NMR based Metabolic Profiling for improving Nutritional Health*

Introduction

Dietary patterns ascribed to the West — high sodium, cholesterol, added sugars, saturated fats coupled with low fiber intake — underpin several public health concerns (O'Keefe et al., 2015). In particular, these consumption patterns are associated with an elevated risk of obesity and non-communicable diseases (NCDs); those that cannot be transmitted from person-to-person, such as heart disease, cancer, and diabetes. Of notable concern are low to middle-income countries where the growing consumption of energy-dense foods is creating new health challenges, such as higher rates of type 2 diabetes. Observation of higher-income countries offers little comfort, as no country has succeeded in reversing rates of obesity. If left unchecked, NCDs are predicted to rise, bringing additional burdens to healthcare systems and economies. Altogether, this highlights the need for improved approaches in tackling this issue.

Despite major advancements in the fields of health and nutrition, individual dietary choices remain poorly understood. This has prevented causal links from being drawn between diet and disease and the effective evaluation of public health policies. Obstruction to progress has, in part, been a product of inaccurate dietary data; a shortcoming of current data collection approaches. Questionnaires and self-reports have long been the mainstay of recording what and how much people consume. Yet, it is known that this data is erroneous as people fail to provide honest reports of their habits or misrepresent the scale of their consumption (Posma et al., 2020). Consequently, big data sets that inform public health policies are in need of revision, as well as the methods used to assess dietary patterns.

Nuclear Magnetic Resonance: a method for assessing dietary habits

Proton nuclear magnetic resonance (^{1}H-NMR) spectroscopy, a technology capable of measuring hundreds of metabolites from a single drop of urine, offers an effective method for assessing the consumption patterns of individuals. Devices, such as the Bruker Avance IVDr spectrometer i.e. Bruker Avance III HD 600MHz with the Bruker's bodyfluid NMR methods package B.I.Methods, can generate an individual's 'dietary fingerprint' within 10 minutes through the identification of diet-discriminatory metabolites. By matching this dietary fingerprint to a database of carefully controlled dietary intervention studies, holistic patterns can be deduced and interpreted for optimizing dietary decisions. Unlike similar sampling techniques, such as venepuncture, urine sampling represents a non-invasive, expedient, and painless method for gaining insights into the diet, thereby favouring subject compliance. The efficacy of this technology was tested in a clinical trial led by researchers at Imperial College London: Prof. Gary Frost, Prof. Elaine Holmes, and Dr. Isabel Garcia-Perez (Garcia-Perez et al., 2017). Using 19 participants, each assigned a diet that complied with WHO dietary guidelines by 25%, 50%, 75%, or 100%, the team ensured complete adherence to the diets through active surveillance. Metabolic profiles were generated through urine samples taken before and after each diet, and the NMRmetabolic profiles were then analyzed through principal component analysis (PCA).

Distinct differences were observed, distinguishing subjects following a healthy diet from those following an unhealthy one. Their model was also able to predict the metabolic profiles of subjects following intermediate diets, as well as tracking the metabolic changes that arise as subjects switch between diets. This proof-of-principle study demonstrates the accuracy of their model in assessing the nutritive qualities of diets and in tracking day-to-day dietary changes.

Does ^{1}H-NMR work in a free-living population?

The ecological validity of the model was evaluated by assessing a free-living population, which were considered healthy based on a dietician-assigned DASH (Dietary Approaches to Stop Hypertension) score. Analysis revealed that DASH scores reflected metabolic profiles in most cases, however, disparities were found in several subjects. Notably, one subject reported substantial consumption of oranges — with citrus fruit consumption producing a characteristic proline betaine biomarker in urine — the peak of which was not represented on the NMR spectra.

This suggests an instance of misreporting or over-reporting dietary habits and underscores the superior validity of empirical testing for deducing dietary habits. To confirm the model's ability to track dietary habits, the same team conducted a second clinical trial using 28 participants over 6 months. Akin to the first trial, the team assessed the participant's adherence to diets conforming to WHO guidelines by assessing metabolic profiles. Similarly, some individuals failed to adhere to the prescribed diets, with many committing at first and then abandoning the diet.

Differing degrees of adherence were observed even between related individuals sharing the same household. Further support was lent to these findings in a study assessing a population of obese individuals pre-and post-bariatric diet. DASH scores assigned to these subjects failed to consistently reflect NMR profiling, with fewer than 50% of subjects displaying adherence to healthy dietary habits.

Personalizing nutrition

Though at an early stage, ^{1}H-NMR based metabolic profiling has remarkable potential in shaping the future of personalized nutrition. Strikingly, its core postulation challenges a long-held assertion that one diet can universally optimize health. By demonstrating individual differences in metabolism, the research team (as mentioned above) exposed a flaw in the logic of such diets (Garcia-Perez et al., 2020). Given the same types and quantities of food, subjects excreted varying amounts of a biomarker. Among other factors, differences can be attributed to the unique consortium of gut microbes each individual possesses; each with their own metabolic potential (Holmes et al., 2008). Using this data, the team was also able to quantify the metabolites that differed between healthy and unhealthy diets and produce a metabolic reaction map network. In doing so, they could contextualize the role of each metabolite across an expansive network of metabolic processes and identify how a particular diet may stimulate beneficial metabolic activity. Based on this model, a tailored diet could be generated.

Conclusion

Under standardized conditions, Bruker's NMR based metabolic profiling , in combination with robust modeling, can be used to capture individual differences in metabolism and identify dietary patterns associated with lower or higher non-communicable disease risk, making the once insurmountable task of tailoring diets for individuals en masse a reality. Moreover, through ongoing empirical analysis and modelling, it can redress erroneous qualitative approaches currently in use, and so help combat growing public health issues associated with certain dietary patterns.

***Research Use Only. Not for Use in Clinical Diagnostic Procedures**

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