(150.6;168.6)	**71.4 mg/1000 kcal [146]**
Cholesterol (*mg*)	368(340.4;395.6)	370.3(345.3;395.4)	344.1(314.2;374.1)	338.1(313.6;362.6)	**<300 mg[143]; ≤ 125.2[44]**
ω-3 fatty acids (*%E*)	0.32(0.27;0.37)	0.31(0.28;0.34)	0.27(0.24;0.31)	0.27(0.25;0.29)	**1-2 % [143]**
ω-6 fatty acids (*%E*)	8.6(8.1;9)	8.8(8.4;9.2)	8.2(7.7;8.7)	7.9(7.5;8.2)	**5-8 % [143]**
α-linolenic acid (*%E*)	0.26(0.25;0.28)	0.28(0.26;0.3)	0.25(0.24;0.27)	0.25(0.24;0.27)	**0.5-2 %E [153]**

Notes: Every value is given as mean and 95% confidence interval of the mean. 95% CI: 95% confidence interval of the mean; [Ref.]: Reference – source of the recommended range; MUFAs: monounsaturated fatty acids; PUFA: polyunsaturated fatty acids; SFA: saturated fatty acids; UFA: unsaturated fatty acids; (%E): intake as percentage of total energy.

Table S4. Micronutrient intakes among Hungarian Roma and general populations, by sex

Micronutrient	Recommendation [Ref.]	Hungarian General (n=359)		Hungarian Roma (n=344)	
		Males	*Females*	*Males*	*Females*
Minerals and trace elements					
Magnesium (*mg/1000 kcal*)	**≥238 mg/ 1000 kcal [146]**	199.84(143.77;255.92)	186.98(176.76;197.21)	174.45(161.27;187.64)	184.42(174.72;194.11)
Calcium (*mg/1000 kcal*)	**≥590 mg/ 1000 kcal [146]**	237.75(219.83;255.66)	258.29(234.68;281.89)	253.64(229.74;277.54)	245.87(229.32;262.42)
Sodium (*mg/1000 kcal*)	**≤1143 mg/1000 kcal [146]**	2698.6(2509.9;2887.3)	2563.9(2458.1;2669.9)	2257.9(2130.4;2385.5)	2535.8(2418.3;2653.4)
Sodium (*mg*)	**≤2000 mg [155]**	5991.4(5503.2;6479.7)	5327.9(4992.6;5663.3)	4850.5(4505.2;5195.8)	5188.8(4901.1;5476.5)
Potassium (*mg/1000 kcal*)	**≥2238 mg/ 1000kcal [146]**	1376.6(1242.8;1510.3)	1404.3(1311.6;1497.0)	1384.6(1226.4;1542.8)	1455.0(1358.5;1551.5)
Potassium (*mg*)	**≥3510 mg [156]**	3120.9(2688.6;3553.2)	2855.3(2658.1;3052.5)	3001.4(2596.0;3406.7)	2960.1(2740.6;3179.6)
Iron (*mg/1000 kcal*)	**-**	5.05(4.77;5.34)	5.41(4.99;5.83)	4.68(4.37;4.99)	5.48(5.06;5.91)
Iron (*mg*)	**1.05 mg [154]**	11.28(10.4;12.15)	11.11(10.2;12.02)	10.09(9.25;10.93)	11.43(10.34;12.53)
Vitamins					
Vitamin A (*μg/1000 kcal*)	**-**	135.67(114.96;156.38)	142.65(118.27;167.03)	138.48(88.63;188.32)	183.19(129;237.38)
Vitamin A (*μg RE*)	**500 μg RE [154]**	0.5(0.44;0.55)	0.51(0.45;0.58)	0.50(0.41;0.59)	0.68(0.51;0.84)
Beta-carotene (*mg/1000 kcal*)	**-**	1.06(0.91;1.2)	1.33(1.12;1.55)	1.18(0.92;1.44)	1.42(1.21;1.64)
Vitamin B_1 (*μg/1000 kcal*)	**-**	467.22(442.94;491.51)	482.9(457.5;508.3)	427.69(394.82;460.55)	474.82(452.4;497.24)
Vitamin B_1 (*μg*)	**≥1100 *μ*g [154]**	1048.02(971.2;1124.8)	1000.46(935.3;1065.62)	924.18(838.38;1009.97)	974.6(916.23;1032.97)
Vitamin B_2 (*μg/1000 kcal*)	**-**	595.6(470.29;720.92)	556.5(523.49;589.51)	516.45(466.77;566.12)	548.61(520.23;576.99)
Vitamin B_2 (*μg*)	**≥1100 *μ*g [154]**	1452.2(936.4;1968.0)	1143.1(1060.8;1225.3)	1124.2(999.3;1249.1)	1139.7(1059.3;1220.1)
Vitamin B_6 (*μg/1000 kcal*)	**-**	812.19(771.75;852.63)	851.07(809.34;892.8)	743.55(686.72;800.38)	781.71(746.21;817.22)
Vitamin B_6 (*μg*)	**≥1300 μg [154]**	1790.5 (1679.0;1901.9)	1735.48(1639.7;1831.2)	1586.25(1452.7;1719.7)	1593.88(1505.7;1682.1)
Vitamin B_{12} (*μg/1000 kcal*)	**-**	2.25(0.14;4.37)	1.2(1.04;1.35)	1.08(0.79;1.36)	1.49(0.78;2.21)
Vitamin B_{12} (*μg*)	**≥2.4 μg [154]**	5.18(0.26;10.11)	2.47(2.14;2.8)	2.36(1.62;3.1)	3.22(1.66;4.77)
Vitamin B_3 (*mg NE/1000 kcal*)	**≥6.6 mg NE/1000 kcal [157]**	10.65(6.91;14.38)	9.39(8.69;10.08)	7.84(7.07;8.6)	8.75(8.25;9.26)
Vitamin B_3 (*mg NE*)	**≥14 mg NE [154]**	44.41(29.2;59.62)	35.36(33.41;37.31)	32.56(30.09;35.04)	33.32(31.55;35.09)
Vitamin C (*mg/1000 kcal*)	**-**	35.66(30.58;40.74)	40.26(34.87;45.65)	36.55(27.51;45.59)	41.38(36.43;46.33)
Vitamin C (*mg*)	**≥45 mg [154]**	76.61(66.49;86.73)	80.88(70.64;91.12)	76.41(58.7;94.13)	80.52(71.56;89.48)
Vitamin D (*mg/1000 kcal*)	**-**	0.81(0.68;0.95)	0.77(0.68;0.85)	0.77(0.68;0.86)	0.79(0.6;0.97)
Vitamin D (*μg*)	**≥10 μg [154]**	1.83(1.51;2.15)	1.61(1.43;1.79)	1.69(1.46;1.92)	1.68(1.26;2.09)

Notes: Every value is given as mean and 95% confidence interval of the mean. 95% CI: 95% confidence interval of the mean; [Ref.]: Reference – source of the recommended range (%E): intake as percentage of total energy.

Table S5. Healthy diet indicator components used in the current study and their coding criteria based on the World Health Organization's dietary guidelines [233]

Nutrient or food group (*daily intake*)	Dichotomous value	
	1	0
Saturated fatty acids (*%E*)	0-10	>10
Polyunsaturated fatty acids (*%E*)	6-10	<6 or >10
Protein (*%E*)	10-15	<10 or >15
Total dietary fiber (*g*)	>25	<25
Monosaccharides and disaccharides (*%E*)	0-10	>10
Cholesterol (*mg*)	0-300	>300
Potassium (*mg*)	≥3500	<3500

E%: Nutrient given as percentage of total daily energy; g: grams; mg: milligrams.

Table S6. Nutrient Targets for DASH Score [234]

Nutrient	DASH Diet Nutrient Composition	DASH Target	Intermediate Target
Saturated fats	6%E	6%E	11%E
Total fat	27%E	27%E	32%E
Protein	18%E	18%E	16.5%E
Cholesterol	150 mg	71.4 mg/1000 kcal	107.1 mg/1000 kcal
Fiber	31 g	14.8 g/1000 kcal	9.5 g/1000 kcal
Magnesium	500 mg	238 mg/1000 kcal	158 mg/1000 kcal
Calcium	1240 mg	590 mg/1000 kcal	402 mg/1000 kcal
Potassium	4700 mg	2238 mg/1000 kcal	1534 mg/1000 kcal
Sodium	2400 mg	1143 mg/1000 kcal	1286 mg/1000 kcal

[a] Based on a 2100-kcal diet. Abbreviation: DASH, Dietary Approaches to Stop Hypertension trial. E%: Nutrient given as percentage of total daily energy; g: grams; mg: milligrams.

Table S7. Diet indicator components used in the current study and their coding criteria based on the EAT-Lancet reference diet [44]

Dietary element	Reference amount	E%*
Alpha linolenic acid (g)	≥2.5	≥0.9
Carbohydrates (g)	≥317.3	≥50.8
Cholesterol (mg)	≤125.2	≤50.1 (mg/1000 kcal)
Dietary fibers (g)	≥42.9	≥6.9
Mono- and poly-unsaturated fats (g)	≥75.9	≥27.3
Proteins (g)	90.1	14.4
Saturated fats (g)	≤22.7	≤8.2
Total fat (g)	≤105.6	≤38.0
Calcium (mg)	≥717.8	≥287.1 (mg/1000 kcal)
Magnesium (mg)	≥732.5	≥293.0 (mg/1000 kcal)
Potassium (mg)	≥4100.7	≥1640.3 (mg/1000 kcal)
Added sugar (g)	≤31.0	5.0

**Dietary element expressed as percentage of total energy, unless otherwise indicated.* *g*: grams; *mg*: milligrams.

The 2019 EAT-Lancet Commission report recommends healthy diets that can feed 10 billion people by 2050 from environmentally sustainable food systems. The EAT-Lancet reference diet is made up of 8 food groups - whole grains, tubers and starchy vegetables, fruits, other vegetables, dairy foods, protein sources, added fats, and added sugars. In addition the report contains detailed information on the nutrient intake level.

Caloric intake (kcal/day) limits and nutrient intake data have been given and add up to a 2500 kcal daily diet. We compare the proportional calorie (daily per capita) shares as energy percentage or the quantity in grams per a thousand calories of selected nutrients in this reference diet.

Table S8. Regression models for DASH score among Hungarian general and Roma populations

DASH†	MODEL 1 *β [95%CI]*	MODEL 2 *β [95%CI]*	MODEL 3 *β [95%CI]*
Roma	-0.023 [-0.176 ; 0.129]	-0.084 [-0.286 ; 0.117]	-0.049 [-0.254 ; 0.156]
BMI (kg/m^2)	0.004 [-0.008 ; 0.016]	0.005 [-0.008 ; 0.018]	0.005 [-0.008 ; 0.018]
Energy intake (kcal)	**0.000 [0.000 ; 0.000]**	**0.000 [0.000 ; 0.000]**	**0.000 [0.000 ; 0.000]**
Age (years)		0.000 [-0.007 ; 0.006]	0.000 [-0.008 ; 0.007]
Secondary/Vocational education ref: Elementary		-0.105 [-0.307 ; 0.096]	-0.105 [-0.306 ; 0.095]
University degree or higher ref: Elementary		0.037 [-0.298 ; 0.373]	0.043 [-0.301 ; 0.386]
Females. ref: males		0.093 [-0.068 ; 0.254]	0.074 [-0.089 ; 0.237]
Financial status: good. ref: challenging			0.144 [-0.098 ; 0.387]
Financial status: fair. ref: challenging			0.194 [-0.003 ; 0.392]
Economic activity: employed. ref: unemployed			0.084 [-0.178 ; 0.346]
Economic activity: inactive. ref: unemployed			0.155 [-0.206 ; 0.517]
Marital status: coupled. ref: single			0.015 [-0.152 ; 0.183]

*† Poisson regression model. *Hungarian general is taken as a reference group in the model. **Model 1: effect adjusted only for BMI and energy intake; Model 2: effect adjusted for BMI, age, education level, energy intake and sex; Model 3: effect adjusted for BMI, age, education level, energy intake, sex, financial status, marital status and economic activity. β [95%CI]: beta coefficient of the regression model, accompanied by its corresponding 95% confidence interval.*

Table S9. Regression models for HDI score among Hungarian general and Roma subjects

HDI[†]	**MODEL 1** *β [95%CI]*	**MODEL 2** *β [95%CI]*	**MODEL 3** *β [95%CI]*
Roma	0.038 [-0.131 ; 0.207]	-0.003 [-0.229 ; 0.223]	-0.001 [-0.231 ; 0.230]
BMI (kg/m^2)	0.004 [-0.010 ; 0.018]	0.004 [-0.010 ; 0.018]	0.004 [-0.010 ; 0.018]
Energy intake (kcal)	**0.000 [0.000 ; 0.000]**	**0.000 [0.000 ; 0.000]**	**0.000 [0.000 ; 0.000]**
Age (years)		-0.001 [-0.008 ; 0.007]	0.001 [-0.007 ; 0.009]
Secondary/Vocational education ref: Elementary		-0.065 [-0.290 ; 0.160]	-0.070 [-0.296 ; 0.156]
University degree or higher ref: Elementary		-0.040 [-0.415 ; 0.334]	-0.044 [-0.426 ; 0.339]
Females. ref: males		0.013 [-0.165 ; 0.192]	0.012 [-0.168 ; 0.191]
Financial status: good. ref: challenging			0.067 [-0.201 ; 0.335]
Financial status: fair. ref: challenging			0.107 [-0.110 ; 0.325]
Economic activity: employed. ref: unemployed			-0.012 [-0.301 ; 0.278]
Economic activity: inactive. ref: unemployed			-0.089 [-0.488 ; 0.310]
Marital status: coupled. ref: single			0.012 [-0.171 ; 0.194]

[†] *Poisson regression model. *Hungarian general is taken as a reference group in the model. **Model 1: effect adjusted only for BMI and energy intake; Model 2: effect adjusted for BMI, age, education level, energy intake and sex; Model 3: effect adjusted for BMI, age, education level, energy intake, sex, financial status, marital status and economic activity. Significant associations are bolded. HDI: Healthy Diet Indicator* [233, 235]. *β [95%CI]: beta coefficient of the regression model, accompanied by its corresponding 95% confidence interval.*

Table S10. Regression models for DII score among Hungarian general and Roma subjects

DII[†]	**MODEL 1** *β [95%CI]*	**MODEL 2** *β [95%CI]*	**MODEL 3** *β [95%CI]*
Roma	**-0.147 [-0.344 ; 0.049]**	**-0.450 [-0.709 ; -0.191]**	**-0.455 [-0.720 ; -0.191]**
BMI (kg/m^2)	0.005 [-0.011 ; 0.021]	0.006 [-0.010 ; 0.022]	0.005 [-0.011 ; 0.022]
Energy intake (kcal)	**0.001 [0.001 ; 0.001]**	**0.001 [0.001 ; 0.001]**	**0.001 [0.001 ; 0.001]**
Age (years)		0.002 [-0.007 ; 0.010]	0.003 [-0.006 ; 0.012]
Secondary/Vocational education ref: Elementary		-0.502 [-0.760 ; -0.244]	**-0.502 [-0.760 ; -0.244]**
University degree or higher ref: Elementary		-0.121 [-0.551 ; 0.309]	-0.059 [-0.496 ; 0.378]
Females. ref: males		0.204 [-0.001 ; 0.409]	0.195 [-0.010 ; 0.401]
Financial status: good. ref: challenging			0.019 [-0.288 ; 0.326]
Financial status: fair. ref: challenging			**0.325 [0.076 ; 0.574]**
Economic activity: employed. ref: unemployed			-0.115 [-0.447 ; 0.218]
Economic activity: inactive. ref: unemployed			-0.196 [-0.649 ; 0.257]
Marital status: coupled. ref: single			0.030 [-0.179 ; 0.239]

*[†] Multiple linear regression model. *Hungarian general is taken as a reference group in the model. **Model 1: effect adjusted only for BMI and energy intake; Model 2: effect adjusted for BMI, age, education level, energy intake and sex; Model 3: effect adjusted for BMI, age, education level, energy intake, sex, financial status, marital status and economic activity. Significant associations are bolded. DII: The Dietary Inflammatory Index [149]. β [95%CI]: beta coefficient of the regression model, accompanied by its corresponding 95% confidence interval.*

Table S11. Regression models for nutrient-based EAT-Lancet score among Hungarian general and Roma subjects

EAT †	**MODEL 1** *β [95%CI]*	**MODEL 2** *β [95%CI]*	**MODEL 3** *β [95%CI]*
Roma	0.021 [-0.073 ; 0.114]	-0.024 [-0.183 ; 0.136]	-0.017 [-0.179 ; 0.144]
BMI (kg/m^2)	0.005 [-0.019 ; 0.029]	0.003 [-0.021 ; 0.027]	0.006 [-0.019 ; 0.030]
Energy intake (kcal)	**0.000 [0.000 ; 0.000]**	**0.000 [0.000 ; 0.000]**	**0.000 [0.000 ; 0.000]**
BMI (kg/m^2) *Energy intake (kcal)	**0.000 [0.000 ; 0.000**	**0.000 [0.000 ; 0.000]**	**0.000 [0.000 ; 0.000]**
Age (years)		0.002 [-0.002 ; 0.006]	0.003 [-0.001 ; 0.008]
Secondary education ref: Elementary		-0.042 [-0.242 ; 0.157]	-0.065 [-0.266 ; 0.136]
Vocational or higher ref: Elementary		-0.067 [-0.235 ; 0.101]	-0.093 [-0.264 ; 0.078]
Secondary/Vocational education*Roma		0.026 [-0.293 ; 0.344]	0.065 [-0.256 ; 0.386]
Vocational or higher*Roma		0.049 [-0.267 ; 0.364]	0.086 [-0.234 ; 0.407]
Females. ref: males		0.018 [-0.082 ; 0.119]	0.019 [-0.082 ; 0.120]
Financial status: good. ref: challenging			0.156 [0.005 ; 0.307]
Financial status: fair. ref: challenging			0.111 [-0.013 ; 0.234]
Economic activity: employed. ref: unemployed			0.036 [-0.129 ; 0.200]
Economic activity: inactive. ref: unemployed			0.019 [-0.204 ; 0.241]
Marital status: coupled. ref: single			0.028 [-0.075 ; 0.130]

*† Poisson regression model. *Hungarian general is taken as a reference group in the model. **Model 1: effect adjusted only for BMI and energy intake; Model 2: effect adjusted for BMI, age, education level, energy intake and sex; Model 3: effect adjusted for BMI, age, education level, energy intake, sex, financial status, marital status and economic activity. Significant associations are bolded. EAT: Nutrient-based EAT-Lancet score; β [95%CI]: beta coefficient of the regression model, accompanied by its corresponding 95% confidence interval.*

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List of publications related to the dissertation

1. **Llanaj, E.**, Vincze, F., Kósa, Z., Bárdos, H., Diószegi, J., Sándor, J., Ádány, R.: Deteriorated Dietary Patterns with Regards to Health and Environmental Sustainability among Hungarian Roma Are Not Differentiated from Those of the General Population.
   Nutrients. 13 (721), 1-15, 2021.
   DOI: http://dx.doi.org/10.3390/nu13030721
   IF: 4.546 (2019)
2. **Llanaj, E.**, Vincze, F., Kósa, Z., Sándor, J., Diószegi, J., Ádány, R.: Dietary Profile and Nutritional Status of the Roma Population Living in Segregated Colonies in Northeast Hungary.
   Nutrients. 12 (9), 1-21, 2020.
   DOI: http://dx.doi.org/10.3390/nu12092836
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List of other publications

3. **Llanaj, E.**, Hanley-Cook, G. T.: Adherence to Healthy and Sustainable Diets Is Not Differentiated by Cost, But Rather Source of Foods among Young Adults in Albania.
   Br. J. Nutr. [Epub ahead of print], 2020.
   DOI: http://dx.doi.org/10.1017/S0007114520004390
   IF: 3.334 (2019)
4. Taneri, P. E., Gómez-Ochoa, S. A., **Llanaj, E.**, Raguindin, P. F., Rojas, L. Z., Roa-Díaz, Z. M., Salvador, D., Groothof, D., Minder, B., Kopp-Heim, D., Hautz, W. E., Eisenga, M. F., Franco, O. H., Glisic, M., Muka, T.: Anemia and iron metabolism in COVID-19: a systematic review and meta-analysis.
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5. **Llanaj, E.**, Pikó, P., Nagy, K., Rácz, G., Sándor, J., Kósa, Z., Fiatal, S., Ádány, R.: Applicability of Obesity-Related SNPs and their Effect Size Measures Defined on Populations with European Ancestry for Genetic Risk Estimation among Roma.
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DOI: http://dx.doi.org/10.1371/journal.pone.0197874
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