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Research Progress on the Mediating Role of Body Fat Percentage and Precision Prevention Strategies in Community Dietary Interventions for Geriatric Diabetes

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Abstract. As the population ages, the challenge of preventing and managing diabetes among older adults has become increasingly severe. Traditional screening based on Body Mass Index (BMI) often fails to identify high-risk individuals with "hidden obesity." Through a literature review, this paper systematically explores the intrinsic connections and underlying mechanisms linking community-based dietary interventions, the optimization of body fat percentage, and precision prevention strategies for geriatric diabetes. Research indicates that reducing body fat percentage—particularly visceral fat—while maintaining skeletal muscle mass plays a pivotal mediating role in how dietary interventions lower the risk of diabetes in older adults. This study suggests that future efforts should focus on shifting metabolic management in the older population from the traditional "broad weight loss" approach to "refined regulation of body composition," and establishing a grassroots precision nutrition intervention mechanism oriented towards regulating body fat and protecting muscle.

Keywords: Geriatric diabetes, Body fat percentage, Community dietary interventions, Mediating effect

1. Introduction

In the 21st century, population aging has become one of the most severe public health challenges faced by the world [1]. According to the latest epidemiological survey data released by the International Diabetes Federation [2], the older population aged 65 and above has become the core subject with the highest incidence of diabetes and the heaviest disease burden around the world. However, in China, the epidemiological situation is particularly severe. The epidemic of diabetes in the older population in China shows the remarkable characteristics of "large base, accelerated growth, high incidence of complications, and low control rate" [3]. Therefore, exploring an effective early prevention and control, screening and clinical intervention path has become a major issue that needs to be solved urgently in the current geriatric medicine and gerontology circles.

In long-standing public health practice, clinical diagnosis, and population screening. Body Mass Index (BMI) has consistently served as a core quantitative indicator for assessing the degree of obesity, defining overweight status, and screening for metabolic diseases. However, the data

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provided by traditional BMI cannot offer a detailed analysis of the specific distribution and proportions of adipose tissue, muscle tissue, body water, and bone density [4]. With advancing age, older adults commonly experience a loss of skeletal muscle and an accumulation of fat; consequently, significant changes in body composition occur even if BMI remains stable [5]. This phenomenon makes BMI prone to missing cases of hidden obesity.

There are two types of hidden obesity. In normal-weight obesity," BMI falls entirely within the normal range, yet the accumulation of visceral fat and ectopic fat deposits—hidden within the body—is frequently overlooked by clinicians and community public health workers [6]. The second type, sarcopenic obesity, is characterized by a progressive decline in skeletal muscle mass and strength, accompanied by adipose tissue infiltration [7]. Even with a normal BMI, metabolic risk remains elevated. Relying solely on BMI as the screening criterion for older adult patients with diabetes would inevitably result in many high-risk individuals going undiagnosed for both hidden obesity phenotypes.

In view of the inherent shortcomings of BMI screening, prevention and control strategies for diabetes in the older population must shift to focus on changes in body composition. Among many lifestyle intervention methods, community dietary intervention is recognized as the core non-drug intervention path because of its high feasibility, low economic cost, non-invasiveness and broad mass base [8]. Based on this, this article conducts a systematic qualitative theoretical review of the cutting-edge literature in recent years based on the logic of biology and public health. The aim is to clarify that the reduction of body fat percentage, especially visceral fat, and the maintenance of skeletal muscle mass play a core "mediating effect" in dietary intervention to reduce the risk of diabetes in the older population [9]. By clarifying the deep molecular metabolic mechanisms between dietary nutrition, body fat distribution regulation and insulin signaling pathway repair, we try to break through the extensive misunderstanding of "broad weight loss" in traditional public health management. Provide solid theoretical support and a scientific basis for public health intervention and individualized clinical nutrition strategies.

2. From BMI to body fat percentage: accurate diabetes risk assessment in the older population

2.1. The biological necessity of shifting from body mass index to body fat percentage

To achieve precise prevention and control of diabetes in the older population from the root cause, the most important thing is to first deeply understand the biological inevitability of the shift from body mass index to body fat percentage [10]. With aging, the internal tissue structure of the human body undergoes systematic remodeling, which is often difficult to capture macroscopically through body mass index. From the perspective of aging biology, the phenotypic characteristics of the older population will manifest as a special rearrangement of body composition. The core of this change lies in the progressive loss of skeletal muscle mass and the remodeling and redistribution of adipose tissue [5]. This phenomenon is clinically referred to as degenerative changes in body composition. This change is the fundamental anatomical basis for the deterioration of metabolic function in the older population and is also a blind spot that traditional body mass index cannot cover [4].

2.2. Pathophysiological mechanisms of the latent obesity phenotype

A deep analysis of the pathological mechanisms reveals that fat accumulation during aging is not merely a simple increase in total body fat; rather, it exhibits distinct characteristics of centripetal obesity [6]. Specifically, as age advances, peripheral subcutaneous fat stores gradually diminish,

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while fat increasingly deposits within the abdominal cavity—particularly in the omentum and around visceral organs—leading to significant visceral fat accumulation. Concurrently, as the buffering capacity of subcutaneous fat becomes saturated, excess lipids spill over beyond the boundaries of conventional adipose tissue and infiltrate non-adipose tissues—a phenomenon medically termed "ectopic fat deposition." These ectopic fats primarily accumulate within the liver, skeletal muscle, and pancreas, exerting direct local toxic effects on these key metabolic organs [7]. From a biological perspective, visceral and ectopic fats exhibit higher rates of lipolysis compared to ordinary subcutaneous fat. This anatomical alteration drives a continuous influx of excess free fatty acids into the portal vein system, directly triggering systemic lipotoxicity. Such persistent lipotoxic stress serves as a critical driver that impairs pancreatic beta cell function and ultimately precipitates the development of type 2 diabetes.

Underlying this process of fat remodeling are the pathological changes of skeletal muscle mass loss and functional decline [11]. As the body's largest organ for glucose uptake and metabolism, skeletal muscle plays a pivotal role in maintaining peripheral insulin sensitivity. When older adults experience skeletal muscle atrophy, their capacity for glucose disposal inevitably undergoes a sharp decline. Even more critically, the infiltration of fat into the spaces between tightly packed muscle fibers leads to marked fatty degeneration of the muscle; this not only further impairs contractile strength but also directly inhibits the translocation and activation of glucose transporter type 4 (GLUT4) on muscle cell membranes through the local release of pro-inflammatory cytokines [12]. This interplay between fat accumulation and muscle wasting—acting as both cause and effect—creates a distinct pathophysiological phenotype in older adults that directly accelerates the onset of insulin resistance.

2.3. Epidemiological evidence on the impact of body composition heterogeneity on diabetes risk

Macro-nutrition epidemiology studies have fully demonstrated this series of pathophysiological degenerations at the micro level. Numerous domestic and international clinical and cohort studies have shown that there is a large hidden obesity population among the older population. Although they have a completely normal body mass index in traditional screening, their high body fat percentage and low muscle mass push them to the high-risk edge of diabetes [13]. Through cross-sectional and longitudinal tracking analysis of a large-scale microdatabase, it was found that the insulin resistance index of the normal-weight obese group was significantly higher than that of older people of the same age with similar body shape but normal body fat percentage [13]. Even older adults whose body mass index fully meets the international health standards still have a high proportion of visceral fat, which often makes their relative risk of developing type 2 diabetes and metabolic syndrome several times higher.

The epidemiological evidence for sarcopenic obesity is even more alarming. The combined exposure of muscle loss and high body fat has a strong synergistic harmful effect on impaired glucose metabolism in the older population [7]. Based on epidemiology, the subjects were refined and stratified according to body composition, and it was found that the increase in the incidence of diabetes caused by simple low muscle mass or simple overweight was far less than the multiplicative effect produced by the combination of the two. This latent obesity phenotype has been underdiagnosed and out of control in community public health practice for a long time because it is masked by traditional body mass index screening.

Therefore, from an epidemiological empirical perspective, accurately shifting the direction of risk assessment of diabetes in the older population from a single body mass index to a multi-dimensional

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body fat percentage is not only an inevitable choice for the development of medical science, but also a core breakthrough to improve the effectiveness of early prevention and control of diabetes in the older population.

3. The regulatory effect of community dietary intervention on body composition in the community dwelling older adults

Nutritional epidemiological studies have shown that healthy diet index scores are broadly and significantly positively correlated with lower body fat percentage and better muscle mass in older adults [14]. This correlation suggests that a high-quality overall dietary structure can provide robust metabolic protection for older adults at a macro level, preventing the blind accumulation of fat.

Among many specific dietary patterns, the Mediterranean diet has the strongest evidence to support its effect on body fat reduction, especially visceral fat [15]. From a biological perspective, the plant polyphenols and unsaturated fatty acids rich in the Mediterranean diet have powerful anti-inflammatory and antioxidant properties. They can accelerate the oxidative decomposition of fatty acids in the abdominal cavity by activating core transcription factors such as peroxisome proliferator-activated receptors, allowing older population subjects to accurately reduce visceral fat accumulation without experiencing large fluctuations in total body weight [15]. At the same time, a strategy that is equally important as fat reduction and even more critical in old age is the effective protection of skeletal muscle mass, and high-protein dietary patterns play an irreplaceable role here [16]. Moderately increasing the proportion of high-quality protein in daily meals, especially increasing the intake of high-quality dairy products, fish and lean meats rich in leucine, can provide sufficient raw material support for muscle tissue [17], which will directly activate the mammalian target of rapamycin complex signaling pathway and promote the repair and regeneration of skeletal muscle fibers. This maintains the ability of peripheral tissues to handle glucose while combating age-related muscle atrophy [16].

Traditional health interventions are often superficial, and it is difficult to break the deep-rooted eating habits of the older population by simply distributing leaflets or verbally persuading them. However, the modern public health community tends to build a comprehensive and multi-layered centralized intervention ecosystem. Promoting healthy diets through community older population canteens, organizing food preparation workshops, and using family collaborative networks for behavioral supervision can help promote a lasting shift from cognition to behavior in the older population [18]. This centralized intervention model, which is based on the community and extended to the family, has been confirmed in recent lifestyle follow-up studies to achieve significant improvements in body composition among the older population. Specifically, the intake of high-sugar and high-fat processed foods has been greatly reduced, while the intake of dietary fiber and high-quality protein has increased significantly [19]. Most notably, when body composition was measured using sophisticated instruments, the body mass index of these older population people did not decline drastically in numerical terms. However, their overall body fat percentage showed a clear downward trend, especially since the waist circumference and visceral fat area were significantly reduced, while the skeletal muscle mass of the thighs was effectively maintained. This article argues that this powerfully demonstrates in practice that standardized community dietary interventions can bypass the misconception of broad weight loss and accurately achieve the public health goal of improving the body composition of the older population.

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4. The mediating role of body fat percentage in dietary interventions to reduce the risk of diabetes

According to modern research in metabolic biology, a shift in dietary patterns primarily triggers a systemic reduction in body fat percentage, characterized specifically by a decrease in intra-abdominal visceral fat. This beneficial alteration in body composition serves as a crucial prerequisite for restoring insulin signaling pathways [20]. Once dietary intervention reshapes energy balance, levels of free fatty acids in the peripheral circulation plummet, directly inhibiting the ectopic deposition of lipid metabolic intermediates—such as ceramides and diacylglycerols—within the liver and skeletal muscle [21, 22]. This improvement in the biochemical environment establishes, at the molecular level, the causal link by which dietary modification alleviates insulin resistance through the regulation of body fat percentage.

In addition to the lipotoxic pathway, the optimization of body fat rate also shows a strong mediating effect among inflammatory factors and adipokines by improving the body's immune and endocrine microenvironment. Under pathological conditions, excessively enlarged visceral adipocytes in the body will attract a large number of macrophages to infiltrate due to local hypoxia. This reaction will continue to secrete pro-inflammatory cytokines such as tumor necrosis factor and interleukin, thereby triggering chronic low-grade inflammation throughout the body and destroying the function of pancreatic beta cells [23, 24].

The decrease in body fat rate caused by dietary intervention can significantly reduce the size of adipocytes. This reverses the infiltration trend of immune cells from the source and leads to a significant decrease in the levels of pro-inflammatory factors. At the same time, the reduction in body fat rate will also prompt healthy fat cells to resume secreting protective factors. The increase in adiponectin levels can enhance peripheral insulin sensitivity by activating the adenylate-activated protein kinase pathway and effectively protect pancreatic beta cells from chronic metabolic stress [25, 26].

While adipose tissue undergoes profound remodeling, dietary intervention maintains and promotes skeletal muscle mass and forms a strong synergistic effect on muscle gain and fat loss with a decrease in body fat rate. When community dietary interventions appropriately incorporate high-quality protein and anti-inflammatory nutrients, skeletal muscle mass is critically protected in an environment of anabolic resistance. This ensures that the body has a large enough peripheral glucose scavenger [16]. From the perspective of molecular mechanisms, maintaining good total skeletal muscle mass can significantly increase the gene expression and protein abundance of glucose transporters within muscle cells [27]. On the premise that lipotoxicity and inflammation are alleviated, the activated glucose transporter can be smoothly translocated to the muscle cell membrane surface, greatly accelerating the clearance and uptake rate of glucose in the peripheral circulation [28]. This metabolic benefit brought by skeletal muscle remodeling and the recovery of insulin sensitivity caused by visceral fat reduction forms a perfect synergistic closed loop, and the final joint output is a substantial reduction in the risk of diabetes in the older population [29].

5. Conclusion

This article believes that optimizing body fat rate through dietary intervention is the core path to achieving precise prevention and control of diabetes in the older population. However, when this strategy is put into practice in grassroots communities, the primary difficulty lies in the trade-off between the promotion cost and accuracy of high-precision assessment tools. The standard method for measuring body composition, dual-energy X-ray absorptiometry, is difficult to popularize at the

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grassroots level due to its high cost. However, the portable and low-cost bioelectrical impedance analysis method is susceptible to interference from the rearrangement of body water and tissue degeneration in the older population, thus reducing the stability of primary measurements.

In addition to limitations at the technical level of the device, this article, as a qualitative theoretical review, also has multiple inherent limitations in research methods and evidence integration that cannot be ignored. In terms of data-driven and quantitative testing, the core conclusions of this article are based on the secondary integration of previous independent studies, and the CHARLS or NHANES large micro-databases cannot be used to conduct first-hand quantitative testing of large-sample multi-factor mediation effects. As a result, the mediation path proposed in this article remains at the theoretical level and lacks direct empirical support for data modeling. In terms of the validity of the evidence synthesis, there is a large span of dietary review methods or meal frequency questionnaires used in each of the included independent studies, and there is a lack of unified calibration standards for body composition measurement methods. Regarding the strength of causal inference, the literature relied on in this article mostly tends to be cross-sectional in design or short-term intervention trials. The lack of long-term prospective public health cohort tracking directly weakens the strength of causal inference, making it difficult to completely exclude the interference of reverse causation.

In response to the above-mentioned dual challenges caused by the limitations of this article's methodology and the technical bottlenecks of the industry, this article believes that future academic research and public health policy urgently need to undergo in-depth reshaping. Subsequent large-scale aging public health cohort studies should use data to provide more robust causal evidence for the multi-path mediating effect between dietary behavior and abnormal glucose metabolism. At the same time, the national clinical nutrition management guidelines should comprehensively promote the transition of older population metabolic management from traditional broad weight loss to refined body composition adjustment. By establishing a precise nutrition intervention mechanism in grassroots communities that is oriented towards regulating body fat and protecting muscles, we can truly overcome the source prevention and control problems of diabetes in the older population and help achieve healthy aging.

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