University of Leicester

The Leicester Lifestyle and Health Research Group (LLHRG) PhD studentship

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**Section 2 – *Project Information***

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| **Project Title** | **Determining the optimal timing of exercise and food intake to enhance health outcomes.** |
| **Project Summary** | |
| **Aim:**  To evaluate how the timing of exercise interacts with nutrient intake to influence health outcomes in individuals with and without type 2 diabetes. This research will seek to determine if there is an optimal timing for these behaviours to maximise metabolic health benefits, and whether this can be personalised based on chronotype.  **Background:**  Diet and exercise are cornerstone treatments for the management of type 2 diabetes (1) but are often prescribed in general terms. However, there is mounting evidence that aligning nutrition and exercise with circadian rhythm can modify the effectiveness of treatment (2).  An array of metabolic processes and endocrine factors exhibit 24-hour circadian rhythm, centrally regulated by the light/dark cycle. Exercise and diet synchronise circadian rhythm in peripheral tissues, suggesting the timing of eating and exercise behaviours have the potential to interact with circadian physiology and affect outcomes. For example, insulin sensitivity lower in the evening compared to the morning (2), and restricting intake in the evening has a proportionally greater impact on reducing energy intake and modulating appetite (3).  Similarly, the time of day that exercise is performed also appears to influence outcomes. Morning exercise is suggested to aid weight loss and evening exercise may enhance glycaemic control (4), but there is considerable variability in how individuals respond to exercise interventions. This variability could partly be due to how individuals time nutrient intake around exercise, as well as interactions between individual circadian rhythm, influenced by chronotype (5).  People living with type 2 diabetes demonstrate signs of circadian rhythm disruption (6), indicating alignment of exercise and nutrition with circadian rhythm could be particularly beneficial. Disentangling these interactions will facilitate personalised guidance on when (and what) to eat before and after exercise at different times of day to achieve optimal health outcomes.  **Methods:**  The programme of work will include epidemiological and experimental methodologies.  Work package 1: Epidemiology (Year 1)  This work package will include a series of analyses harnessing large, readily available local (7,8) and national datasets (e.g., UK Biobank). Within these, time-stamped exercise/physical activity and dietary data will be used to explore relationships between energy and macronutrient intake timing around exercise with diverse outcomes linked to cardiometabolic and physical health.  Work package 2: Randomised Control Trial (RCT) (Year 2-3)  This work package will comprise of an acute (within-participant) RCT rolling into a chronic (between participant) trial. The acute trial will examine behavioural and physiological responses to morning, afternoon and evening exercise in cohorts with and without diabetes. Participants will then be allocated to a morning or evening exercise condition for 4-weeks, stratified by chronotype. A metabolic assessment will take place pre and post intervention to collect biological samples to undertake a suite of experimental outcomes assessing muscle biology, insulin sensitivity, blood lipid profile, and appetite regulation. This will yield new mechanistic insights and compliment continuous glucose monitoring (CGM), physical activity (accelerometery), diet intake (food diaries, appetite surveys), and sleep, measured during the intervention.  **Outcomes and Impact:**  This multi-disciplinary project will generate multiple high-quality publications in the field of chrononutrition and data will be disseminated at impactful conferences. The findings will be valuable for shaping diet and exercise prescription, facilitating evidence-based programmes personalised to patient outcomes and preferences, which could enhance adherence and long-term success. | |
| **References** | |
| 1) Davies *et al.,* (2022) Management of Hyperglycemia in Type 2 Diabetes, 2022. A Consensus Report by the American Diabetes Association (ADA) and the European Association for the Study of Diabetes (EASD). *Diabetes Care*. 45(11):2753-2786. doi: 10.2337/dci22-0034..  2) Ruddick-Collins *et al.,* (2020) Mealtime: A circadian disruptor and determinant of energy balance*? J Neuroendocrinol*. 32(7):e12886. doi: 10.1111/jne.12886.  3) Ruddick-Collins *et al.,* (2022) Timing of daily calorie loading affects appetite and hunger responses without changes in energy metabolism in healthy subjects with obesity. *Cell Metab*. 34(10):1472-1485.e6. doi: 10.1016/j.cmet.2022.08.001.  4) Thomas *et al.,* (2025) Timing of resistance exercise and cardiometabolic outcomes in adults with prediabetes: a secondary analysis. *J App Physiol*. 138:2, 439-4495. doi.org/10.1152/japplphysiol.00507.2024.  5) Shen *et al.,* (2023) Effects of exercise on circadian rhythms in humans*. Front Pharmacol*. 14:1282357. doi: 10.3389/fphar.2023.1282357.  6) Mason *et al.,* (2020) Impact of circadian disruption on glucose metabolism: implications for type 2 diabetes. *Diabetologia* 63, 462–472. doi.org/10.1007/s00125-019-05059-6.  7) Brady *et al.,* (2019) Rationale and design of a cross-sectional study to investigate and describe the chronotype of patients with type 2 diabetes and the effect on glycaemic control: the CODEC study. *BMJ Open*. 9(11): e027773. doi: 10.1136/bmjopen-2018-027773.  8) Sargeant *et al.,* (2024) Impact of exercise training in combination with dapagliflozin on physical function in adults with type 2 diabetes mellitus: study protocol for the Dapagliflozin, Exercise Training and physicAl function (DETA) randomised controlled trial. *BMJ Open*. 14(11): e084482. doi: 10.1136/bmjopen-2024-084482. | |