SHORT THESIS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY (PHD)

Policy surveillance of prevention and treatment of type 2 diabetes mellitus across the member states of the European Union

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DOCTORAL SCHOOL OF HEALTH SCIENCES

DEBRECEN, 2023

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The defense is held in Lecture Hall of the Department of Internal Medicine, Building "A", Faculty of Medicine at 1 p.m., on March 1st, 2024.

1. Introduction

Diabetes mellitus (DM) is one of the four main non-communicable diseases (NCDs). DM results from insufficient pancreatic insulin production or from improper insulin usage in the body, both of which have an impact on blood sugar regulation. Uncontrolled DM may cause the body to develop many systemic diseases [1, 2]. The prevalence of DM has grown in the European Union (EU) from 6.63 % in 2000 to 10.66% in 2019 [3], and this trend is predicted to keep on rising in the upcoming decades [4-6]. In addition, projections propose a rise in the prevalence of DM among adults in the EU member states in the upcoming years [2, 5]. When comparing this tendency to other main NCD, it is quite unfavorable.

Such an increase in DM burden has major effects on premature mortality rates and quality of life, along with its growing economic burden. According to estimates, the cost of DM accounts for nearly 9% of all EU healthcare spending in 2019 [2, 7].

According to the World Health Organization (WHO), there is three main types of DM which are type 1 diabetes mellitus (T1DM), type 2 diabetic mellitus (T2DM), and gestational diabetes. By far the most prevalent of DM classification, accounting for 90% of the disease is T2DM [1]. By tackling health determinants and risk factors such as smoking, alcohol intake, poor diets, and insufficient physical exercise, T2DM is largely preventable. Policies and programs focusing on the prevention of DM primarily address T2DM due to its frequency and preventability [8].

Behaviors such as increasing physical activity and exercise and reducing sedentary behavior are needed to prevent the development of T2DM. [9]**.**

Socioeconomic and demographics factors have also an impact on the development of T2DM. There are also an association between old age groups, low labor position, and education status and occurrence of T2DM which has been found in population-based researches [10]. In the EU, T2DM burden varies considerably between member states, and this variety is visible both at the national and regional levels [11, 12], which may require EU efforts to enforce programs that promote healthy lifestyle and tackle socioeconomic inequalities [13].

Currently, in the EU, it is up to both member states and the EU to establish laws and regulations aimed at preventing NCDs. However, the EU has competence in well-defined areas of public health, but the burden of health mandate is not equally distributed between the EU and its states.

The member states bear main accountability for health protection and other healthcare system responsibilities (The Treaty on the Functioning of the European Union - Article 168). [14-17]

EU manages to regulate health by regulating different legal areas as monetary legislation, common market regulations, etc. [18]. One of the EU tools to prevent DM is through supporting and funding research to minimize the burden of DM —for example, by assisting the construction of comparable datasets for the identification and adoption of effective health policy measures. The most important tool for gathering health data is the European Health Interview Survey (EHIS). It makes data comparison between the member states easier by providing information on the health status, health determinants, and healthcare services [19]. These similar data enable stakeholders to measure the burden of NCDs including DM and investigate their potential risk factors.

Another tool that is used by the EU to prevent DM is the regulation of food information to consumers (FIC) which according to the standards outlined in Articles 30-34 of the regulation, all prepackaged foods currently available on the EU market must have front- and a back nutrition labels [20]. This strategy focuses on tackling food and nutrition related risk factors associated with NCDs including DM. However, consumers should not be misled by such labels. For front-of-pack nutrition labelling (FOPL), which is often designed to convey simplified information, the presentation of scientific evidence is important.

The EC adopted a report in May 2020 to evaluate the effects of FOPL schemes and came to the conclusion that the EU needed a standardized and obligatory FOPL system [21]. The use of color-coding, with or without a graded indicator, seems to be most promising for enhancing the nutritional quality of food options, according to the EC report, although the ideal option has not yet been determined [21, 22]. The EU's Farm to Fork strategy (draft action plan) aims to make food systems equitable, healthy, and environmentally sustainable, empowering consumers to remain informed, stay healthy, and make sustainable food choices. The EC has announced a proposal to harmonize mandatory FOPL within this framework. . By the end of 2023, the EC proposal will be expected [23].

2. Literature review

Diabetes Mellitus (DM) poses a significant public health challenge in the EU, ranking among the most prevalent Non-Communicable Diseases (NCDs) [24]. Studies in Germany's Augsburg region found a high prevalence of DM and undiagnosed cases, highlighting the magnitude of

the issue [25]. Germany, once in the top 10 globally for DM prevalence, faced rates around 7.5% in 2010 [7]. Similarly, Slovakia reports challenges with higher DM prevalence compared to the EU average [26].

The burden of DM in the EU is linked to lifestyle factors like high BMI, low physical activity, and inadequate fruit and vegetable intake [27]. Research stresses the importance of promoting healthier habits and weight management to reduce DM prevalence [28]. However, a comprehensive understanding of the EU's DM burden is hindered by limited studies across member states [29].

EU policies and country-specific efforts address DM and NCDs. For instance, the EU Action Plan on Childhood Obesity showed progress in reducing childhood obesity, a major DM risk factor, through various interventions [30]. The EAT-Lancet Commission emphasized sustainable food systems to prevent NCDs, including DM, advocating for healthy diets and discouraging unhealthy food consumption [31]. Projects like the HEPAHEALTH initiative underscored the role of physical activity in preventing DM and NCDs, advocating for comprehensive policies to promote exercise [32]. However, assessments reveal a need for clearer, multi-disease action plans and increased focus on women in DM policies [33].

Social media platforms, notably Twitter, are increasingly pivotal in advocating for EU public health policies combating DM, aiding in awareness-raising and garnering support [34]..

2.1 Objectives

The following objectives were set according to the four topics of the dissertation:

1. Identification of available EU legislations that include DM, obesity and NCDs to gain a comprehensive representation of the EU's legal system in this area.

2. Content analysis of legislations focusing on DM, obesity and NCDs including their assessment according to DM specific guidelines, target groups and functional categories.

3- Examination of the impact of nutritional and physical activity policies, national DM plans and national DM registries on prevalence of DM in the EU member states.

4- Examination of the association between demographic and socioeconomic status as well as the lifestyle choices, taking into account available nutritional and physical activity policies, national DM plans and national DM registries.

5- Description of changes of DM prevalence in the adult population of Slovakia through the three EHIS waves.

6- Assessing the association between DM and socioeconomic and/or lifestyle characteristics through the three EHIS waves in Slovakia.

7-Evaluation of the public discourse on FOPL in the EU via Twitter by analyzing tweet content, sentiment, and mapping network characteristics.

3. Methodology

3.1 How the European Union legislations are tackling the burden of diabetes mellitus: a legal surveillance study

The research was carried out in two sections: identification of EU legislations and analysis of their text, which includes evaluation in accordance with DM specific guidelines, target groups, and functional categories.

3.1.1. Identification of EU legislations

By using the EUR-Lex database [35], two researchers (Nour Mahrouseh and Anggi Septia Irawan) conducted a systematic search to find and evaluate relevant laws. Currently, the term “legislation” is used to refer to a wide range of soft laws, legal acts, and treaties. The search was expanded to include obesity and NCDs as well. The search was divided into two stages, the first concentrating on DM and the other on obesity and NCDs. The search was conducted in English with no time restriction, using the terms “obes* OR: non-communicable illnesses” and “diabet*” in the title or text.

Treaties, legal actions, consolidated texts, international agreements, preparatory documents, and documents from the European Free Trade Association (EFTA) were exclusively extracted. Between October 2021 and January 2022, the screening procedure was carried out by Nour Mahrouseh and Anggi Septia Irawan. A manual screening of the legislations' relevance was assessed after duplicates were removed (using an excel spreadsheet); the first step of the selection was based on titles, and the second phase was based on full-text.

As part of the EU's approach of health in all policies, legislations have been categorized as either direct or indirect. Direct legislations specifically target DM, NCDs, or obesity prevention in their text. All recognized legislations were categorized according to their EuroVoc terms and authorship. EuroVoc terms are developed for documenting information which are produced by EU institutions [36].

3.1.2 Content analysis

Only legislations that were expressly adopted to prevent DM, NCDs, or obesity directly were examined for content analysis. MonQcle, a platform for analyzing legal text documents, was used [37]. Each document was added as a record to the MonQcle database and independently coded by two coders (Nour Mahrouseh and Anggi Septia Irawan). A list of themes on which each of legislation should be categorized was established following the preliminary reviewing the legislations. This initial worklist of themes discussing the objectives and strategies partly resulted from "Toward an EU Strategic Framework for the Prevention of NCDs", a joint publication by the European Public Health Alliance (EPHA) [38] and the WHO "Global Report on Diabetes" [8].

The original themes from the guidelines were revised repeatedly, and new themes were added. With each change, the legislations were reviewed over to confirm that all existing data were coded. Themes included several forms of enforcement, including binding as regulations, non-binding as white papers, and conditionally binding as decisions. In order to better understand the themes, legislations were coded also based on target populations in accordance with the modified classification of Timpel et al [39]. Functional categories were employed to address risk factors of DM, NCDs, and obesity [40]. Based on the primary data retrieved from Eur-Lex, the validity of the documents (where relevant) and legislator/author are recorded.

3.1.3 Statistical analysis and internal validity

Descriptive analysis was used to present the frequency of legislations by themes, target populations, and functional categories. The following programs were used to carry out the analyses' visualization: a cluster network analysis was created using Gephi 0.9.5 and a heatmap was produced using TIBCO Cloud Spotfire analyst.

Two independent reviewers (Nour Mahrouseh and Anggi Septia Irawan) conducted a systematic evaluation of each legislation on similarity of coding as part of the quality appraisal (internal validity). Conflicts were resolved through open dialogue and the participation of an impartial reviewer (Orsolya Varga). Inter-rater reliability for each legislation was evaluated using Cohen's kappa (k) inter-rater reliability test.

3.2 Impact of policies in nutrition and physical activity on diabetes and its risk factors in the 28 member states of the European Union

3.2.1 Data sources

Four sources are used to gather the dataset: The World Cancer Research Fund International (WCRF International) "NOURISHING" and "MOVING" policy databases [41], the European

Coalition for Diabetes report “Diabetes in Europe policy puzzle: the state we are in” [42], and the 2014 European Health Interview Survey (EHIS).

3.2.2 Policies, national plans and national DM registries

Policies that focus on good nutrition and physical activity were extracted from the “NOURISHING” and “MOVING” policy databases [43]. Different legislative tools aimed at promoting healthy eating or physical activity were considered policies in this context.

Policy categories, policy areas, and sub-policy areas are the three levels at which policies are categorized; policy categories and policy areas. Policies that were in effect in 2014 that partially or exclusively targeted adult populations in the 28 EU member states were extracted for analysis.

National DM plans, which included governmental plans on preventive treatment strategies that target DM exclusively or as part of a plan for NCDs, were introduced in many EU countries to combat the rise in DM prevalence over the past few decades.

National DM registries are databases that allow the tracking and monitoring of the clinical progress of individuals with T1DM and/or T2DM and based on these data targeted preventive strategies could be implemented. Databases that exclude T2DM were not taken into account when conducting the analysis. The 4th edition of “Diabetes in Europe policy puzzle: the state we are in” contains information on national DM plans and national DM registries that were in effect in 2014 [42].

3.2.3 Study sample

Data was collected for 28 member states of the EU, including the United Kingdom (UK), from Eurostat's 2014 EHIS [44-46].

The dataset included (304,168) observations. Based on a self-reported response to the following question: “Have you had diabetes during the past 12 months?” Individuals that responded “Yes” were considered as having DM. Demographic, socioeconomic and lifestyle characteristics included were sex, age, degree of urbanization, educational attainment, labor status, net monthly equalized income of the household the respondent belongs to, body mass index (BMI, kg/m^2), frequency of eating fruits and frequency of eating vegetables per week.

3.2.4 Statistical analysis

The distributions of the variables for respondents with and without DM were described and compared. The DM prevalence in 2014 was computed for each of the EU member states using sample weight.

Chi-square analysis was utilized to identify significant DM variables. Correlation between the prevalence of DM for the entire study population, stratified by age and sex, and the number of first-level policies of nutrition and physical activity, as well as the availability of national plans and/or registers in each state, were calculated using point-biserial correlation analysis. Point-biserial correlation coefficient, ranges from -1 to +1, measures the strength of correlation; -1 denotes a negative association, +1 denotes a positive association, and 0 denotes no association [47]. A multi-level logistic regression model for DM as the dependent variable was used to account for the data's hierarchical structure while controlling for individual and national-level covariates.

Country (place of residence) was regarded as a level-2 factor. STATA version 16.0® was used for all statistical analyses.

3.3 Diabetes mellitus and associated factors in Slovakia: results from the European Health Interview Survey 2009, 2014, and 2019

Microdata from Slovakia's EHIS from 2009 (n = 4972), 2014 (n = 5490), and 2019 (n = 5527) were used to conduct cross-sectional analyses. The microdata for the EHIS 2009 and 2014 and 2019 were collected from “Eurostat” and “The Statistical Office of the Slovak Republic”, respectively. The samples in the 3 waves are representative of the Slovakian population who live in private households and are at least 15 years old [19]. Questions that were asked in the 2009, 2014, and 2019 EHIS served as the basis for our study variables. People who answered yes to the question “Have you had diabetes during the past 12 months?” were included in the group with DM, which includes all forms of DM. Self-reported sociodemographic and lifestyle factors were examined as independent variables which included sex, age, regions based on level 2 of nomenclature of territorial units for statistics (NUTS2) of Slovakia, degree of urbanization, education level, labor status.

The included lifestyle variables were body mass index (BMI, kg/m^2), frequency of walking for transportation purposes (to get to and from places) at least 10 min per day, physical activity per week and the frequency of eating fruits and frequency of eating vegetables per week. Variable distributions for respondents with and without DM were reported and compared. Descriptive statistics were conducted using proportions. Based on the study sample, the expected prevalence of DM for each year was calculated. Chi-square test was used to conduct bivariate comparisons and examine the relationship between the study variables and DM. A multivariable unconditional logistic regression model was used, incorporating variables from the bivariate analysis that were statistically significant and variables from the epidemiological

perspective that were not statistically significant but nonetheless of interest. The odds ratios (ORs) represent the regression results, along with a 95% confidence interval (CIs). For analysis, we analyzed each of the three datasets independently. The database contained sampling weights, and Stata's svy function was used to maintain the EHIS survey weight and was used only in the multilevel analysis.

3.4 Analysis of content, social networks, and sentiment of Front-of-pack nutrition labeling in the European Union on Twitter

3.4.1 Study settings

Data was collected via Twitter using "Twitter's application programming interface (API)" between November and December of 2021. Both tweets and retweets were included in the dataset. This covered tweets posted in EU member states as well as the UK, since the UK was a member of the EU. No time or language filter was used.

3.4.2 Data collection

In order to obtain the data from Twitter, Twitter API V2.0 was used to conduct a systematic archive search [48]. The data were gathered using keywords associated with the EU FOPL and the names of all EU countries from the time Twitter was founded, until 1st of December 2021. The relevant data, including user ID, user description, tweet text, location, date, Retweet, Reply-to, tweets-ID, and user type, were extracted and imported into Microsoft Excel 365. The translation to English was necessary via Google Translate since the tweets were written in eight different languages: English, Spanish, French, German, Czech, Croatian, Italian, and Dutch.

Following the development of the coding, manual and training of six coders was conducted, 10% of the Twitter dataset was tested using the detailed guidelines and definitions made accessible to the study team. The tweets were manually classified into the following categories: relevance, announcement, opinion, science, and EU legislation/policy in accordance with the study's research questions. If a tweet contained any information about food labeling, it was categorized as relevant. If a person offered an opinion on a subject connected to FOPL systems in the EU, that opinion was categorized under the opinion category. If a tweet contained only a declaration or factual statement regarding FOPL, it was categorized as an announcement. If the tweet was based on or connected to science, it was given categorized under the scientific category. If the tweet addressed FOPL EU policies and included any commentary on EU FOPL regulation, it was taken into account as EU legislation/policy. One or more categories could apply to a tweet.

A third party (Orsolya Varga) who was not part of the coding process supervised a public discussion to settle disagreements. The six investigators then categorized the remaining tweets independently. Intra-class correlation coefficient and Cronbach's alpha correlation coefficient were determined for 10% of the total number of tweets in order to evaluate the internal consistency and inter-rater reliability of the classification for tweets classified by six raters using SPSS 23.

Then, using QSR NVivo, automatic coding of the relevant tweets was conducted. Automatic coding was used in order to understand and develop the process related to FOPL. Two researchers (Anggi Septia Irawan and Orsolya Varga) collaborated during the content analysis using a combination of inductive and deductive approaches in the production of codes after analyzing the automatically generated codes [49]. Themes and subthemes were manually created from the scripts, and this framework served as the basis for the study.

Discussions or dialogues were identified and examined independently. Two coders (Anggi Septia Irawan and Diana Wangeshi Njuguna) classified around 20% of the total sample of dialogues, with the assistance of a third party (Orsolya Varga) for the themes already described.

3.4.3 Sentiment Analysis

Natural language processing is used in the sentiment analysis to extract and quantify affective and subjective information, which is then utilized to describe attitudes and emotions in texts. Users' opinions were identified and divided into three categories: positive (very positive), neutral (moderately positive and negative), and negative (very negative). Using the NVivo software, sentiment analysis of relevant tweets was conducted [49]. The automatic sentiment analysis of NVivo software bases its findings on the expressions of sentiment found in the content.

3.4.4 Network analysis

Network analysis is an approach that is becoming more and more used which connects the original tweets with the retweets and reply tweets in order to provide information on the flow and relationship between tweets. By examining the relationships between the nodes that reflect the object of interest, using Gephi 9.2, an open source program, facilitates additional qualitative analysis. In the context of this study, a tweet and their edges, which reflect the ties such as the ties between the tweet and its retweet is used to illustrate one or more relationships related to the tweet.

The analysis aids in comprehension of how the conversation and interaction were represented on Twitter, which involved the usage of the primary tweet and conversation ID for this analysis

[50]. Only the relevant tweets were included in the network analysis. A network analysis was also carried out for tweets with a similar conversation ID that were included in the conversations and chains of tweets (such as replies and retweets).

3.4.5 Geographic heat map

Geographic heatmaps show how information are localized based on their density. The country and city at the time the tweet was published are indicated by the Twitter data sheet geo location-ID. With the help of the map function in Microsoft Excel, a heat map was created.

4. Results

4.1 How the European Union legislations are tackling the burden of diabetes mellitus: a legal surveillance study

4.1.1 Description of the identified legislations

The data collection included 1099 relevant legislations related to DM, NCDs, and obesity, and of these 1099 laws, 22 were focused primarily on the direct prevention of DM, NCDs, and obesity. Only five legislations were designed to prevent DM. The identified legislations covered the time span from 1968 until 2022. 366 of these legislations are currently in effect. EuroVoc terms were available in 853 legislations. 853 different legislations contained a total of 6189 Eurovoc terms, of which 1486 were unique due to the fact that some terms were repeatedly used in several legislations. The distribution of EuroVoc terms demonstrates that the “social questions” domain, which includes the subdomains of “family”, “health”, “social framework”, “social affairs and protection”, “culture”, “religion”, “construction”, and “town planning” is the most prevalent. “Public health”, however, was the subdomain with the most records. The distribution of EuroVoc phrases over time demonstrates how the regulatory focus has evolved over time.

Since 2005, there have been a substantial number of new legislations passed. The most popular subdomains in 2021 were varied and focused on areas related to “social questions” domain such as “epidemic”, “corona virus”, “disease prevention”, etc., in addition to other domains such as “economics” and the “European Union”. In 1973, the most popular subdomains focused on “trade” as “custom duties”, “trade agreements”, etc.

4.1.2 Content analysis

There were 6 binding legislations (five regulations and one conditional binding decision) and 17 non-binding legislations that focused on DM, NCDs, or obesity prevention. The legislations authors were diverse, with one or more EU establishments were acknowledged as legislators. The EC has generated the majority of the documents with 13 legislations.

4.1.3 Assessment of legislations according to the WHO Global Report on Diabetes and EU Strategic Framework for the Prevention of NCDs Guidelines

"A life-course approach to preventing diabetes" (n = 20), which frequently included non-binding legislations, was the most common classification type. "Elaborate a pan-European system for data collecting, policy evaluation and accountability" were the themes that received the least attention. All EU legislations did not address the "Launch a "Health in All Policies" online policy portal". There is no mandatory legislation available for the six themes. Food-related laws, such as "Trade and agricultural policies that promote healthy diets" (n = 3) and "Regulations of marketing of foods high in sugars, fats, and salt", were the most common binding laws.

4.1.4 Assessment according to target groups and functional categories

The target groups varied depending on the legislations, with the majority of them focusing on the general population or communities. Only a few non-binding legislations focused on pregnant women, organizations, or countries (governments).

The functional categories employed in legislations extensively included the topic of energy intake for example. In our dataset, DM, NCDs, and obesity were targeted directly through the application of energy intake mechanisms that included food labeling and the provision of nutritious food. Energy expenditure legislations that regulated physical activities such as community running programs or building essential infrastructure. Information legislations offer strategies for promoting health, education, research, and innovation. EU strategies included screen and treatment legislations related to detection, early diagnosis, and treatment, and enhancing patients' quality of life. Only in the areas of energy expenditure and screening and treatment are non-binding legislations only.

4.1.5 Internal validity

Cohen's kappa analysis of the themes derived from WHO Global Report on Diabetes and the EU Strategic Framework for the Prevention of NCDs, and functional categories had excellent agreement of 0.805 and almost perfect agreement of 0.945 consequently between the two

coders (NM, ASI); the level of agreement for the target group was interpreted as substantial agreement (0.788).

4.2 Impact of policies in nutrition and physical activity on diabetes and its risk factors in the 28 member states of the European Union

4.2.1 Overview of the study population

According to the results of the chi-square test, there are significant relations between the study variables sex, age, educational level, employment status, net monthly equalized income of the household the respondent belongs to, BMI, and frequency of fruit and vegetable consumption and the prevalence of DM.

22,566 participants were reported to have DM. In the EU, DM prevalence was predicted to be (6.94%, 6.82-7.06%) in 2014. The highest values were reported by Portugal (9.33%, 8.76–9.93%), Greece (9.24%, 8.56–9.97%), and France (9.98%, 9.45–10.54%). Lithuania had the lowest prevalence percentage at (4.41%, 3.92-4.97%), followed by Denmark at (4.62%, 4.14-5.15%), and Ireland at (4.63%, 4.22–5.08%).

4.2.2 Overview of nutrition and physical activity policies, national DM plans and national DM registries in the EU member states

According to the WCRF International database, the United Kingdom (34) had the highest number of implemented policies, while Malta (2), Slovakia (2), Luxembourg (2), and Lithuania (2) had the lowest number of implemented policies during that year. The only policy that was introduced in all 28 member states on "nutrition label standards and regulations on the use of claims and implied claims on food".

The least frequently used policies were those that provide addressing "Set incentives and rules to create a healthy retail and food service environment" and "Give nutrition education and skills". In 2014, the latter was not made available in any member state.

Seven of the 28 member states operated a national DM registries, while 17 of the 28 member states had an active national DM strategy in 2014.

4.2.3 Individual level correlation between national policies, DM plans and registries and DM prevalence

The prevalence of DM was positively correlated with "Food environment" and "Food system" policies, according to the findings of point-biserial correlation analyses. These findings were significant for the general population, men, and the age ranges of 15 to 44 and 45 to 64. "Food

environment" policies and "Food systems" policies for people 65 and above showed a weak significant negative correlation with DM.

All sex and age groups, with the exception of those 65 and above, exhibited a weak negative significant link with DM. "Behavior change communication" policies had a positive weak correlation with the prevalence of DM.

In our total population and its sex and age subgroups, "Active society" policies had only a marginally significant negative correlation with the prevalence of DM.

In our total sample, including males and the age ranges of 15–44 and 45–64, there was a weak positive correlation between a higher number of "Active environment" policies and DM that was statistically significant. In the total population, the male group, and the age range of 15 to 44, higher number of "Active people" policies showed a weak positive correlation with DM. A significant negative association between the age group of 65 and older and "Active persons" policies was also found. An increase in national DM plans and registries had a negative correlation with the total population, women, and the age groups of 15–44 and 45–64.

4.2.4 Country level correlation between national policies, DM plans and registries and DM prevalence

The multilevel logistic regression analysis model included variables of epidemiological relevance and were significant in the study's bivariate analysis. The variation attributed to countries as a grouping factor for DM was minimal (ICC: 1.3%) after adjusting for individual variables. The observed variation in DM prevalence between countries was caused by demographic, socioeconomic, and lifestyle factors rather than by variations in the availability of preventive policies. The risk of having DM was not significantly correlated with any of the policy types. The multilevel analysis' findings revealed that females, less urbanized environments (suburban and rural), higher levels of education (secondary and tertiary), middle and lower household income (between quintiles 2 and 4 and between quintiles 4 and 5), and fruit consumption 1-6 times a week significantly influenced the prevalence of the disease, with lower odds of being effected compared to their reference group.

Contrary to participants in the older age groups (45–64 and 65 and above), higher BMI ranges (25–29.9 and 30) and labor status (unemployed and others) significantly increased the likelihood of disease prevalence in comparison to their comparable reference group. Contrary to participants in the older age groups (45–64 and 65 and older), higher BMI ranges (25–29.9 and 30) and labor status (unemployed and others) significantly increased the likelihood of DM prevalence in comparison to their comparable reference group.

4.3 Diabetes Mellitus and associated factors in Slovakia: Results from the European Health Interview Survey 2009, 2014, and 2019

In the 2009 EHIS, the prevalence of DM was 6.1%, 8.2% in 2014, and 9.8% in 2019. Bivariate analysis revealed that in 2009, the number of people with DM varied by gender (p-value < 0.05); female respondents had a greater percentage of the DM group than male respondents. In 2009, 2014, and 2019, frequencies by age groups were statistically significantly different; DM responses belonged to the elder age categories of 65 and above which were 3.59%, 4.81%, and 6.06%, respectively. It has been found that respondents with secondary education were significantly more affected by DM than respondents with other education levels. Only in 2009 and 2014 the degree of urbanization did show a significant correlation with DM; in 2009, more respondents had DM and lived in rural areas. 2014 had the highest number of DM patients lived in towns and suburbs.

The prevalence of DM varied according to labor status; respondents who had DM were more likely to be in the other categories (such as students and pensioners). In 2009, 2014, and 2019, there was a substantial correlation between the prevalence of DM and BMI. The majority of people with DM fell into the category of being overweight or obese. In 2009 and 2014, the BMI group between 25 and 29.9 had a greater proportion of people with DM, while in 2019, the BMI group ≥ 30 had a higher prevalence of the disease. The DM participant had different frequencies of number of days walking for at least 10 minutes a week.

Most of the DM respondents walked one to six times a week for 10 minutes to get to and from their destinations in 2009 and 2014. In 2009 and 2014, more people walked for transportation had walked every day, while fewer people with DM never walked. For 2019, in comparison to those who walked one to six times a week for 10 minutes or never, individuals with DM were more likely to walk for transportation on a daily basis. In 2009, 2014, and 2019, a correlation between the presence of DM and various physical activity categories was observed. In 2009, 2014, and 2019, persons who never engaged in any sort of physical activity each week had higher rates of DM than those who did. Only in 2009 did the association between eating fruits and vegetables and having DM become significant. Compared to eating one to six times a week or less than once a week or never, diabetic respondents had the highest frequency of eating one or more fruits and vegetables per day in 2009.

According to the findings, women were 27% less likely than men to have DM in 2019. In all three surveys, there was a low association between DM and the age categories of 15 to 44 and

45 to 64 compared to the reference age group (65 and older). There was no correlation between the degree of urbanization and the occurrence of DM. Comparing respondents with higher education to those with primary or less than primary education, DM was positively associated with having DM in 2019.

In comparison to the reference group of other labour status, employment had a significantly decreased likelihood of developing DM in the years 2009, 2014, and 2019. Only in 2014, the reference group of other labor status showed a lower probability of having DM than those who were unemployed.

Lower BMI (18.5 to 24.9) was associated with a low probability of having DM in 2009, 2014, and 2019, respectively. People with a BMI of 30 or higher had a greater likelihood of developing DM compared to the overweight group (BMI 25 to 29.9).

Regarding physical activity, it was discovered that in the years 2014 and 2019, walking for at least 10 minutes daily or for at least one to six times a week was associated with a lower risk of developing DM compared to our reference category of “never”. A lack of physical activity, "never," increased the likelihood of developing DM in 2014. The frequency of eating fruits and the presence of DM were not associated. In comparison to our reference category of eating vegetables one or more a day, eating vegetables one to six times a week reduced the probability of having DM in 2009. Regarding Slovakian regions, there was no statistically significant association (data from 2019, exclusively).

4.4 Analysis of content, social networks, and sentiment of front-of-pack nutrition labeling in the European Union on Twitter

4.4.1 Overall description

A total of 4,073 tweets were published by the quest, of which 2,278 (or 56%) were original tweets, 1,321 (or 32%) were reply tweets, and 474 (or 12%) were quoted tweets. There were 2,819 different accounts that associated with these tweets. In all, 229 accounts (4.6%) belonged to institutions or organizations, whereas 278 accounts (6.8%) belonged to people (individuals). Twitter defines entity annotations as references to people, organizations, locations, products, and others.

3,202 tweets in all were relevant to our scope of the study, whereas 871 were deemed as unrelated. A total of 493 items were classed as announcements, 2,624 as opinions, 68 as science and 165 related to EU policies. The result of measuring the internal consistency of the set of questions used to categorize the tweets was 0.70, which was a generally satisfactory Cronbach's

alpha value [51, 52]. The intra-class correlation coefficient, which was used to test the inter-rater reliability, was 0.876, which was considered a good level of reliability. The inter-rater reliability of dialogues and conversations was 0.949, which was regarded as an excellent level of reliability. [53, 54].

Over the previous ten years, social networking participation has increased throughout the EU countries on average (creating user profiles, posting messages, etc.). With 81% of the population using social networks on average over the past five years, Denmark has led the way. In the previous five years, countries other than Denmark that have appeared in the top five include the United Kingdom, Belgium, Cyprus, Malta, and Sweden. Over the past five years, Poland, Germany, Bulgaria, France, and Slovenia have had the lowest frequencies, but the lowest rates have consistently been more than 40%. In the last five years, 63% of people from Spain, a nation that has been very active on this subject, used the internet to social networking [55].

The UK (n = 1,434, 44.8%), Spain (n = 582, 18.2%), France (n = 468, 14.6%), Belgium (n = 244, 7.6%), Germany (n = 131, 4.1%), Ireland (n = 113, 3.5%), the Netherlands (n = 97, 3%), and Italy (n = 72, 2.2%) were the major geographical origins of the accounts, while 15 countries had <1% and five countries had no tweets. Since 2010, the UK has had a significant portion of tweeters, with a peak in 2016 followed by Spain and France.

4.4.2 Content analysis

The main topics include different types of nutritional food labeling, the food industry, healthy vs. unhealthy foods in the context of food labeling, EU regulation, political conflict, science and education.

The most representative food label in the studied dataset is Nutri-Score. Six of the top 10 influencers are Nutri-Score supporters, while only two are opponents. The other subthemes of Nutri-Score covered a variety of traffic lights, warning signs, allergies, alcohol, the environment, CO2 emissions labels, indication of origin, etc. Within this theme, the usefulness of the Nutri-Score has received the most discussion; however, there were tweets in favor of and against it. The encouraging tweets were general but also were founded on first-hand experience. The primary topics of skeptic tweets concerning effectiveness were personal accountability and inconsistent food labeling. Additionally, food labeling was generally rejected by some tweets. Both encouraging and discouraging tweets are present for Nutri-Score. The justification for the claim is that Nutri-Score has been shown to have a favorable

impact on consumers' product preferences. However, the problem and discussion were sparked by a lack of consistency: Can a soft drink be categorized in the same way as a natural juice or a sweetened soft drink?

The healthy food subtheme, from healthy vs. unhealthy food theme, usually featured ingredients from Mediterranean cuisine, such as olive oil, packaged fruits and vegetables, or dairy products. The subtheme of unhealthy foods included goods, such as junk food, ultra-processed foods, packed and packaged meals, and fast foods that are described to be discriminated exclusively by food labeling. This topic has mostly been explored in relation to Nutri-Score, and some individuals believe that Nutri-Score encourages people to make healthier decisions. Some tweets assume that Nutri-Score promotes industrial companies at the expense of healthy food. One of the two main subthemes of the food industry was to celebrate the beginning of the use of Nutri-Score by food companies. However, some tweets discussed as previously mentioned, that food companies are less interested in promoting healthy eating and may take action against FOPL. The interests of the food business can also be regarded as the defense of regional and local producers. For instance, other people brought up the cost of the new food labeling system, relativizing the effects on public health.

The food industry is frequently held firmly accountable for the effects of consuming unhealthy foods. Some have expressed skepticism toward officials because they think that even if regulation does occur, it may be because they were able to come to an agreement with them. Others, on the other hand, think that the food business is preventing Nutri-Score from being successfully implemented. Tweets also reflected the political and food industry's mutual interests.

Moreover, tweets about EU legislation primarily featured conferences, events, and announcements. Because of how EU legislation affects the internal market or has a good impact on people, those who were evaluative in their tweets tended to support it. Most tweeters support a single-market strategy and the harmonization of FOPL, even though some disagree with the symbolic Nutri- Score's value.

In some tweets, the mandatory versus optional application of the regulation is also discussed, with a sizable portion of the participants favoring mandatory while others disagreed.

Several tweets brought up the Brexit subtheme, which had a big impact on UK FOPL regulation.

The tweets, taken in a broader context, represented a political confrontation in which the interests of agribusiness and the public health conflict, with varying responses from private, political, and governmental actors. The majority of tweets included doubtful, critical, and

unfavorable remarks. The conflict seems between the countries that support NutriScore and those in the Mediterranean region. The significance of local product protection seems to be influential. Differences in politics have been found not only across nations, but also against certain politicians. A comparatively small number of tweets with a science topic highlighted the foundations of Nutri-Score science, while others made references to academic articles and discussed the importance of science. Some tweets were encouraging action relating to the population's health education made up another subtheme. After the FOPL was implemented, some people emphasized the importance of education. Some tweets explained how this education should be delivered.

The dialogues were located and examined to determine which themes appeared frequently in order to be more specific. There were 327 dialogues or conversations that were found. Label type (97.55%) was the most often mentioned tweet topic, followed by the food industry (26.91%), bad food (18.96%), EU regulations (14.06%), science (11%), political conflict (10.09%), and healthy food (9.78%).

4.4.3 Sentiment analysis

We analyzed the sentiments associated with the main themes. Sentiments were divided into four categories based on the frequencies: very negative, moderately negative, moderately positive, and positive. Neutral or mixed feelings were defined as a combination of both moderately negative and moderately positive. The tone of the text was generally negative sentiment. Tweets on the food industry generated more positive feedback than tweets about political conflict.

4.4.4 Network analysis

The communications both within and across countries were represented in the chord diagram. There were a total of 3,138 nodes and 626 edges in the network study. The graph indicates that there were few international links and that most tweets were domestic in nature. The majority of connections were observed in France.

The network analysis of the conversations/dialogues resulted in 736 nodes and 581 edges. The tweets were represented by the nodes, while the connections between tweets that were a part of dialogues were represented by the edges. Each conversation was broken down into a number of coded topics.

5. Discussion

5.1 How the European Union legislations are tackling the burden of diabetes mellitus: a legal surveillance study

The aim of the article was to present a thorough summary of the legislations affecting DM prevention in the EU. This research is the first that, to the best of our knowledge, analyzes EU initiatives and legislations in the area of DM prevention.

Our main conclusion demonstrates that numerous EU legislations included the prevention of DM as a part of NCDs or through risk factors. A relatively small number of non-binding legislations particularly between 2006 and 2012 addressed DM. The European Parliament released a resolution in 2012 that addresses the DM epidemic and urges the EU to prioritize DM [56]. Nevertheless, DM was never given the spotlight it deserved during the legislative procedure. A recent initiative "The Blueprint for Action on Diabetes in the European Union by 2030" demands for DM to be placed at the top of the legislative upcoming plans [57] and could result in the creation of EU soft laws focused on DM in the near future.

The goal of the health programs has been to battle diseases and enhance the health of residents in the EU ever since they were introduced. Health programs should focus on DM as it can be prevented as other NCDs by altering risk factors like obesity and a sedentary lifestyle and by prescribed medications [58, 59]. Due to the increased emphasis on health, the ongoing health program, EU4health, has been funded more than earlier programs [60]. The recent COVID-19 pandemic has disproportionately affected the poor, older age groups and individuals suffering from chronic illnesses which include significant high rates of obesity and DM, highlighting the necessity for future efforts to focus more on prevention [61].

The EU's strategies for combating NCDs, particularly DM, have evolved over time. Early laws tended to be more concerned with EU market rules. The movement of goods as well as food products, and imposition of customs tariffs on these goods between the EU and other countries are regulated by the EU common market [62]. These legislations govern the food production, how the food market changes, and which goods are available for EU citizens to purchase. Since 2010, the EuroVoc terminology has evolved to include more preventive strategies for NCD risk factors.

Most of the legislations were in focus of a life course approach strategy that was proposed by the WHO diabetes report. This strategy has demonstrated its effectiveness through reducing risk factors and boosting protective behaviors and characteristics during crucial stages of an individual's life, from the antenatal period and childhood and adolescence to adulthood. EU

strategies also included trade, agricultural, and fiscal regulations to promote a healthy diet. The EU's single market strategy has impacts on health. A few tools in the EU, such as health program funds [58, 59] directly support public health, and DM was on the health program's agenda as stated above. Informational legislations cover areas including promoting health, education, and research and innovation, which have lately ranked highly on the EU's priority list and received major funding [63].

Unfortunately, food taxation as a sort of fiscal legislation has not been implemented at the EU level. The adoption of such laws should be promoted in the member states.

The EU's strategy to subsidizing with better options includes using legislation as a tool to target energy intake. This included promotion, educating, and regulating the marketing unhealthy foods. Consumer education through labeling is the primary method of nutritional legislation in the EU, according to the findings of a comprehensive review [64]. Food labeling has been shown to be successful in several countries [65]. This justifies a focus on food information and labeling in EU legislations. The setting in which food is consumed is crucial in determining eating choices. Changing one's diet early in childhood can potentially stop the onset of obesity and DM in adulthood [66].

As shown by the functional category of energy expenditure, an environment supportive of physical activity should be at the center of EU regulations which included legislation governing physical activity and its structure. According to literature, the success of physical activity laws around the world is low to moderate [67]. Policies promoting physical activity should be changed if they have proven ineffective as it is the most effective preventive measure against DM [67]. The EU's member states are responsible for enacting physical activity laws; the Commission's role is limited to supporting and coordinating these efforts.

In Europe, a prominent and constant health gradient exists between socioeconomic groups. Social legislations that focus on socioeconomic concerns may have indirect health effects [68]. One of the included legislations in our study, the White Paper on “Strategy for Europe on Nutrition, Overweight, and Obesity Related Health Issues”, had underlined the significance of addressing socioeconomic determinants and lowering disparity to diminish obesity and other NCDs as DM in the EU [69]. The general population was the most frequent target group. The numbers alone demonstrate that the legislation's structure is simple and that subgroups, particularly pregnant women, receive no special consideration.

Screen and treat strategies, which cover detection, early diagnosis, and treatment as well as enhancing patients' quality of life, were part of the EU strategies. In the EU, more than 38% of people with DM go undiagnosed, and by the time they are diagnosed, many have already

experienced one or more complications [57]. These issues have catastrophic effects on individuals and are quite expensive for health systems. The development of a screening tool and framework for people at risk across the EU to be used by 2024 has been suggested in the document “Blueprint for Action on Diabetes in the European Union by 2030 [57].

The theme focused on launching a 'Health in All Policies' online policy portal did not yield any legislation, but a number of stakeholders lobbied for its foundation. This may also aid in achieving the second objective, which is to provide health a political home within the EC and to guarantee inter-institutional coordination on health and well-being. The EU recently built a new interactive platform called the "EU Health Policy Platform" to gather laws under the EU4Health fund, which might be a step toward creating the online policy for Health in All Policies [70, 71].

In conclusion, there is not much binding regulation regarding DM prevention. Despite the fact that there are many relevant soft laws, the EU does not take use of the already available legislations. For instance, there is no "Health in All Policies" online policy to track the effects of EU legislation. All DM-specific laws are soft laws that have been in effect for at least ten years. The EU has begun to concentrate on risk factors, but mostly through mechanisms related to energy intake rather than addressing the complete range of preventive measures. High-risk populations that might have severe repercussions in the event of a future outbreak receive limited attention.

This study had several limitations. Despite the fact that not all types of DM are thought to be preventable, legislations did not differentiate between DM subtypes and instead regulated the area as a whole. Legal mapping has limits, despite the fact that this qualitative research offers fresh insights on the application of the “WHO Global Report on Diabetes” and the “EU Strategic Framework for the Prevention of NCDs”. There are worries that current EU legislation does not accurately reflect how it is being employed in the member states. There is a gap between what is suggested and launched and how much of it is really implemented. Furthermore, while EU legislation may be beneficial, it may take time for changes to take effect. Finally, based on our analysis, it is unclear if EU legislations are effective in preventing, detecting, and responding to disease. Accordingly, more "legal epidemiology" research will be required to examine how laws affect national health systems and public health outcomes [72].

To conclude, legislations aimed at DM prevention are few in number and narrowly focused. Since the 1960s, the EU has made enormous efforts to combat obesity, NCDs, and DM, yet the prevalence of DM is still rising in the majority of EU member states. To ensure that DM and its associated risk factors are incorporated in all new relevant initiatives, programs, and

legislation, it is imperative to ensure that DM is high on the agenda of various EU institutions. In our opinion, more advanced and comprehensive legislative network suggested by the WHO should be adopted in the EU.

5.2 Impact of policies in nutrition and physical activity on diabetes and its risk factors in the 28 member states of the European Union

EU members have directly aimed at tackling DM through national plans and operating DM registries, or indirectly by implementing nourishing, food-related and moving policies that address the primary risk factor for obesity, in an effort to lessen the burden of DM. Despite the fact that some relevant policies have been implemented in each member state, the results of our analysis reveal significant disparities in their types and numbers. However, having more policies—of any kind—do not appear to guarantee a decline in the burden of DM; poor association between the prevalence of DM and preventative strategies was found. Although the greatest and lowest DM prevalence rates across the member states range significantly according to our findings were 5.57%, results from the "Global Burden of Disease 2019" report shows that these rates have been rising ever since [3].

In our study, nutritional policies that had been implemented ranged from 2 to 34; only four countries had policies that were solely concerned with nutritional labeling. The use of economic instruments for food affordability and restrictions on food advertising were the more underutilized nutrition policy categories, which present governments' reluctance to implement regulatory measures and their preference for educational strategies. This type of legislative preference has already been documented, for instance by an analysis of England and Southampton City policies of maternal and child health [73].

The number of countries with adopted physical activity policies ranges from 0 to 15, with the majority of countries having none at all. The least used category of moving policies was the provision of an environment for physical activity at work, which may present a reflection of governments' detachment from the industrial sector.

According to the study's findings, there is no or very little link between the prevalence of DM and any type of nutrition or physical activity policies, existing DM plans, or DM registries. The sole legal category that was used across all member states was product labeling, emphasizing the EU's legislative role. "Upstream" dietary and multi-component programs, for example, pricing modifications, are to be unfailingly successful in encouraging healthy eating [74], despite economic tools for food affordability and advertisement restrictions were scarcely used

in EU countries. It has been observed that the successful of actions, such as labeling or restrictions on the availability or marketing of unhealthy food, are less effective and provide fewer firm long-term benefits [74]. Some EU members (such as France and Hungary) have imposed taxes on beverages with added sugar, however these taxes have only had a minor impact on the retail price. Introduction of plain packaging, warning labels, and a 20% tax on SSBs have predicted a significant behavior change [75].

Comprehensive research is also done on how effective policies are at encouraging physical activity. A recent systematic analysis reported solid evidence supporting the efficacy of policies in some areas, such as supporting walking and cycling policies and school environments for kids [76].

Our analysis did not find evidence of a relationship between the prevalence of DM and school related legal policies, likely because the EHIS dataset only includes people over the age of 15 [19].

Populations are not homogenous collections of individuals. Our outcomes were divided by age groups and gender in order to better understand how policies affect certain groups. The effectiveness of initiatives promoting good eating and exercise is influenced by population structure. Age and gender, for instance, were discovered to be associated with the effectiveness of policy actions addressing NCDs [77]. An article evaluating the impact of the SSB tax on the occurrence of obesity in Portugal, by simulation model, reported the relationship between age groups and taxation strategies. According to this simulation study, adolescents between the ages of 10 and 18 were likely to experience the greatest projected impact [78].

In 2014, only 25% of the member states maintained national registries for DM, and nearly half of them had no DM plans. The number of policies was not related to the existence of DM plans and/or registries; for instance, in 2014, neither a national diabetes plan nor a national diabetes registry existed in the United Kingdom, which had the most policies in effect. The focus on risk factors of NCDs rather than DM itself may help in explaining this disparity. Since population-based registries are regarded as a pillar of assessment of policy interventions, the frequent absence of registries, however, shows clearly that DM is not at the core of public health policies in many EU countries [79].

Living in a particular country might be a risk factor of itself. For instance, the SCORE chart for cardiovascular risk levels uses a low- or high-risk scale depending on the country of residency [80]. As a grouping factor for DM in our analysis, the difference attributed to countries was minimal. In contrast to disparities in the availability and variety of different

preventive strategies, discrepancies in disease prevalence between member states were caused by differences in demographic, socioeconomic and lifestyle variables.

There was no significant association between any policy type and the likelihood of DM occurrence. The findings of the multilevel analysis showed that female gender, younger age groups, higher levels of urbanization, mid/low income, and higher levels of education were substantially associated with a reduced risk of DM prevalence. In contrast to some good eating behaviors, such as eating fruits 1 to 6 times a week, which may strongly correlate with reduced disease burden, having a higher BMI has a considerable consequence on the likelihood of DM occurrence.

Our analysis revealed that no member state has completely addressed all the WCRF's suggested areas for nutrition and physical activity policies.

In conclusion, it implies the necessity to establish international treaties or other binding legislation because the only area of policy that was genuinely regulated across member states was labeling, which is a result of an EU regulation. It would appear essential to work with international organizations to create effective policies and oversee their implementation [81-83].

However, the study had several limitations. The cross-sectional design of the study, which prevents the establishment of causation, is a significant disadvantage.

The most recent EHIS dataset accessible at the time of the manuscript's creation was the 2014 data, which we used in our analysis. Since the survey relied on self-reported questionnaires, the results and conclusions may not be accurate. Unfortunately, the study was unable to evaluate the physical activity characteristics since Belgium and the Netherlands did not provide data on them. Additionally, policy databases might not include all of the policies that were in force in 2014, and policies might require more time to fully realize their potential.

Although DM includes all subtypes with a variety of pathophysiology, the publication did not take into account this diversity; instead, the analysis employed the broad category of DM. Since T2DM accounts for the vast majority of cases of DM, dietary and physical activity guidelines are designed to address T2DM risk factors. Due to the small number of policies, conclusions based on the study should be for careful implemented.

To conclude, our research suggests that a higher adoption of dietary and physical activity guidelines is not always linked to a reduced prevalence of DM. There is some variation in the policies regarding nutrition and exercise among EU member states, and those areas that are heavily regulated are always as a result of EU legislation. Undoubtedly, policies put into place up to 2014 had some effect on lowering the DM burden, but not enough to reverse the growing

trend. In our opinion, a matrix of policies is required to control the burden of DM; interventions cannot be restricted to a few policy areas that are simpler to implement for political or other reasons. To determine the magnitude of policies' effects on the burden of DM, more research is required.

5.3 Diabetes mellitus and associated factors in Slovakia: results from the European Health Interview Survey 2009, 2014, and 2019

As far as we are aware, this is the original study to examine the DM burden throughout the course of the three waves of the EHIS. Our study establishes the necessary baseline data for subsequent evaluation by providing adult population-wide, representative data on a range of basic health monitoring markers. Our data shows that between 2009 and 2019, the prevalence of DM patients has increased. Similar increases in prevalence have been observed throughout the majority of EU member states and the EU average [3].

Contrary to findings from a meta-analysis, which suggested that living in metropolises would increase the risk of DM [84], the results revealed that the degree of urbanization was not associated with the risk of DM. Socioeconomic factors such lower educational attainment and employment position may have a role in increasing inequalities in the population [85, 86]. Results from Denmark and other European states show that those with less education are more likely to develop DM than people with higher education. In the three waves, employment is adversely associated with DM; research has shown that people with DM leave the workforce earlier and produce lower-quality outcomes [87].

Our analysis has confirmed the already established information that obesity and overweight are linked with a higher risk of developing DM, as observed in the three waves. The intake of fruits and vegetables is frequently at the heart of health policies addressing DM. Consuming fruit and vegetables has been found to lower the risk of developing DM in various prospective studies [88, 89]. However, our cross-sectional analyses could not find a consistent association between their consumption and the development of DM. Based on healthcare recommendations, individuals suffering from DM can consume the same amount of fruits and vegetables as healthy people [90, 91] This discrepancy is not unexpected based on a meta-analysis that previously revealed that there was no clear relationship between total vegetable and fruit intake and the prevalence of T2DM [92].

Our findings are consistent with a dose-response meta-analysis, which showed that walking as part of active transportation reduces the risk of developing DM; however, walking for more

than two to three hours per week had no additional protective effect [93]. Resistance training and aerobic exercise both show inverse relationships with the risk of developing DM, according to clinical trials and cohort studies [94].

The burden of DM is still high even though Slovakia has already established legislative efforts in these areas [95, 96] While population-based interventions often show initial results, they do not always lead in long-term declines in the burden of disease.

The main shortcoming of this study is the inability to establish a causal link between DM and risk factors due to the cross-sectional methodology. The employment status was not taken into account in our analysis. Only level 2 of the nomenclature of territorial units for statistics (NUTS2) were available in wave 3, hence only 2019 was used to study the relationship between DM and residing in different regions of Slovakia. Since the EHIS is a self-reported survey, there is a possibility that the reported data and estimated associations may not be accurate or reliable. Additionally, despite the fact that each kind of DM has a different pathological background, the different types of DM were not identified in our analysis due to the uniform category of DM that was employed in the EHIS waves.

To conclude, results from 2009 showed that consumption of vegetables several times a week may decrease the occurrence of DM in addition to moving for at least 10 minutes, such as walking, may prevent DM. Lifestyle factors including eating fruit and vegetables were not linked to DM. To assess their involvement in the growing prevalence in Slovakia and in contrast to other EU countries, further lifestyle characteristics and socioeconomic factors need to be examined. Existing health policies and initiatives in Slovakia were unable to stop the steadily rising DM burden, demonstrating the need for a more methodical approach. To conclude, in order to achieve improvement, creating and implementing complex policy initiatives and legislative measures seem unavoidable, both at national and EU levels.

5.4 Analysis of content, social networks, and sentiment of front-of-pack nutrition labeling in the European Union on Twitter

This is the first manuscript that, to the best of our knowledge, evaluates the general discourse on Twitter about FOPL in the EU. Our study has revealed limited Twitter activity despite the subject matter's significant importance in the field of public health. Based on our findings, the discussion often revolves around the reliability of the Nutri-Score rather than FOPL system as a whole.

The question of whether it was worthwhile to use a basic color label with a clear message but no nutrition information was one of the major debates on Twitter [21]. Ultra-processed foods

with minimal nutritional value can also be classified under a better FOPL, as has been frequently stated in tweets. FOPL systems that are based on an algorithm or score, like Nutri-Score, multiple traffic lights, and health star rating, may not always differentiate between foods that are nutritionally recommended and those that are less recommended [97]. For instance, Israel has adopted an interpretive FOPL system that uses two colors to indicate negative or warning (red) and positive (green) labels in order to address the conflict between employing nutrition labels and suggesting traditionally healthy foods. The positive FOPL is optional, but the warning FOPL is required. However, a product's lack of a warning label does not imply that it is endorsed to consume [97, 98].

Olive oil, a staple of the Mediterranean diet, is the food at the center of the Nutri-Score controversy. The "Yellow C" label given to any olive oil by Nutri-Score is considered by several industry advocates to be misleading to consumers because it does not accurately reflect the recognized health benefits of extra virgin olive oil. They contend that extra virgin olive oil belongs in the "Green A" food category, which is the greatest one for healthy foods [99]. In an effort to help customers choose healthier and more sustainable foods and to combat food waste, the EC has opened a public consultation on proposed changes to food labeling. The deadline for stakeholders to express their opinions was March 7, 2022. However, as of that date, 214 legitimate comments had already been received, many of which from olive oil-producing countries indicating lobbying activity [100].

FOPL nutrition systems significantly impact the marketing plans of large agribusinesses. Twitter users had negative perceptions of the subject in general, but some had favorable perceptions about the food industry. Positive opinions of the food industry were probably influenced by the food brands' Twitter activity as well as tweets praising the adoption of Nutri-Score by a number of food brands.

The lobbying power of the food industry is well known throughout the world, therefore it is not surprising that this theme has emergence in the Twitter discourse [101, 102].

The ultra-processed food sector has aggressively used Twitter to influence discussions about food and health policy, according to an Australian study. The study found that following seven general tactics were found in tweets: combining public health narratives; opposing regulation; promoting voluntary, co-regulation, or self-regulation; interacting with the political system and decision-makers; connecting the governing environment to the need for continued profitability; effecting public perceptions and value judgments; and using ignorance claims to distort policy

narratives [103]. The EU suggests that better consumer education will lead to more precise, informed, and understandable food decisions [103].

Many people are drawn to the WOM debates on social networks that revolve around FOPL discussions, as it facilitates the process of communication and information transfer. The customer experience, often known as the customer journey, has a significant impact on social networking debates about FOPL on Twitter. Customer journeys are important in how people use social networks to share ideas, follow certain issues, or solve problems. Regulations governing FOPL and consumer discourse are closely related [104]. There is no one-size-fits-all solution across Europe due to national preferences, and the flaws and inadequacies of FOPL have slowed its implementation [105, 106].

To combat obesity and other NCDs, the EU planned to establish a harmonized FOPL in the near future, although the optimal strategy is a subject of fierce debate among member states [107]. The Nutri-Score, most widely used and highly debate summary indicator-type, has been discussed at major political levels, particularly in Italy and other Mediterranean countries, as indicated above [108]. Even though there were little or no further political disputes between countries in the tweets, there are still other political debates with the harmonized FOPL.

Several EU member states have expressed that if a new standardized nutrition labeling system with FOPL is adopted, it should adhere to the text of the FIC regulation, i.e., it should provide factual information on the individual nutrients in a product and, as a result, exclude any system that would offer an overall assessment of food, such as the Nutri-Score. France, Belgium, Spain, Germany, the Netherlands, and Luxembourg are among the member states that support the exemption of products with protected origins and those with a single ingredient [109]. Political conflicts cover a wide range of negative emotions, as shown by the fact that this theme came up as the most negative in the sentiment study.

In conclusion, an EU proposal calls for the implementation of a unified FOPL system throughout all EU member states starting in 2020 [23, 110]. As nutrition information should not be reliant exclusively on the ineffective ingredient list of prepackaged meals, such a system is seen as an important tool to combat obesity and NCDs. Our findings demonstrated that talks concerning FOPL on Twitter are restricted to a small group of users; as a result, consumers' FOPL education should be prioritized, informing people about current and prospective FOPL systems [111]. Consumers should be empowered by educational programs to comprehend what a healthy diet is and how FOPL systems are relevant to national nutritional guidelines.

The study had several limitations. Twitter's text limit is quite strict (280 characters maximum), which restricts the expressing of opinions and the inclusion of background information thereby inevitably impacting content analysis. The tweets were published in multiple languages, which may have hindered interactions across countries. Additionally, some tweets original meanings may be changed by machine translation. It is important to note that NVivo does not categorize content based on sentiment in sentiment analysis. Without considering the context, sentiment analysis considers single words. NVivo lacks the ability to recognize sarcasm, double negatives, slang, dialect variations, idioms, ambiguity, etc. like the majority of text analysis tools. The network analysis, which was designed to represent the countries by displaying each user ID and the required coordinate data.

In particular, the majority of the tweets lacked coordinates to identify their posting location, which was one of several inconsistencies in the data gathered from the complete archive of Twitter API Postman investigation, covering the period from March 2006 to early December 2021. We did not characterize accounts due to limited access to user information, including the number of followers, which would have hindered our ability to identify false accounts. Another issue is the fact that trust surveys are context-dependent and display considerable variations, despite the significant overall lack of trust in internet and social media information sources across EU member states [112]. Analysis could not incorporate the impact of mistrust of various sources on discussions about EU policy due to a lack of information on this aspect.

5.5 New findings

New results are listed below:

1. A total of 1099 relevant legislations related to DM, NCDs, and obesity were collected. Among these, 22 legislations primarily focused on the prevention of DM, NCDs and obesity and only five legislations were specifically designed for DM prevention. The identified legislations spanned from 1968 to 2022, with 366 legislations currently in effect. Among the identified legislations, there were six binding legislations and 17 non-binding legislations.

2. EuroVoc terms were available in 853 legislations, with a total of 6189 terms identified. Over time, there has been an increase in the number of new legislations passed since 2005. In 2021, the most popular subdomains were related to "social questions" and "epidemic" areas, while in 1973, the focus was on "trade" subdomains.

3. The assessment of legislations based on the WHO Global Report on Diabetes and EU Strategic Framework for the Prevention of NCDs Guidelines revealed that the most common

classification type was "a life-course approach to preventing DM." Food-related laws, such as trade and agricultural regulations supporting healthy diets, were the most common binding legislations.

4. The target groups of the legislations varied, with the majority focusing on the general population or communities. The functional categories employed in the legislations included topics like energy intake, food labeling, physical activities, health promotion strategies, and screening and treatment. Non-binding legislations were only present in the areas of energy expenditure and screening and treatment.

5. The study analyzing the impact of policies in nutrition and physical activity on diabetes and its risk factors in the EU member states found that the prevalence of DM varied across countries. In the 28 member states of the EU, the prevalence of DM in 2014 was predicted to be 6.94%. Portugal, Greece, and France had the highest prevalence rates, while Lithuania, Denmark, and Ireland had the lowest rates.

6. Nutrition and physical activity policies, national DM plans, and national registries differed among member states. Seven out of the 28 member states had national DM registries, and 17 had active national DM strategies in 2014. Among the nutrition and physical activity policies in the EU, the policy on "Nutrition label standards and regulations on the use of claims and implied claims on food" was introduced in all 28 member states. However, policies addressing a healthy retail and food service environment and nutrition education and skills were less frequently implemented. Country-level regression indicated that demographic, socioeconomic, and lifestyle factors had a greater influence on DM prevalence than variations in policy availability.

7. The prevalence of DM in Slovakia increased from 6.1% in 2009 to 9.8% in 2019. Women had a lower likelihood of having DM compared to men. The age groups of 15-44 and 45-64 had a lower association with DM compared to the reference age group of 65 and older. Higher education and employment are associated with lower likelihood of DM. Higher BMI and lack of physical activity increased the likelihood of DM. There was no significant association between the presence of DM and the frequency of fruit and vegetable consumption. The geographical regions in Slovakia did not show a statistically significant association with DM prevalence.

8. The study analyzed a large number of tweets related to front-of-pack nutrition labelling in the EU. A significant portion of tweets being opinions and announcements. Different

countries, including the UK, Spain, were major contributors to the Twitter discussions. The network analysis revealed that most tweets were limited to same country, with few international links. France had the highest number of connections.

9. The main topics discussed in the tweets included different types of nutritional food labelling, the food industry and healthy vs. unhealthy foods. Nutri-Score emerged as the most representative food label in the dataset. The sentiment analysis showed a generally negative tone. Tweets related to the food industry received more positive feedback compared to tweets about political conflict.

5.6. Recommendations and Conclusions

The Results presented and discussed previously have great of repercussions on the burden of DM in the EU. Policy surveillance of existing and available policies in the EU that address obesity and NCDs including DM is very crucial to allocate resources for studying current actions and obstacles and to develop solutions that can benefit political society as a whole. Nonetheless, EU policies in this area are available but limited. A comprehensive and holistic approach, along with the adaptation of comprehensive network of actions as recommended by the WHO, is necessary due to the ongoing increase in the burden. Studying dietary and physical activity policies and their relationship to the burden and risk factors, taking into consideration member states, was the first to be introduced in the EU, and the results have showed that even although dietary and physical activity policies are regulated in most member states, several modifiable risk factors, along with sex and age, are associated with the increasing burden. No association was shown with the current policies. This could be translated into that the policies were unable to alter or had significant effect on halting the prevailing rise of DM. Result from the most recent microdata available in the EU on DM burden, EHIS 2019, with Slovakia as an example of a member state demonstrated how the burden of DM has changed over the years and its association with different factors affecting this burden. All of these investigations have been conducted to accumulate evidence and aid in determining the most significant interventions and actions that could be made and assess EU actions that will be made in the upcoming years. One of the suggested interventions is the implantation of a unified front-of-pack nutrition labelling, as studied by evaluating the public disclosure on the topic, we found that educational program should be introduced along with new proposed policies to ensure its upmost success of the policy.

All in all, the result suggests that increase burden of DM in the EU needs to be addressed more by EU policies and current policies should be adjusted to fit the rising prevalence.
Recommendations include studying existing interventions implemented in different EU member states in order to gather evidence based results on best practices that can guide future actions.

6. Summary

This study extensively reviewed 1,099 legislations concerning diabetes mellitus (DM), obesity, and non-communicable diseases (NCDs) within the EU, aligning them with the "Toward an EU Strategic Framework for the Prevention of NCDs" [38] and WHO's "Global Report on Diabetes." Out of these legislations, only 22 primarily targeted DM, with just five specifically for DM prevention. They spanned from 1968 to 2022, with 366 currently in effect. The European Commission authored 13 of these, comprising six binding and 17 non-binding laws. Notably, EuroVoc terms were present in 853 legislations, mainly associated with "social questions" and "public health."

A temporal analysis highlighted a growing number of legislations over time, shifting focus from "trade" to "social questions" and "epidemic" subdomains. These laws predominantly adopted a life-course approach, with a significant emphasis on food-related regulations.

Examining the impact of nutrition and physical activity policies on DM prevalence across EU member states revealed variations. Portugal had the highest predicted DM rates, while Lithuania had the lowest. National DM plans varied among countries, with certain policies universally implemented, but others less frequently adopted. Country-level regression indicated that demographic, socioeconomic, and lifestyle factors played a more substantial role in DM prevalence than policy availability.

A specific focus on Slovakia showed an escalation in DM prevalence from 6.1% to 9.8% between 2009 and 2019. Factors such as gender, age, education, employment, BMI, and physical activity influenced DM likelihood, while fruit and vegetable consumption showed no significant association.

Furthermore, an analysis of tweets across the EU regarding front-of-pack nutrition labeling highlighted extensive discussions primarily within national boundaries. The Nutri-Score label garnered the most attention, with varied opinions and sentiments expressed. Tweets covered aspects like nutritional labeling, food industry, health, regulations, political conflict, science, and education. Sentiment analysis suggested a generally negative tone, with tweets on the food industry receiving more positive feedback compared to those involving political disputes.

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Subject: PhD Publication List

Candidate: Nour Mahrouseh
Doctoral School: Doctoral School of Health Sciences

List of publications related to the dissertation

1. Septia Irawan, A., Shahin, B., Wangeshi Njuguna, D., Nellamkuzhi, N. J., Thiên, B. Q., **Mahrouseh, N.**, Varga, O.: Analysis of Content, Social Networks, and Sentiment of Front-of-Pack Nutrition Labeling in the European Union on Twitter.
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3. **Mahrouseh, N.**, Soares, A. C. A., Kovács, N., Njuguna, D. W., Varga, O.: Diabetes Mellitus and Associated Factors in Slovakia: results from the European Health Interview Survey 2009, 2014, and 2019.
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DOI: https://doi.org/10.3390/cancers12061520
IF: 6.639

Total IF of journals (all publications): 52,151
Total IF of journals (publications related to the dissertation): 26,463

The Candidate's publication data submitted to the iDEa Tudóstér have been validated by DEENK on the basis of the Journal Citation Report (Impact Factor) database.

14 June, 2023