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The screening and monitoring of type 2 diabetes by indirect calorimetry

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Abstract. An increasing amount of study is being dedicated to the identification of biomarkers associated with type 2 diabetes, with particular emphasis on the field of Metabonomics. To screen and prevent type 2 diabetes, indirect calorimetry measures real-time oxygen consumption (V_{02}) and carbon dioxide production (V_{C02}) and measures an individual's metabolic tendency which is the ratio of glucose and fat as energy substrate for a specific activity. A person with aberrant glucose metabolism after measurement may have type 2 diabetes. Adjusting food intake helps type 2 diabetics control blood glucose. Now, type 2 diabetes become personalized. In other words, type 2 diabetes needs to be analysed case by case. The population can be divided into different categories in terms of metabolic adjustment. After classification, indirect calorimetry can be used in clinical research whose purposes are to screen, prevent and treat type 2 diabetes. This paper uses literature reviews to summarize the genetic factors and environmental factors of type 2 diabetes, explain the necessity and limitations for screening, monitoring, preventing and curing type 2 diabetes, and the reasons for calorimetry can screen and monitor type 2 diabetes and how to calculate the percentage of energy substrates for a certain activity.

Keywords: indirect calorimetry, type 2 diabetes, respiratory quotient.

1. Introduction

In the world, there are 415 million diabetes patients, and about 193 million people have been not diagnosed so far. More than 90% of diabetes patients have type 2 diabetes, and the symptoms of type 2 diabetes are increased thirst and hunger, frequent urination, unexplained weight loss, feeling tired, and sores that do not heal. It also leads to cardiovascular diseases, such as high blood pressure, dyslipidemia, and heart failure. The prevalence of type 2 diabetes is increasing rapidly due to the global growth in obesity, sedentary lifestyles, and the ageing population. The management of type 2 diabetes imposes significant social and economic burdens on individuals, with an estimated cost of around US$825 billion. This has profound implications for the worldwide healthcare system. And type 2 diabetes has regional differences and individual differences. Above all, screening, preventing, and treating type 2 diabetes are important for people and patients. Now, some methods of screening for type 2 diabetes are lack evidence to explain their results or hard to be used on a large scale in clinical practice because of the overwhelming costs. In randomized clinical trials, the Whitehall study, and the Bedford study, it does not ensure that type 2 diabetes could be prevented or delayed. However, indirect calorimetry may be a good and efficient way to screen and prevent type 2 diabetes because it can find the metabolic tendency of different individuals. For treatment, scientists give existing and future therapeutic drugs to lower internal glucose in terms of organ or organ system. But a certain therapeutic drug takes a long time from trials to clinical use. Adjusting food intake with appropriate exercise for individuals is a healthy and safe way to control blood glucose. This paper uses literature reviews to summarize the genetic factors and environmental factors of type 2 diabetes, explain the necessity and limitations for screening, monitoring, preventing and curing type 2 diabetes, and the reasons for indirect calorimetry can screen and monitor type 2 diabetes and how to calculate the percentage of energy substrates for a certain activity. This paper gives a good way to screen and monitor type 2 diabetes and a healthy way to prevent and cure this disease to a certain degree.

2. The causes and influence factors of type 2 diabetes

Type 2 diabetes is a chronic metabolic disease, and someone suffers from it because of relative insulin deficiency caused by pancreatic β-cell dysfunction and insulin resistance in target organs [1]. Common symptoms include Polydipsia, frequent urination, unexplained weight loss, and may include overeating, tiredness, or soreness [2]. Long-term complications of high blood sugar include heart disease, stroke, diabetic retinopathy, which can lead to blindness, kidney failure, and even poor blood flow to limbs requiring amputation, and rarely diabetic ketoacidosis.

Type 2 diabetes is influenced by gene factors and environmental factors. For gene, if a parent has type 2 diabetes, the progeny individual has a 40% chance to develop type 2 diabetes and if the mother has type 2 diabetes, the chance is higher than the father. However, if both parents have type 2 diabetes, the chance will rise to 70% [3]. The possibility of reaching the same level of type 2 diabetes for monozygotic twins is about 70%, but the possibility of reaching the same level of type 2 diabetes for dizygotic twins is simply 20% - 30% [3]. The large prevalence differences between different ethnic groups may also depend on genetic factors [3]. Certain genes associated with type 2 diabetes, such Adenylate cyclase 5, Melatonin receptor 1B, and glucose or insulin concentration-related genes such as Melanocortin 4 receptor and Neuronal growth regulator 1, may undergo mutations, hence contributing to the development of type 2 diabetes [3]. Based on the known gene, the candidate genes that have a high possibility to affect the phenotypic character of type 2 diabetes can be studied to screen for type 2 diabetes in individuals [3]. But the identification of candidate genes may be complicated.

Three main environmental factors lead to the development of type 2 diabetes: Public facilities, community, air condition and transport. In a community, If there are some recreational places, such as green spaces, walkable destinations, and sidewalks, people will have more chances to exercise. And if there are many supermarkets, people are more likely to develop a good diet [4]. On the contrary, in situations where there is a limited availability of recreational areas and supermarkets, individuals may have less opportunities for physical activity while facing an increased likelihood of opting for fast food and unhealthy food options. The influence of various surroundings on calorie intake and expenditure can potentially alter the likelihood of acquiring type 2 diabetes.

The unsafe communities may reduce sports activities and a dense neighbourhood may increase stress, and let people have unhealthy behaviours. Heavy stress can decrease the immunity of the human body and human systems which increases the possibility to develop and get type 2 diabetes [4]. Stress also contributes to the development of unhealthy habits, such as eating and drinking too much, smoking and insomnia. The metabolism may be impacted because of unhealthy behaviour and poor mental health, increasing the risk of type 2 diabetes.

Air pollution has the potential to alter endothelial function, resulting in the development of insulin resistance and impeding individuals' ability to engage in physical exercise [4]. If individuals increasingly depend on automobile transportation for their mobility, it is likely that their engagement in physical exercise will also diminish. Certain road traffic noise has the potential to adversely affect blood lipid levels, as well as blood pressure and the susceptibility to type 2 diabetes [4]. In summary, it can be concluded that a range of environmental factors have the potential to impact the susceptibility to and occurrence of type 2 diabetes. Additionally, genetic mutations and some candidate genes have been identified as contributing factors to the development of type 2 diabetes.

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3. The necessity and limitations for screening, monitoring type 2 diabetes

One-third or nearly half of type 2 diabetes patients still are not diagnosed because type 2 diabetes may not have or few symptoms and type 2 diabetes is difficult to diagnose because of high costs, long pre-clinical time and fewer nursing chances [5]. In addition, Overdiagnosis and subsequent overtreatment may contribute to some adverse consequences [5]. With the increase in high blood sugar for type 2 diabetes patients, some complications may occur and develop such as high blood pressure, cardiopathy and diabetic foot and those complications influence human longevity. Thus, screening and monitoring for type 2 diabetes are important for common populations and high-risk populations. There is not enough evidence to prove that screening and monitoring have direct benefits for common populations, but screening and monitoring may increase the quality-adjusted life years for high-risk groups whose risk factors are age and hypertension [5]. Nevertheless, the process of screening for type 2 diabetes has been found to be associated with increased levels of short-term anxiety and concerns. However, it is important to note that the overall impact of this phenomenon is quite minor, and there is a lack of conclusive evidence suggesting any detrimental long-term impacts on psychological well-being [5]. In summary, the implementation of screening and monitoring protocols for type 2 diabetes necessitates careful consideration of both financial implications and the specific demographic being targeted.

The prevention and curing of type 2 diabetes can limit the occurrence and development of complications so that the lifetime of patients will be prolonged. It is a preventable disease by changing lifestyle, for example, healthy food intake and a moderate amount of physical activity [6]. And type 2 diabetes can be prevented by taking metformin and thiazolidinediones to a small extent but the modification of an intensive lifestyle, such as physical activity and a low-fat diet to lower weight, reducing 58% relative risk reduction, is more effective than drugs therapy [1]. Drugs therapy is considered to be effective, but the risk of hypoglycaemia increases with the use of insulin, meglitinides, and sulfonylureas is relatively high and other glucose-lowering therapies, such as metformin, thiazolidinediones, DPP-IV inhibitors, GLP-1 receptor agonists, and SGLT-2 inhibitors will also increase the risk of hypoglycaemias when they are combined with those agents [1]. Currently, there is a growing trend towards personalised treatment for type 2 diabetes, and it is worth noting that many medication therapies employed in its management are not without their drawbacks [7]. Therefore, modifying dietary consumption may serve as a viable approach for the prevention and management of type 2 diabetes. Nevertheless, for those with severe type 2 diabetes, combining dietary modifications with pharmacological interventions may provide more favourable outcomes.

4. The advantages for indirect calorimetry to screen and monitor type 2 diabetes

Indirect calorimetry measures real-time oxygen consumption (VO2) and carbon dioxide production (VCO2) to calculate resting metabolic expenditure (RMR), thermic effect of food (TEF), and activity thermogenesis and those are the components of total daily energy expenditure (TDEE) [2]. In other words, indirect calorimetry can estimate the value of TDEE and its various components.

Patients with type 2 diabetes are poor at metabolizing glucose. The oral glucose tolerance test is considered one of the main approaches for screening type 2 diabetes. This test is often regarded as the most effective but also the most laborious and time-intensive diagnostic tool. It requires a two-hour duration to complete and necessitates prior preparation for overnight fasting [5]. However, Indirect calorimetry can find the abnormity of the metabolic tendency for a patient with type 2 diabetes by calculating the value of the respiratory quotient (RQ). In other words, indirect calorimetry can measure the energy supply ratio of glucose and fats. After an individual was tested by indirect calorimetry and calculate the respiratory quotient under a certain physical activity, the abnormity of glucose utilization will be discovered. If the value of RQ is smaller than 0.7 or greater than 1.0, the human body is prone to use fats as an energy substrate rather than glucose. Then the individual may have a problem with glucose metabolism and may be a type 2 diabetes patient.

Indirect calorimetry can be applied in early monitoring, adjuvant diabetes treatment monitoring, and prognostic monitoring. In other words, indirect calorimetry can be used as a reference for adjusting diet to cure or control the development of type 2 diabetes. For example, a patient with diabetes has very bad eating habits, and this leads him to have this disease. At this time, adjusting his types of intake food can intervene in the development of type 2 diabetes and the rationality of adjusting his diet can be measured by indirect calorimetry. If the RQ value becomes to be normal for him, then the adjusting is considered to be effective. If the RQ value still is abnormal, then this means that the adjusting is not correct and needs to be readjusted. In conclusion, adjusting the structure of diet to cure this disease can be applied or adjusted in terms of the energy supply ratio of glucose and fats.

5. The calculation for the percentage of different energy substrates by indirect calorimetry

The respiratory quotient (RQ) is determined by indirect calorimetry to get substrate utilization [8]. The respiratory quotient equates to the volume of produced carbon dioxide divided by the volume of consumed oxygen. When carbohydrates serve as the predominant source of fuel, the quantity of carbon dioxide generated is equivalent to the quantity of oxygen used, resulting in a respiratory quotient (RQ) of 1.0. Conversely, when fats are the principal fuel source, the RQ for fats is 0.7 [9]. When the RQ value falls between the range of 0.7 to 1.0, it signifies a combination of carbohydrate and fat utilisation during a certain exercise. The precise value of RQ might fluctuate based on the proportion of carbs to lipids being oxidised.

The main energy substrate is carbs and fats, protein is not suitable as an energy substrate. So when calculating respiratory quotient, protein can be negligible. Here are procedures to calculate the percentage of energy derived from carbohydrates (CHO%) and fats (FAT%): First, the difference between the measured RQ and the RQ value for pure fat oxidation (0.7) is calculated: RQ difference = measured RQ - RQ for fat (0.7). Then, the difference between the RQ value for pure carbohydrate oxidation (1.0) and the RQ value for fat (0.7) is calculated: RQ difference between carb and fat = RQ for carb (1.0) - RQ for fat (0.7). Finally, the percentage of energy from carbohydrates (CHO%) is calculated: CHO% = (RQ difference)/(RQ difference between carb and fat) × 100 and the percentage of energy from fats (FAT%) is calculated: FAT% = 100 - CHO%.

6. Conclusion

Type 2 diabetes is classified as a metabolic disorder characterised by elevated blood glucose levels, a relative insufficiency of insulin, and insulin resistance. The development of type 2 diabetes is impacted by both hereditary and environmental factors. The emergence of type 2 diabetes is accompanied by a progressive onset of problems, making early detection challenging, while over diagnosis may be detrimental to certain demographic groups. In contrast to direct calorimetry, indirect calorimetry has the capability to assess the proportion of different constituents contributing to the overall daily energy expenditure, commonly referred to as total daily energy expenditure (TDEE). In contrast to the intricate oral glucose test, indirect calorimetry offers a method for assessing type 2 diabetes patients by quantifying the energy utilisation ratio and respiratory quotient (QR). Both pharmacological interventions and dietary modifications have been shown to be effective in the prevention and treatment of type 2 diabetes. However, it is important to note that drug therapy may have certain drawbacks. The composition and quantity of dietary intake can be modified based on the ratio of glucose and fat utilisation. Indirect calorimetry exhibits certain drawbacks, such as its significantly elevated cost and protracted duration of testing.

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