Collective health, individual lives

Consensus on the need to address the wider influence of social determinants of health (SDOH) on a personal and structural level is growing. Specifically in type 2 diabetes, susceptibility to develop the disease as well as disease progression are related to structural (i.e. the social factors determining the distribution of SDOH between more and less advantaged groups) and intermediary determinants (i.e. social causes of health). Population Health Management (PHM) aims to bridge the current gaps between domains, including health promotion and prevention, social care, and welfare. The overall aim of this dissertation was to gain new insight into how a PHM approach can facilitate tailored care for type 2 diabetes populations based on whole-person characteristics. We specifically focused on the opportunities of routine data to perform the first three steps of the analytical framework for PHM (population identification, triple aim assessment, and risk stratification) under two overarching objectives:

- To identify the Dutch type 2 diabetes population in detail and comprehensively assess their health, healthcare expenditures, and equity of care when adopting new treatment methods using routine data (*Chapter 2 to 4*)
- To enhance understanding of the status quo of PHM for type 2 diabetes populations and contribute to new insights by stratifying the population based on cardiovascular risk (*Chapter 5 and 6*)

Chapter 1, the general introduction, provides insight into the concepts and challenges explored in this dissertation. Firstly, the influence of SDOH in general as well as for the type 2 diabetes population are explained by the Framework of the Commission on Social Determinants of Health (CSDH) of the World Health Organization (WHO). Secondly, the concept of PHM is explained through elaborations on the added value of PHM compared to integrated care, steps to establish PHM, the value of PHM for type 2 diabetes, and prerequisites of PHM. Lastly, the introduction zooms into one of the prerequisites of PHM: an integrated data warehouse, and why and what kind of data are essential in PHM.

Part I of the dissertation largely concentrated on identifying and gaining detailed insight into the Dutch type 2 diabetes population. To do so, we conducted retrospective observational cohort studies based on all-payer claims data (APCD) of the Dutch population. In **Chapter 2** we identified and delineated the Dutch type 2 diabetes population and the distribution of healthcare utilization and expenditures across the health system from 2016 to 2018. Findings confirm current challenges regarding the increased healthcare expenditures and use of this population. For instance, 9.4% of total national healthcare expenditures was reimbursed for individuals with type 2 diabetes (i.e. 6.5% of Dutch adults) in 2018. Moreover, virtually all

individuals with type 2 diabetes (97.0%) utilized specialized care compared to 43% of the entire insured population. Overall, most of the healthcare use and expenditures were not directly related to diabetes.

Chapter 3 specifically zooms into utilization and expenditures of medical specialist care and medication of the Dutch type 2 diabetes population using the APCD. Similar to overall healthcare use, findings showed diverse medical specialist care use. Different medical specialties, both related to diabetes and/or other health problems, were used by a considerable share of the population. For medication, a large share of expenditures (almost 75%) was related to medication other than drugs to treat diabetes. Consequently, care for type 2 diabetes is not necessarily expensive, but whole-person care for people with type 2 diabetes can be costly. Specifically, findings in *Chapter* 3 show that a large share of healthcare use is attributable to a small part of the type 2 diabetes population emphasizing the different health statuses throughout the population.

Thus, while care for type 2 diabetes is integrated, both *Chapter 2 and 3* confirm that individuals with type 2 diabetes heavily use other services throughout healthcare sectors and service types. This shows type 2 diabetes is often just one part of the puzzle and emergent problems, comorbidities, and/or the presence of diabetes-related complications additionally require care. Moreover, it is well known that the influence of SDOH on the susceptibility to develop and progression of type 2 diabetes mellitus is substantial. Consequently, treatment approaches that focus solely on type 2 diabetes seem insufficient. There is a need for a more tailored, whole-person approach that considers the entire individual, including co-morbidities, emergent problems, and SDOH.

To gain further insight into the Dutch type 2 diabetes population and the influence of SDOH, we explored equity of care in adoption of new treatment methods. By logistic regression models using both APCD and routine data, **Chapter 4** specifically analyses the presence of socioeconomic disparities in initiation of sodium-glucose cotransporter-2 inhibitors (SGLT-2is) and glucacon-like-peptide-1 receptor agonists (GLP-1RAs) among individuals with type 2 diabetes with very high cardiovascular risk. These medications significantly reduce risk and progression of cardiovascular disease (CVD) and chronic kidney damage within this group, but prior studies raised concerns regarding socioeconomic disparities in its prescriptions (i.e. found that individuals with lower socioeconomic backgrounds are less likely to be prescribed SGLT-2is and GLP-1RAs). However, within the Dutch type 2 diabetes population with very high cardiovascular risk, we did not observe profound socioeconomic differences in SGLT-2is and

GLP-1RAs initiation. These first observations were promising in light of socioeconomic equity in treatment, however, limited to the first year after guideline alterations. Thus, SGLT-2is and GLP-1RAs initiation and maintenance should be continually monitored. Overall, *Chapters 2 to 4*, show the value of both APCD and routine data in delineating healthcare use, expenditures, and the influence of certain SDOH. Such insight can inform health policy and practice and, thereby, support better decisions to promote long-term sustainability of healthcare systems.

Part II of the dissertation builds on the need for a more tailored, whole-person approach in diabetes care, and the potential of a PHM approach to do so. In **Chapter 5**, we utilized a scoping review to examine the extent to which and how PHM is used in the care for people with type 2 diabetes. Based on the analytical framework for PHM (described in detail in the introduction), we analyzed 18 PHM initiatives. In these initiatives, we observed considerable variation in whether and how the PHM steps are operationalized. Population identification, impact evaluation, and quality improvement processes were generally part of the PHM initiatives. However, detailed health assessment was scarce and, if executed, often limited to clinical measures. Similarly, risk stratification actions were scarce or explained in little detail. Moreover, cross-domain integration is essential but scarce in practice as the initiatives were mostly small-scale and situated within the primary care sector. Thus, operationalization of PHM in practice is limited compared to the PHM steps described in the analytical framework. This medical and targeted approach limits PHM's potential to provide whole-person, integrated care. Extended risk stratification and integration efforts in PHM for type 2 diabetes would contribute to whole-person care and further health improvements within the population.

CVD is the leading cause of death worldwide. Type 2 diabetes is associated with higher cardiovascular risk, influenced by various medical, lifestyle, psychosocial, demographic, and socioeconomic factors. In **Chapter 6**, we identified subgroups based on whole-person lifestyle and psychosocial cardiovascular risk factor patterns. For the identified subgroups, three-year CVD incidence and differences in demographic, socioeconomic, and medical characteristics were explored. Identification as well as exploration of the subgroups was done using a Latent Class Analysis (LCA), which is a data-driven, person-centered analysis technique that identifies subgroups with similar patterns of variables. The analysis revealed three latent classes with varying cardiovascular risk factor patterns, those with 'mobility related risk' (19.3%), 'psychosocial risk' (9.5%), and 'low risk' (71.2%). The 'mobility related risk' class showed high probability of limitations in mobility (0.90) and not meeting the exercise norm (0.89). The

'psychosocial risk' class had similar risks, with additional probabilities to be lonely (0.49) and have anxiety and depression (0.56). Those in the 'low risk' class had low probability to have lifestyle and psychosocial cardiovascular risk factors. In the three years after classification, fewer members of the 'low risk' class had cardiology care and/or stroke diagnosis compared to the 'psychosocial risk' and 'mobility related risk' classes. Women, non-western immigrants as well as those with lower education, financial difficulties, who are unfit for work and/or experienced prior heart failure were more likely to be a member of the 'mobility related risk' or 'psychosocial risk' classes. The relation between SDOH and increased cardiovascular risk underlines the importance of a whole person view in prevention. The cardiovascular risk groups as well as their characteristics may inform such tailored interventions developed to their specific needs.

To conclude, **Chapter 7** summarizes the main findings of all studies included in this thesis, followed by theoretical and methodological considerations. The theoretical considerations first focus on the PHM cycles that have been developed since publication of the analytical framework for PHM, similarities and differences between the PHM cycles, as well as the potential added value of the newer models. Secondly, current discussions in the field regarding the definition of both integrated care and PHM concepts are elaborated. Regarding current integrated diabetes care, we conclude that a broader, whole-person approach, would be beneficial. The third and last section of the theoretical considerations reflect on why the current medical view is, however, unsurprising but further emphasizes why expanding this view is essential. The methodological considerations shed light on the opportunities and challenges of APCD and routine data. The challenges in developing integrative data infrastructures as well as the potential opportunities of such infrastructures are similarly considered. Lastly, methodological considerations highlight prerequisites of data use in PHM, such as suitable data analysis techniques and multidisciplinary workforce to co-design and translate statistical to clinical findings, and vice versa. Following the considerations, several recommendations for policy, practice, and research are presented.