

Original article

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Application of body composition zones in boys with nonalcoholic fatty liver disease

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Purpose: Screening nonalcoholic fatty liver disease (NAFLD) by body mass index (BMI) as a single surrogate measure for obesity has limitations. We suggest considering body composition zones by drawing a body composition chart composed of body composition indices, including BMI and percent body fat (PBF), to visualize the risk of NAFLD in obese children and adolescents.

Methods: Thirty-eight boys diagnosed with NAFLD were selected retrospectively from patients who visited Konkuk University Medical Center from 2006 to 2015. They had gone through body composition analysis by bioelectrical impedance analysis (BIA), and biochemical analyses, including a liver function test (LFT) and lipid panel, were performed. Fat-free mass index (FFMI) and fat mass index (FMI) were calculated from body composition analysis and height. We plotted FFMI and FMI of patients on a body composition chart and classified the patients into zones A to D. In addition, we analyzed the correlations between LFT, lipid panel, and body composition indices.

Results: Thirty-three of 38 boys (86.8%) were located in zone C, corresponding to high BMI and PBF. Four boys (10.5%) were located in zone D, which correlates with sarcopenic obesity. One boy located in zone B was a muscular adolescent. Alanine aminotransferase level was positively correlated with PBF, FMI, and BMI z-score.

Conclusion: Body composition zones on a body composition chart might be useful in risk assessment in obesity-related diseases such as NAFLD. Zones on a body composition chart could have practical applications, especially in sarcopenic obese children and adolescents.

Keywords: Nonalcoholic fatty liver disease, Childhood and adolescent obesity, Body composition, Sarcopenic obesity

Introduction

Nonalcoholic fatty liver disease (NAFLD) is the most common cause of chronic liver disease in children.¹⁾ It encompasses a spectrum of liver diseases ranging from fatty liver alone to the triad of fatty infiltration, inflammation, and fibrosis, termed nonalcoholic steatohepatitis. Early detection of NAFLD is important, and the disease can be screened using risk factors, including obesity, hypertriglyceridemia, and insulin resistance. Since it is strongly associated with obesity, NAFLD prevalence is increasing with that of obesity due to changes in lifestyle and diet patterns.^{2,3)} Body mass index (BMI) has been used widely as a marker of adiposity⁴⁾; however, use of BMI to identify excess body adiposity has poor sensitivity because it cannot differentiate body fat from lean mass.⁵⁾ Meanwhile, sarcopenic obesity is closely associated with chronic diseases.⁶⁾ The term sarcopenia comes from the Greek words sarx (meaning flesh) and penia (meaning loss). The definition of sarcopenic obesity necessarily combines those of sarcopenia and obesity, describing those who have low muscle mass with a relatively high proportion of fat mass (FM).⁷⁾ In this paper, we suggest considering BMI and percent body fat (PBF) simultaneously to reflect body adiposity and identify at-risk patients for obesity-related

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disease. Furthermore, we plotted the body composition indices of NAFLD patients in a chart and visualized the distribution of patient body composition. We also divided the patient group based on values of PBF and BMI and sorted them into zones to compare patient characteristics.

Materials and methods

1. Study subjects

Thirty-eight boys diagnosed with NAFLD were selected retrospectively from the patients who visited Konkuk University Medical Center between 2006 and 2015. The criteria of the American Association for the Study of Liver Disease were used to diagnose NAFLD.⁸⁾ Thirty-six boys presented hyper-echoic liver in ultrasonography, and 2 boys showed fatty liver on computed tomography (CT). They had no factors for secondary hepatic fat accumulation such as alcohol consumption, use of steatogenic medication, or hereditary disorders. The study protocol was approved by the Institutional Review Board of Konkuk University Medical Center (Protocol No; KUH1090061). Informed consent was waived by the board due to the retrospective study design.

2. Anthropometric measurement and body composition analysis

Weight was measured by digital scale to the nearest 50 g, and height was evaluated with a stadiometer to the nearest 0.1 cm. The z-scores of height (HTZ), weight (WTZ), and BMI (BMIZ) were calculated based on the 2007 Korean National Growth Charts. All patients had gone through body composition analysis with bioelectrical impedance analysis (BIA) using Inbody 720 (Biospace Co., Seoul, Korea) to evaluate body fat-free mass (FFM) and FM. BMI was calculated from body weight (kg) and height (m) using the formula $BMI = \text{weight} / (\text{height})^2$.

Based on the 2-compartment model,⁹⁾ body weight was calculated as the sum of FM and FFM. To evaluate the height-adjusted body indices, FMI and FFMI, these variables were substitutes for weight in the BMI equation: $BMI = (FM + FFM) / \text{height}^2 = FM / \text{height}^2 + FFM / \text{height}^2 = FMI + FFMI$. PBF was calculated by dividing FM by body weight.

3. Body composition chart and zones

We used the body composition chart of Hattori,¹⁰⁾ which is a 2-dimensional expression of FFMI and FMI, to graphically present body constitution as a quantitative measure. In addition, we plotted coordinates of FFMI and FMI, along with reference values for BMI and PBF, to visualize the distribution of patient body composition, as in previous studies.¹¹⁻¹⁴⁾ We suggest dividing the chart into zones using values of BMI and PBF that correspond to the 85th percentile of each subject. Values for boys at age 13, the mean age of study subjects, are demonstrated in Fig. 1. We used the reference values of body composition

indices derived from the Korean National Health and Nutrition Examination Surveys.¹⁵⁾ We divided the field into 4 zones: zone A, $BMI < 23 \text{ kg/m}^2$ and $PBF < 30\%$; zone B, $BMI \geq 23 \text{ kg/m}^2$ and $PBF < 30\%$; zone C, $BMI \geq 23 \text{ kg/m}^2$ and $PBF \geq 30\%$; zone D, $BMI < 23 \text{ kg/m}^2$ and $PBF \geq 30\%$ (Fig. 1). We also compared the biochemical profiles and body composition indices between boys in zones C and D.

4. Laboratory analysis

Blood biochemistry analyses including liver function test (LFT) and lipid panel were performed for all patients. The LFT comprised aspartate transaminase and alanine transaminase (ALT), and the lipid panel involved total cholesterol, triglycerides, and high-density lipoprotein and low-density lipoprotein cholesterol. Patients who suffered from viral hepatitis or autoimmune hepatitis were excluded. We analyzed the correlations between blood biochemistry and body composition indices.

5. Statistical analysis

All analysis was performed using SPSS ver. 17.0 (SPSS Inc., Chicago, IL, USA), and a *P*-value less than 0.05 was considered statistically significant. The Mann-Whitney *U*-test was used to test for differences between zones. The relationships between biochemical profiles and body composition indices were assessed by Pearson correlation analysis.

Results

The mean age of the population of 38 boys was 13.0 ± 2.3 -years.

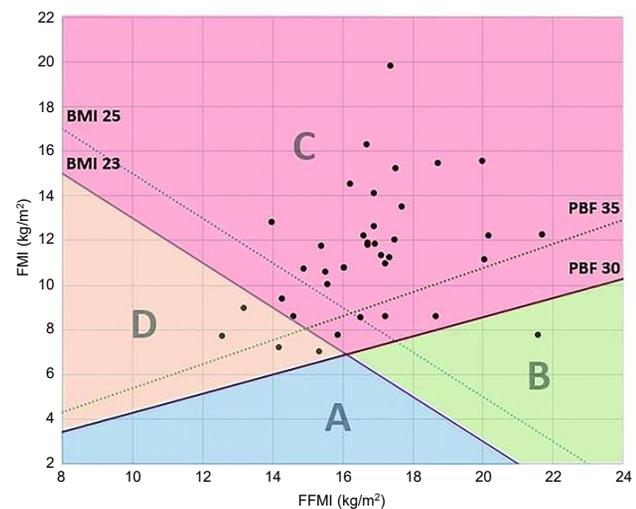


Fig. 1. The plotting of FFMI and FMI in NAFLD patients on body composition chart. The x-axis represents the FFMI, and the y-axis depicts FMI of individual. The lines of BMI and PBF were added to the same plane. NAFLD, nonalcoholic fatty liver disease; BMI, body mass index; PBF, percent body fat; FMI, fat mass index; FFMI, fat free mass index.

The mean BMI and BMIZ were 28.2±4.0 and 1.85±0.68, respectively. Mean PBF was 39.9%±5.5% (Table 1).

We expressed the body composition indices of subgroups using the body composition chart with FFMI on the *x*-axis and FMI on the *y*-axis. BMI of 23 kg/m² and PBF of 30%, corresponding approximately to the 85th percentile for 13-year-old boys,¹⁵⁾ were chosen as reference lines on the chart, as the mean age of this study group was 13. The plane was divided into zones A–D by the reference lines (Fig. 1). Thirty-four boys showed BMI over 23 kg/m², and 37 boys showed PBF over 30%. Thirty-three boys were located in zone C, indicating that a large percentage of NAFLD patients has both high BMI and PBF.

Table 1. The characteristics of NAFLD male patients (n=38)

Characteristic	Mean±SD
Anthropometric data	
Age (yr)	13.0±2.3
Height (cm)	157.2±11.9
Weight (kg)	70.7±17.3
BMI (kg/m ²)	28.2±4.0
HTZ	0.5±1.1
WTZ	2.4±0.8
BMIZ	1.9±0.6
Body composition	
FFM (kg)	42.4±10.9
FM (kg)	28.3±8.2
FFMI (kg/m ²)	16.9±2.1
FMI (kg/m ²)	11.4±2.8
PBF (%)	39.9±5.5
Biochemical profiles	
Alanine aminotransferase (IU/L)*	129.2±97.1
Triglyceride (mg/dL)*	153.1±101.1
HDL cholesterol (mg/dL)*	48.1±10.5
LDL cholesterol (mg/dL)*	104.9±28.8
Total cholesterol (mg/dL)*	183.6±33.6

NAFLD, nonalcoholic fatty liver disease; SD, standard deviation; BMI, body mass index; HTZ, Height z-score; WTZ, Weight z-score; BMIZ, BMI z-score; FM, fat mass; FFM, fat free mass; PBF, percent body fat; FMI, fat mass index; FFMI, fat free mass index; HDL, high-density lipoprotein; LDL, low-density lipoprotein.

*Three patients have no acquired value.

Four boys were located in zone D, which represents sarcopenic obesity. The boy in zone B was 16 years old with a BMI of 29.3 kg/m², 95th–97th percentile, and PBF of 26.5%, 75th–85th percentile, probably indicating a muscular body (Table 2).

Furthermore, we compared the biochemical profiles and body composition indices between boys in zones C and D. Boys in zone C had higher WTZ, BMIZ, FM, FMI, FFM, and FFMI values than those of zone D (*P*<0.05). The difference in ALT between the 2 groups was not significant (Table 3).

In the correlation analysis between biochemical profiles and body composition indices, ALT level was positively correlated with BMIZ, PBF, and FMI. The correlation coefficients of ALT with PBF, BMIZ, and FMI were 0.498 (*P*<0.005), 0.326 (*P*<0.005), and 0.433 (*P*<0.005), respectively (Table 4).

Discussion

NAFLD is usually asymptomatic and requires screening for detection. No screening guidelines exist outside of weight categorization (BMI ≥85th percentile for age and sex).¹⁶⁾ However, screening the risk population only by BMI has limitations. There is a considerable number of NAFLD patients

Table 3. Comparison of the patient characteristics of zone C and D

Variable	C zone (n=33)	D zone (n=4)	<i>P</i> -value
Age (yr)	13.1±2.2	11.0±1.5	0.056
HTZ	0.5±1.2	0.7±0.5	0.922
WTZ	2.5±0.7	1.2±0.5	0.003
BMIZ	2.1±0.5	0.9±0.4	0.002
FM (kg)	30.0±7.4	16.6±2.0	0.002
FMI (kg/m ²)	11.9±2.6	7.7±0.9	0.001
FFM (kg)	43.5±10.4	29.8±3.8	0.007
FFMI (kg/m ²)	17.1±1.7	13.8±1.2	0.003
PBF (%)	40.8±5.0	35.8±4.1	0.056
ALT (IU/L)	136.4±102.4	86.8±10.1	0.607

Values are presented as mean±standard deviation.

HTZ, Height z-score; WTZ, Weight z-score; BMIZ, BMI z-score; FM, fat mass; FMI, fat mass index; FFM, fat free mass; FFMI, fat free mass index; PBF, percent body fat; ALT, alanine aminotransferase.

Table 2. Clinical manifestations of patients in zone B and D on body composition chart

Variable	D zone	D zone	D zone	D zone	B zone
Age (yr)	13	10	10	10	16
BMI (kg/m ²)	21.4	20.3	22.2	22.3	29.3
BMIP	50–75	50–75	75–85	75–85	97
PBF (%)	33.7	38	40.4	31.3	26.5
PBFP (%)	85–90	85–90	90–95	50–75	75–85
FM (kg)	17.8	16.4	18.3	13.9	20.4
FMI (kg/m ²)	7.2	7.7	9	7	7.8
FFM (kg)	35	26.8	27	30.5	56.6
FFMI (kg/m ²)	14.2	12.6	13.2	15.3	21.6
ALT (IU/L)	78	78	96	95	63

BMI, body mass index; BMIP, body mass index percentile; PBF, percent body fat; PBFP, percent body fat percentile; FM, fat mass; FMI, fat mass index; FFM, fat free mass; FFMI, fat free mass index; ALT, alanine aminotransferase.

Table 4. Correlation coefficients between ALT and body composition indices

Variable	<i>r</i>	<i>P</i> -value
HTZ	-0.327	0.045
WTZ	-0.023	0.892
BMIZ	0.231	0.046
FMI	0.433	0.007
FFMI	-0.101	0.547
PBF	0.498	0.001

ALT, alanine aminotransferase; HTZ, Height z-score; WTZ, Weight z-score; BMIZ, BMI z-score; FMI, fat mass index; FFMI, fat free mass; FFMI, fat free mass index; PBF, percent body fat. *r*=correlation coefficient.

who maintain a weight lower than the 85th percentile for age and sex, and they usually have a large FM proportion, showing high PBF. Low muscle mass, representing sarcopenic obesity, is associated with metabolic risk, and muscular strength is positively related to higher insulin sensitivity in children and adolescents.¹⁷⁻¹⁹ Early detection of sarcopenic obesity in childhood will help prevent obesity-related metabolic diseases.

In this study, although most of the NAFLD patients were located in zone C, with both high BMI and PBF, 4 NAFLD boys were located in zone D and might not have been identified by a screening test considering only BMI. Furthermore, one NAFLD patient was located in zone B, showing BMI \geq 85th percentile but PBF<85th percentile, suggesting similar limitation to considering only PBF. This study implies that screening for obesity-related disease using both BMI and PBF can increase detection sensitivity. In addition, dividing body composition chart into zones could be practical at an individual person level.

Recently, new normative standards were proposed for ALT concentration (\leq 25 U/L for boys and \leq 22 U/L for girls).²⁰ Higher ALT level suggests a more advanced stage of NAFLD, hepatitis, or fibrotic changes.²¹ Thus, even though ALT elevation underestimates liver injury in NAFLD, it is still an easily available screening tool for clinicians to use when assessing children and adolescents who are overweight or obese.²² In this study, 37 of 38 NAFLD patients had ALT above the normal value ($>$ 25 U/L). Furthermore, ALT showed positive correlation with BMIZ, PBF and FMI, meaning that the more obese is the patient, the more likely it is that severe liver disease is present.

BMI is an indicator of adiposity; however, both FMI and FFMI affect BMI, preventing differentiation of body fat from lean mass using BMI alone.⁵ We suggest using body composition indices in evaluating obesity, which is a significant risk factor of many diseases, including NAFLD. It is important to monitor proper accretion of lean body mass including bone mineral content in children and adolescents during growth. Presenting the body composition indices using a graph and visualizing where the child is located can arouse the attention of both patient and clinician.

In this study, BIA was used for body composition analysis instead of dual-energy X-ray absorptiometry (DXA), which is often used in research and is considered the standard. BIA was used because it is a simple, easy, and time-saving technique

that avoids radiation exposure and shows high correlation with other methods of obesity assessment, such as DXA and CT.^{23,24}

There are some limitations to the study. A small group of 38 NAFLD patients was involved, and only boys were considered. A larger study considering both boys and girls should be performed in the future. In addition, waist circumference, which is a well-known risk factor of obesity-related disease, was not included among variables in this study due to the limited data.

Dividing the chart by single lines of BMI and PBF has limitations, because BMI and PBF are age- and sex-dependent, and increases in growth during the adolescent period are accompanied by increases in BMI and FFMI.¹⁵ Plotting charts for each age subgroup or age-specific assessment at the individual level should be performed to overcome this limitation.

Looking closer at the three 10-year-old boys located in zone D, BMI of all 3 is below the 85th percentile, but the one boy with PBF 31.3% is in the 50th–75th percentile (Table 2). When dividing the chart by reference values for a 10-year-old boy, this boy is located in zone A; however, since his PBF is greater than 30%, he could be considered to have high PBF and needs to be carefully evaluated. In a study of children and adolescents aged 5 to 18 years, PBF above 25% in males and 30% in females has been reported as a significant risk factor of cardiovascular disease (CVD).²⁵ Overweight children and adolescents with increased CVD risk need to be evaluated according to PBF percentile subgroup even with PBF below the 85th percentile.

In conclusion, we suggest considering both BMI and PBF to reflect body adiposity and detect those at risk of obesity-related disease such as NAFLD. Body composition zones on a body composition chart might be a useful screening tool in risk assessment, especially in sarcopenic obese children.

Conflict of interest

No potential conflict of interest relevant to this article was reported.

Ethical statement

The study protocol was approved by the Institutional Review Board of Konkuk University Medical Center (Protocol No; KUH1090061). Informed consent was waived by the board due to the retrospective study design.

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