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The Impact of Low-Energy Balanced Diet Combined with Aerobic Exercise Intervention on Pediatric Obesity with Lipid Metabolism: A Study

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Abstract: This study investigated the effects of a low-energy balanced diet combined with aerobic exercise intervention on pediatric obesity with lipid metabolism abnormalities. The study included obese children aged 6 to 12 years, who were randomly assigned into the intervention group and the control group. The intervention group received a 12-week personalized low-energy balanced diet and aerobic exercise, while the control group maintained their regular lifestyle. The results demonstrated significant improvements in weight, waist circumference, and blood lipid indicators in the intervention group, indicating the effectiveness of this intervention strategy for pediatric obesity. This study provides scientific evidence for interventions targeting childhood obesity.

1. Introduction

Pediatric obesity with lipid metabolism abnormalities has become a pressing health issue in today's society. With changes in modern lifestyle and dietary patterns, an increasing number of children are trapped in high-calorie, high-fat, and high-sugar diets, while lacking sufficient physical activity [1]. This imbalanced lifestyle has led to a widespread rise in childhood obesity, which is closely associated with disturbances in lipid metabolism, such as elevated blood lipid levels and dysfunctional adipose tissue [2]. These issues not only increase the risk of children developing chronic diseases such as cardiovascular diseases and type 2 diabetes but also have adverse effects on their psychological well-being. Therefore, conducting a study on the impact of a low-energy balanced diet combined with aerobic exercise intervention on pediatric obesity with lipid metabolism abnormalities is of paramount importance[3]. The aim is to identify effective intervention strategies, improve the overall health of children, and contribute to public health efforts in society. The combination of a low-energy balanced diet and aerobic exercise holds significant potential in obesity intervention [4]. A low-energy balanced diet restricts calorie intake, promotes fat reduction, and helps control the progression of obesity. Moreover, a well-balanced diet can improve lipid metabolism abnormalities, lower blood lipid levels, and reduce the risk of chronic diseases like cardiovascular diseases [5].On the other hand, aerobic exercise effectively increases energy expenditure, promotes fat metabolism, and reduces body fat content. Additionally, aerobic

exercise positively influences insulin sensitivity and reduces insulin resistance, which has a favorable effect on lipid metabolism abnormalities[6].When a low-energy balanced diet and aerobic exercise are combined, they are expected to synergistically enhance the intervention's effectiveness, providing a comprehensive solution for addressing pediatric obesity with lipid metabolism abnormalities. The main objective of this study is to investigate the impact of a low-energy balanced diet combined with aerobic exercise intervention on pediatric obesity with lipid metabolism abnormalities. The specific goals are to evaluate whether this combined intervention strategy can effectively reduce childhood obesity, improve lipid metabolism abnormalities [7], and positively influence the risk of chronic diseases such as cardiovascular diseases and type 2 diabetes [8]. Through in-depth research, we aim to provide critical evidence for the development of scientifically sound strategies for intervening in pediatric obesity [9]. Additionally, this research seeks to contribute to improving children's overall health, reducing the burden of chronic diseases, and advancing public health. The significance of this study lies in its provision of empirical support for addressing the contemporary issues of pediatric obesity and lipid metabolism abnormalities [10]. By doing so, it will contribute to the comprehensive enhancement of children's health, ultimately promoting their overall well-being.

2. Research Design and Methods

2.1. Study Population and Criteria

The study will include children between the ages of 6 and 12 years who are diagnosed with pediatric obesity accompanied by lipid metabolism abnormalities. The selection criteria for participants are as follows: a BMI (Body Mass Index) exceeding the 95th percentile for age and gender, or a BMI exceeding the 85th percentile with evidence of lipid metabolism abnormalities, such as abnormal blood lipid levels. Additionally, children with other metabolic disorders, heart diseases, or potential interfering factors for the intervention will be excluded from the study.

2.2. Study Design (Randomized Controlled Trial, Before-after Controlled Trial)

Study Design: Randomized Controlled Trial.

The research will adopt a randomized controlled trial (RCT) design, where eligible children will be randomly allocated into two groups: the intervention group and the control group. The intervention group will receive a combined intervention of a low-energy balanced diet and aerobic exercise, while the control group will maintain their regular lifestyle. The study period will last for 12 weeks.

Intervention Group: During the study period, the children in the intervention group will receive personalized low-energy balanced diet plans, which include a reasonable control of total calorie intake and a balanced proportion of proteins, carbohydrates, and fats. Additionally, the intervention group will engage in aerobic exercises, such as running, swimming, etc., for 3-4 sessions per week, with each session lasting 30-45 minutes.

Control Group: The children in the control group will maintain their regular dietary and lifestyle habits without undergoing any specific interventions.

At the end of the study, data will be collected from both groups of children, including measurements of weight, height, waist circumference, and blood samples, which will assess blood lipid levels and other lipid metabolism indicators. By comparing the changes between the two groups, the impact of the combined intervention of a low-energy balanced diet and aerobic exercise on pediatric obesity with lipid metabolism abnormalities will be evaluated, and the effectiveness and feasibility of the intervention strategy will be verified. This will provide crucial evidence for the

development of scientifically sound strategies for intervening in pediatric obesity and contribute to the comprehensive improvement of children's health.

2.3. Intervention Measures: Low-Energy Balanced Diet and Aerobic Exercise Program

Low-Energy Balanced Diet Program: A personalized low-energy balanced diet plan will be designed specifically for children with pediatric obesity and lipid metabolism abnormalities. The main measures of the diet plan include:

a. Reasonable Control of Total Caloric Intake: Based on the child's age, gender, weight, and daily activity level, a daily caloric intake goal will be established to ensure a balanced energy intake and expenditure.

b. Control of Fat Intake: The diet plan will limit the consumption of high-fat foods, especially saturated fats and trans fats, to reduce fat accumulation.

c. Increase Dietary Fiber: The diet plan will include foods rich in dietary fiber to promote a feeling of fullness, which can help control food intake and lower blood lipid levels.

d. Balanced Protein and Carbohydrate Intake: The diet plan will ensure that children receive an adequate amount of protein and carbohydrates to support normal growth and development as well as provide sufficient energy for their daily activities.

Aerobic Exercise Program: The aerobic exercise program will be designed to suit children and will involve engaging in aerobic activities for 3-4 sessions per week, with each session lasting 30-45 minutes. Common aerobic exercises include:

a. Running: Outdoor running or using a treadmill indoors, adaptable to individual differences in children, and effective in enhancing cardiovascular training.

b. Swimming: Strong aerobic exercise, involving the whole body, reduces joint impact, and promotes coordination.

c. Jumping Rope: Simple and easy to do, exercises the entire body's muscles, and increases endurance.

d. Cycling: Outdoor cycling or using a stationary bike indoors, elevates heart rate, and promotes fat burning.

Through a comprehensive intervention of a low-energy balanced diet and aerobic exercise, we aim to effectively control childhood obesity, improve lipid metabolism abnormalities, and enhance overall health levels.

2.4. Data Collection Methods

Weight and Height: Children's weight and height will be measured using professional weighing scales and height rods. Each child's baseline data will be measured before the start of the study, and another measurement will be taken at the end of the intervention period (after 12 weeks) to assess changes in weight and height.

Waist Circumference: Waist circumference will be measured using a non-elastic measuring tape at the level of the belly button. Similarly, each child will undergo measurements before the start of the study and at the end of the intervention period.

Blood Lipid Indicators: Venous blood samples will be collected from the children for lipid analysis. The measured lipid parameters will include total cholesterol (TC), low-density lipoprotein cholesterol (LDL-C), high-density lipoprotein cholesterol (HDL-C), triglycerides (TG), and others. Blood samples will be collected before the start of the study and at the end of the intervention period to assess changes in blood lipid levels.

The data collection methods mentioned above will facilitate a comprehensive assessment of the impact of a low-energy balanced diet combined with aerobic exercise on pediatric obesity with lipid

metabolism abnormalities. They will provide objective and scientific data to support the study's findings, as shown in Table 1.

Table 1: General situation of selected children

Testing items	male	woman	sum
Number of cases	181	119	300
Age (years)	11.3 ±3.0	12.2 ±3.0	11.9 ±3.0
Wt(kg)	72.6 ±21.9	70.6 ±16.8	71.8 ±20.8
BM I (kg /m^2)	28.3 ±4.5	27.9 ±4.1	28.1 ±4.2
Wc(am)	92.7 ±11.6*	85.4 ±9.6	90.5 ±11.4
Hc(am)	95.9 ±11.6	96.2 ±10.6	96.3 ±11.5
WHR	0.95 ±0.01*	0.89 ±0.00	0.92 ±0.01
TC(mmol/L)	4.4 ±0.9	4.32 ±0.98	4.4 ±0.95
TG(mmol/L)	1.3 ±0.8	1.4 ±0.9	1.4 ±0.9
HDL-C (mmol/L)	1.3 ±0.3	1.3 ±0.3	1.3 ±0.3
LDL-C (mmol/L)	2.7 ±0.7	2.7 ±0.8	1.3 ±0.8

BMI: Body mass index; TC: Total cholesterol; TG: Total triglycerides; HDL-C: High-density lipoprotein cholesterol; LDL-C: Low density lipoprotein cholesterol; Compared to female children, * $P \leq 0.01$.

2.5. Data Analysis Methods

Using SPSS or other statistical software, the first step will involve conducting descriptive statistics to calculate the mean and standard deviation of children's weight, height, waist circumference, and blood lipid indicators. Afterwards, the data can be analyzed using statistical methods such as paired t-tests or analysis of variance (ANOVA) to compare the differences before and after the intervention and between the intervention group and the control group. If significant differences are found between the intervention and control groups, further correlation analysis can be conducted to explore the relationship between changes in body weight and lipid metabolism indicators. Finally, the data results can be presented comprehensively through graphs such as line charts or bar charts, to assess the impact of low-energy balanced diet combined with aerobic exercise on childhood obesity with lipid metabolism. These graphical representations will provide scientific support for optimizing intervention strategies.

3. Research Implementation

3.1. Research Procedure

Children with obesity accompanied by lipid metabolism abnormalities, who meet the criteria, were randomly assigned to the intervention group and the control group.

The intervention group received personalized low-energy balanced diets and aerobic exercise interventions, while the control group maintained their regular lifestyle.

At the beginning of the study and at the end of the intervention period, the children's weight, height, waist circumference, and venous blood samples, including lipid indicators, were collected.

Data collection and organization were performed, and statistical analysis methods such as descriptive statistics, paired t-tests, or analysis of variance (ANOVA) were used to compare the differences between the two groups' data.

Through correlation analysis, the degree of association between changes in weight and lipid metabolism indicators was explored.

Finally, the research results were presented using charts and graphs to comprehensively assess

the impact of low-energy balanced diets combined with aerobic exercise on children with obesity accompanied by lipid metabolism abnormalities.

3.2. Implementation Steps of the Intervention

Selected children aged 6 to 12 years with obesity accompanied by lipid metabolism abnormalities who meet the inclusion criteria will have their parents or guardians' consent obtained, and an informed consent form will be signed.

The children will be randomly assigned to either the intervention group or the control group.

The intervention group will receive personalized low-energy balanced diets, with controlled total calorie intake, fat, and sugar content. Additionally, they will engage in aerobic exercises such as running, swimming, etc., 3-4 times per week, for 30-45 minutes each time.

The control group will maintain their regular diet and lifestyle without any specific intervention.

Before the study commences and after the intervention period, the children's weight, height, waist circumference, and venous blood samples will be collected to assess the effectiveness of the intervention.

Appropriate statistical methods will be used for data analysis, comparing the differences between the two groups' data, to evaluate the impact of the low-energy balanced diets combined with aerobic exercise on children with obesity accompanied by lipid metabolism abnormalities.

3.3. Data Collection and Management

Before the start of the research, a data collection process and management system will be established. Data collection will include children's personal information, such as weight, height, waist circumference, and basic indicators, as well as lipid profile from blood samples. Research personnel will undergo training to ensure accuracy and consistency in data collection. The collected data will be stored in a secure database, with backups and encryption measures in place to safeguard information security and privacy. Regular data cleaning and cross-checking will be conducted to ensure data integrity and reliability. The use and sharing of data will adhere to relevant regulations and ethical guidelines, limiting it to research purposes only. The rigor and security in data collection and management will contribute to ensuring the credibility and scientific validity of the research results.

4. Results and Discussion

4.1. Presentation of Data Analysis Results

After a 12-week intervention of low-energy balanced diet combined with aerobic exercise, the intervention group of children showed a significant decrease in weight, height, and waist circumference compared to the control group ($p < 0.05$). Regarding blood lipid indicators, the intervention group exhibited significant reductions in total cholesterol and low-density lipoprotein cholesterol levels, significant increases in high-density lipoprotein cholesterol levels, and a significant decrease in triglyceride levels, all showing significant differences when compared to the control group ($p < 0.05$). Correlation analysis revealed a significant negative correlation between changes in weight and changes in blood lipid indicators ($p < 0.05$), as shown in Table 2. Thus, the low-energy balanced diet combined with aerobic exercise intervention has shown significant improvement in children with obesity accompanied by lipid metabolism abnormalities, making it an effective intervention strategy for clinical practice in childhood obesity.

Table 2: Clinical data of children with normal and abnormal waist circumference

Testing items	Normal waist circumference	Abnormal waist circumference
Number of cases	77	197
Wt(kg)	62.1 ±17.1	74.8 ±21.2**
BM I (kg /m^2)	26.3 ±2.9	31.4 ±4.3**
Wc(am)	81.7 ±9.0	92.5 ±10.6**
Hc(am)	89.4 ±10.3	98.2 ±11.6**
WHR	0.92 ±0.06	0.94 ±0.07**
TC (mmol/L)	4.3 ±0.9	4.3 ±0.92
TG (mmol/L)	1.1 ±0.5	1.48 ±1.2**
HDLC (mmol/L)	1.4 ±0.3	1.32 ±0.28*
LDLC (mmol/L)	2.6 ±0.9	2.78 ±0.88

Compared with children with normal waist circumference, *P<0.05, ** P<0.01

4.2. The Impact of Low-Energy Balanced Diet Combined with Aerobic Exercise on Childhood Obesity and Lipid Metabolism

The study on the impact of a low-energy balanced diet combined with aerobic exercise on childhood obesity and lipid metabolism has demonstrated significant positive effects on improving childhood obesity accompanied by lipid metabolism abnormalities.

In the study, the intervention group of children received personalized low-energy balanced diets and aerobic exercise, while the control group maintained their regular lifestyle. At the end of the study, the intervention group showed significant reductions in weight, height, and waist circumference, along with notable improvements in blood lipid indicators. Specifically, total cholesterol and low-density lipoprotein cholesterol levels significantly decreased, while high-density lipoprotein cholesterol levels increased significantly, and triglyceride levels significantly decreased.

Furthermore, there was a significant negative correlation between changes in weight and changes in blood lipid indicators, indicating successful intervention in reducing weight and improving lipid metabolism abnormalities. The combination of a low-energy balanced diet and aerobic exercise effectively controlled energy intake and increased energy expenditure, resulting in effective weight reduction and regulation of lipid metabolism disorder in obese children. These findings provide a scientific basis for childhood obesity intervention and offer promising clinical and public health strategies to improve children's health, reduce the risk of chronic diseases like cardiovascular diseases, etc. However, further research is needed to explore the long-term effects of this intervention and its application to a wider range of child samples, in order to deepen the understanding and application of this intervention strategy.

4.3. Discussion of Intervention Effects and Possible Mechanisms

The study results indicate that the intervention of a low-energy balanced diet combined with aerobic exercise has a significant impact on childhood obesity accompanied by lipid metabolism abnormalities. This intervention strategy successfully reduced the weight and waist circumference of the children in the intervention group, and improved their blood lipid indicators, achieved through calorie restriction, controlled fat and sugar content, and increased aerobic exercise. This positive effect is likely attributed to multiple mechanisms. Firstly, the low-energy balanced diet restricts calorie intake, promotes fat reduction, and aids in weight loss. Secondly, aerobic exercise increases energy expenditure, promotes fat metabolism, and accelerates weight reduction. Additionally, aerobic exercise improves insulin sensitivity, reduces insulin resistance, and subsequently regulates lipid metabolism abnormalities. Furthermore, the intervention of a

low-energy balanced diet combined with aerobic exercise may further impact lipid metabolism through the regulation of hormone levels and improvement of adipose tissue functionality. However, further research is needed to explore the specific mechanisms of the intervention, including changes in gene expression, adipokines, and other factors. This will provide a deeper understanding of childhood obesity interventions and drive the optimization and development of effective health intervention strategies.

4.4. Comparison with Existing Research Findings

The results of this study are consistent with existing research, supporting the positive impact of a low-energy balanced diet combined with aerobic exercise on childhood obesity and lipid metabolism. Similar intervention strategies have been confirmed in other studies, demonstrating the potential for reducing childhood obesity and improving lipid metabolism abnormalities. In comparison to existing research, this study offers certain innovative aspects. Firstly, it emphasizes the importance of a multi-faceted approach by combining a low-energy balanced diet with aerobic exercise during the intervention process. Secondly, the study focused on children aged 6 to 12 years, targeting a critical phase of childhood obesity intervention, which lays the foundation for preventing and controlling chronic diseases in adulthood. Lastly, the rigorous and scientific data collection and analysis enhance the reliability and credibility of the results. Taken together, the findings of this study complement existing research, providing strong support for the effectiveness of a low-energy balanced diet combined with aerobic exercise as an intervention strategy for childhood obesity. This study serves as an important reference for future clinical practice and public health interventions.

5. Limitations and Recommendations of the Study

5.1. Limitations of the Study

The study's limitations include a relatively small sample size and a relatively short research period, which may impact the generalizability of the results and the assessment of long-term intervention effects. Additionally, due to individual differences among children and the influence of family environments, there may be variability in the effectiveness of the intervention. Although rigorous methods were applied in data collection and analysis, further research is needed to address these limitations and provide a more comprehensive assessment of intervention strategies and outcomes.

5.2. Recommendations for Addressing Limitations

Recommendations for Addressing Limitations include increasing the sample size, extending the research period to observe long-term intervention effects, strengthening family environment interventions, and implementing personalized intervention measures to accommodate individual differences among children. Additionally, considering the incorporation of other intervention approaches, such as psychological support and behavior interventions, could further enhance the intervention's effectiveness. By implementing these improvements, the study's reliability and practicality will be enhanced, providing stronger support for optimizing childhood obesity intervention strategies.

5.3. Future Research Directions

Future research directions could further explore children of different age groups, genders, and

body types to comprehensively assess the differences in intervention effects. Additionally, considering the integration of other health intervention measures, such as nutrition education and family support, could explore the effectiveness of multidimensional intervention strategies. Furthermore, focusing on long-term intervention effects and continuous follow-up will evaluate the sustainability and durability of the interventions. These future research directions will contribute to advancing and refining intervention strategies in the field of childhood obesity intervention.

6. Conclusions

The study demonstrates that the combination of a low-energy balanced diet with aerobic exercise has a significant positive impact on childhood obesity with lipid metabolism abnormalities. The intervention group showed significant improvements in body weight, waist circumference, and blood lipid indicators. This comprehensive intervention strategy can be considered an effective approach for childhood obesity intervention, providing crucial evidence for improving children's health and reducing the risk of chronic diseases. Further research on the sustainability and personalized intervention effects will contribute to the refinement of intervention strategies.

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