

# Relationship between percent body fat, body anthropometric indices and body composition in Japanese elementary school children

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## ABSTRACT

The body compositions of 966 school children were measured and a comparison of the difference in judgment of obesity was made through a study of the relationship between body indices and percent body fat, as well as body composition, the Kaup index and percent body fat. Percent body fat showed a strong correlation to body indices, however, upon comparison of the judgment of obesity by the Kaup index and percent body fat, the Kaup index showed children with high lean body mass and total body water, as well as well developed bone and muscular physique, to be obese. Judgment through percent body fat showed children with high percent body fat to be obese. It was found that the judgement of obesity for 6<sup>th</sup> grade boys and girls by percent body fat, showed Kaup index of greater than 22, indicating obesity.

## KEY WORDS

Body composition, Kaup index, Rohrer index, Obesity degree index, Percent body fat

## Introduction

It has been found that the most effective way to judge obesity is in the measurement of body fat<sup>1)</sup>. From this, in recent years our country has also come to judge obesity by the measurement of body fat. However, body indices derived from height and weight calculations have been used to judge obesity. In this case of using only anthropometric body indices to judge obesity, it is necessary to think more carefully about special characteristics in judging obesity through the use of various body indices. The present research presents a standard for judgment of obesity in children relative to body composition.

## Methods

The survey took place in September of 1998, at the Ibaraki Prefecture Public Elementary School, with 966 children in 3<sup>rd</sup> to 6<sup>th</sup> grade (494 boys and 472 girls)

as subjects. A Sekisui Science Bio-impemeter SS103 (Japan) was used to measure body fat. From height (H) and weight (W), the three most commonly used indices of obesity in our country, the Kaup index, Rohrer index and obesity degree index were used. For each body index formula, we have for the Kaup index :  $Wg/Hcm^2 \times 10$ , for the Rohrer index :  $Wg/Hcm^3 \times 10^4$ , and for the obesity degree index :

$\{\text{actual measured body weight/standard body weight}-1\} \times 100\%$ .

## Results

From figures 1 through 8, we show the correlation between body index and percent body fat relative to school grade and sex of the subjects. Figure 1 shows the results for 3<sup>rd</sup> grade girls, with Rohrer index  $r=0.709$ , Kaup index  $r=0.701$ , and obesity degree index  $r=0.580$ , respectively showing strong correlation. Fig.

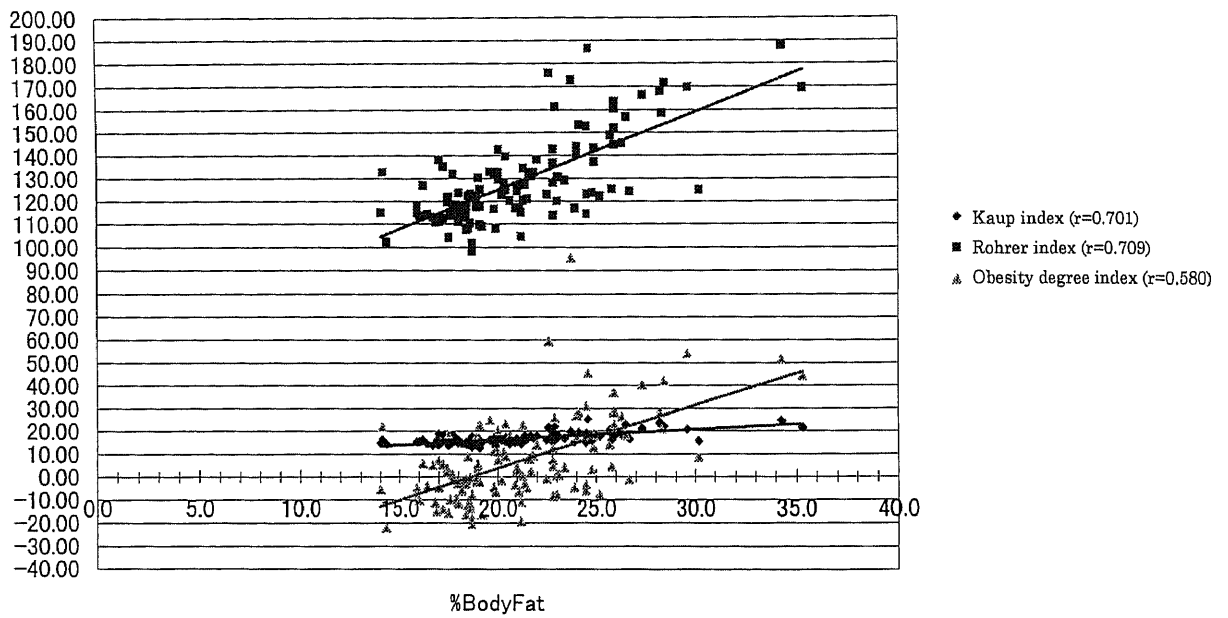


Figure 1. Relationship between percent body fat and body indices for 3<sup>rd</sup> grade girls.

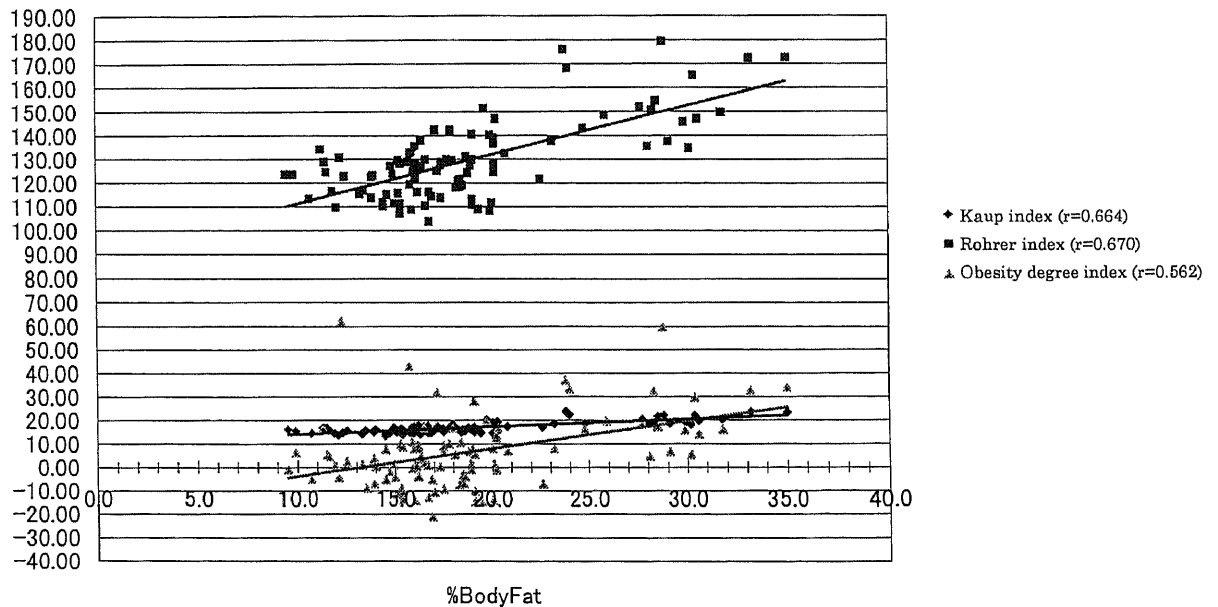


Figure 2. Relationship between percent body fat and body indices for 3<sup>rd</sup> grade boys.

2 shows results for 3<sup>rd</sup> grade boys, with Rohrer index  $r=0.670$ , Kaup index  $r=0.667$ , and obesity degree index  $r=0.562$ , respectively showing strong correlation, particularly in that boys and girls show strong correlation in percent body fat relative to Rohrer and Kaup indices. In comparing boys with girls, girls showed stronger correlation. Fig. 3 shows results for 4<sup>th</sup> grade girls, with Kaup index  $r=0.611$ , Rohrer index  $r=0.599$ , and obesity degree index  $r=0.539$ ,

respectively showing strong correlation. Fig. 4 shows results for 4<sup>th</sup> grade boys, with Kaup index  $r=0.808$ , Rohrer index  $r=0.757$ , and obesity index  $r=0.738$ , showing strong correlation. For both boys and girls, Kaup and Rohrer indices showed strong correlation. In comparing boys with girls in this case, boys showed stronger correlation. Fig. 5 shows results for 5<sup>th</sup> grade girls with Kaup index  $r=0.664$ , Rohrer index  $r=0.660$ , and obesity degree index  $r=0.645$ ,

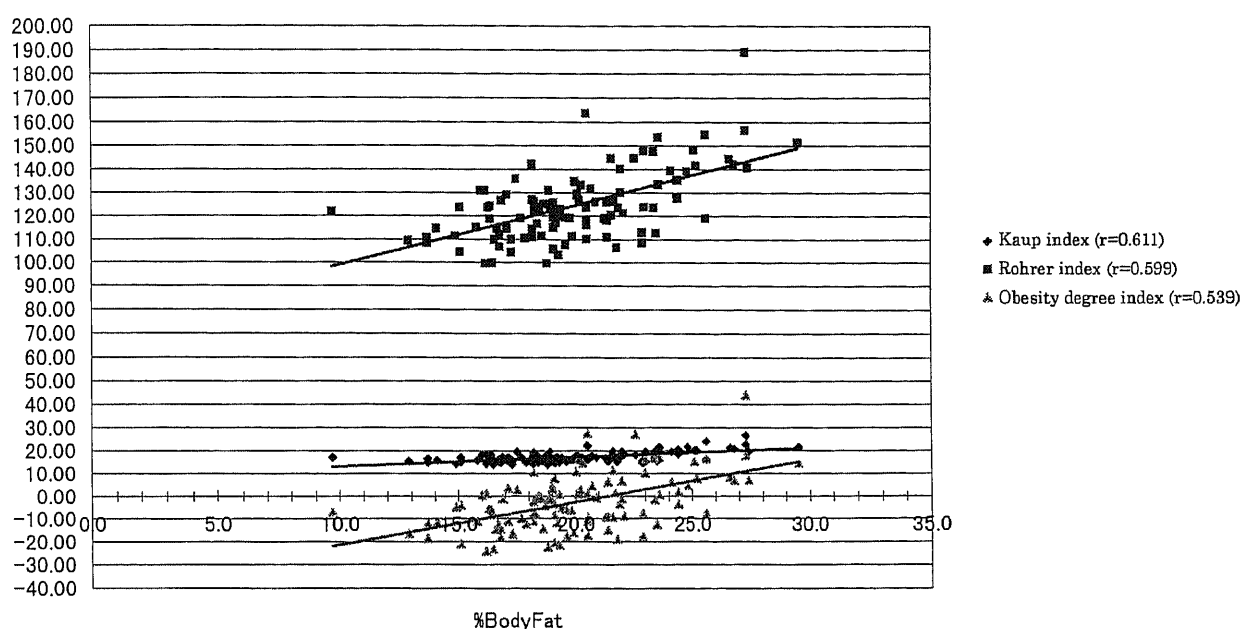


Figure 3. Relationship between percent body fat and body indices for 4<sup>th</sup> grade girls.

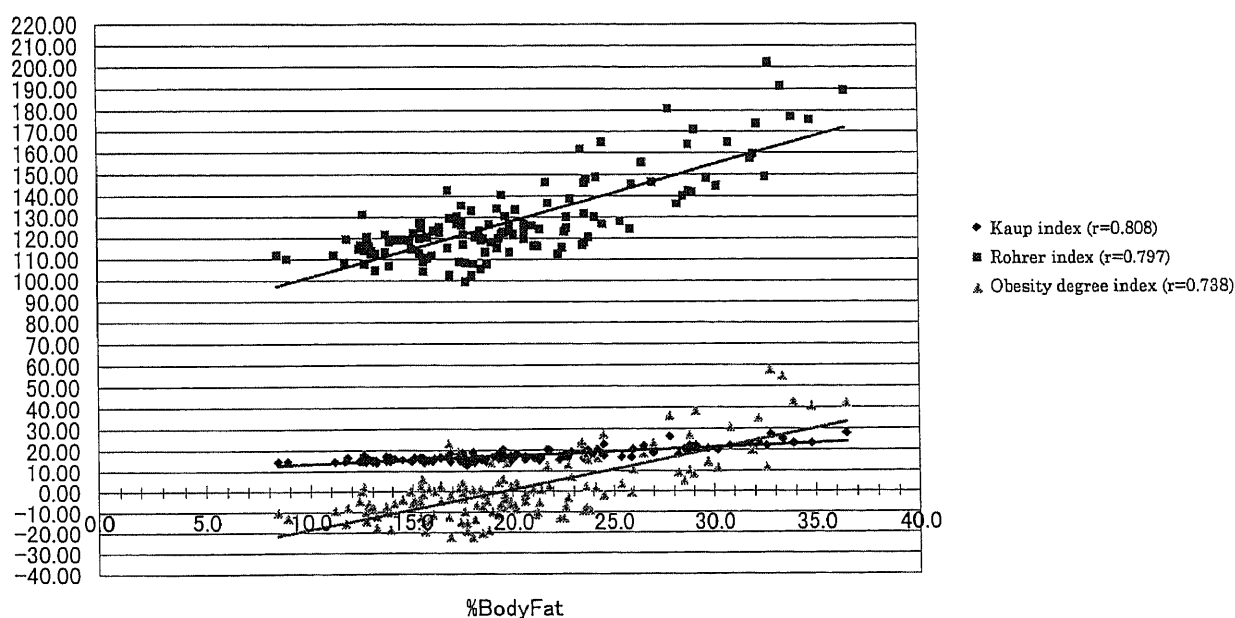


Figure 4. Relationship between percent body fat and body indices for 4<sup>th</sup> grade boys.

respectively showing strong correlation. Fig. 6 shows results for 5<sup>th</sup> grade boys, with Kaup index  $r=0.726$ , Rohrer index  $r=0.724$ , and obesity degree index  $r=0.694$ , respectively showing strong correlation. In comparing boys with girls, boys again showed stronger correlation. Fig. 7 shows results for 6<sup>th</sup> grade girls, with Rohrer index  $r=0.713$ , Kaup index  $r=0.710$ , and obesity degree index  $r=0.709$ , all showing strong correlation. Fig. 8 shows results for 6<sup>th</sup> grade

boys, with Rohrer index  $r=0.631$ , obesity degree index  $r=0.620$ , and Kaup index  $r=0.582$ , all showing strong correlation. In comparing boys with girls, girls showed stronger correlation.

As shown above, it was recognized that Kaup and Rohrer indices showed strong percent body fat correlations for any grade level. On that point, investigations of the present research first of all show the relationship between body composition and the Kai

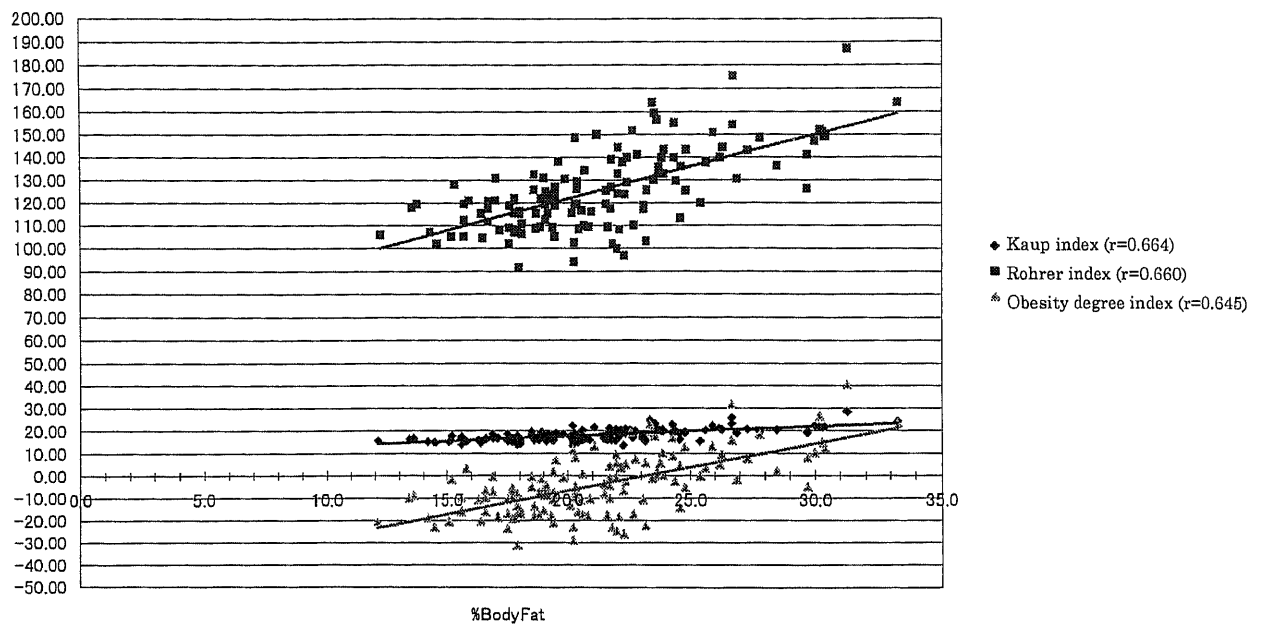


Figure 5. Relationship between percent body fat and body indices for 5<sup>th</sup> grade girls.

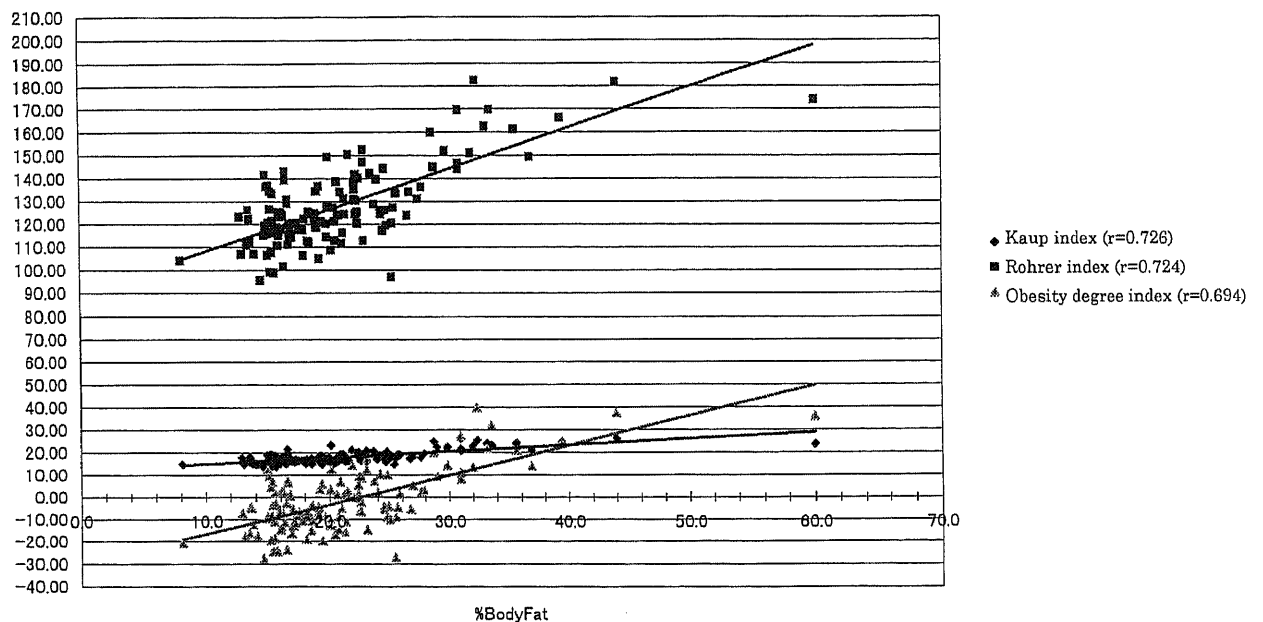


Figure 6. Relationship between percent body fat and body indices for 5<sup>th</sup> grade boys.

index. The Kaup index, similar to the Body Mass Index ( $BMI\{Wkg/Sm^2\}$ ), has been used throughout the US and Europe to judge obesity in adults and children, and widely recognized to show strong correlation to percent body fat<sup>2,3)</sup>.

In Table 1 are listed height, weight, body composition, as well as Kaup index with average and standard deviation, categorized by grade level and sex. Compared to the national average for height and

weight, the children in this study were average. The height for 4<sup>th</sup> graders :  $F = 16.363$ ,  $P < 0.001$ , around which there was a difference recognized by sex, in all cases girls being the taller. There was no difference recognized for weight. Percent body fat for 3<sup>rd</sup> graders was :  $F = 7.88$ ,  $P < 0.01$ , and for 6<sup>th</sup> graders, with girls significantly higher :  $F = 4.727$ ,  $P < 0.03$ . For lean body mass, there was a difference between the sexes recognized only for 5<sup>th</sup> graders, with girls significantly

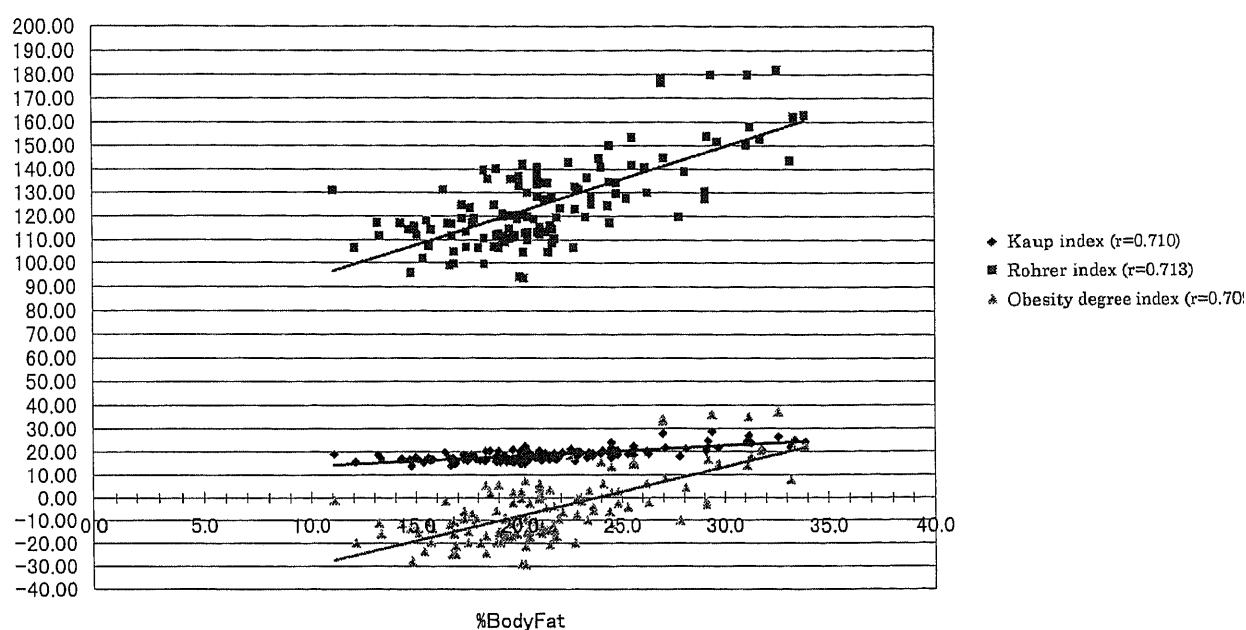


Figure 7. Relationship between percent body fat and body indices for 6<sup>th</sup> grade girls.

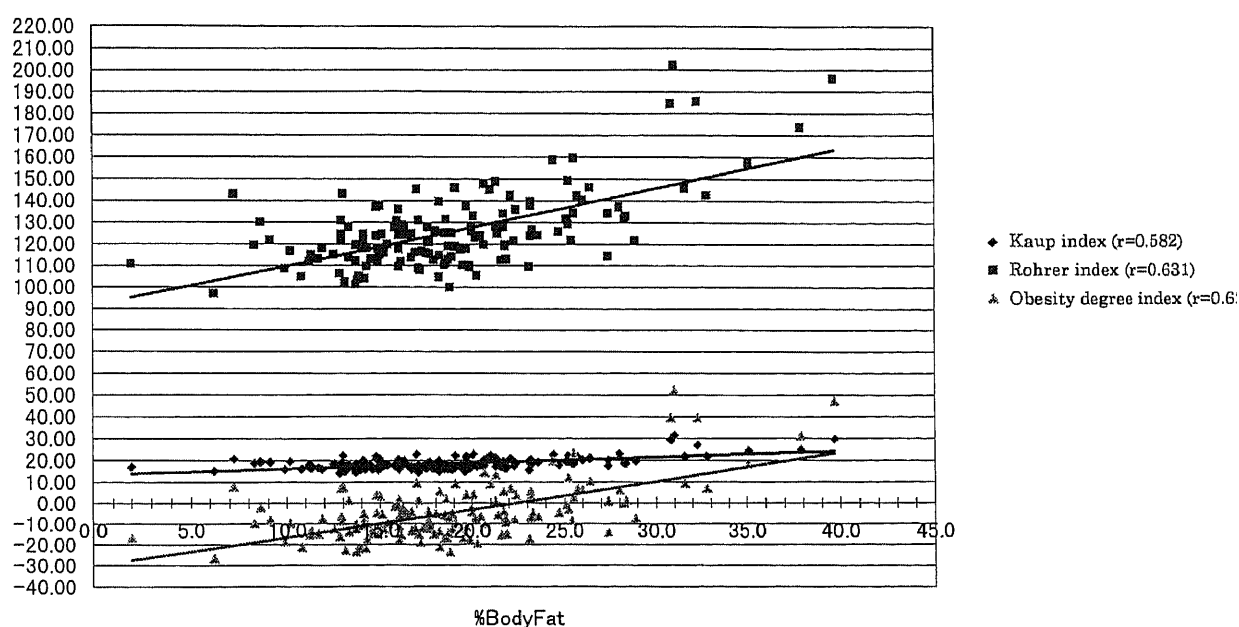


Figure 8. Relationship between percent body fat and body indices for 6<sup>th</sup> grade boys.

higher :  $F=4.150$ ,  $P<0.04$ . For total body water, a difference between the sexes was also recognized for 5th graders, with girls significantly higher :  $F=6.314$ ,  $P=0.012$ . There was no difference between the sexes recognized for the Kaup index.

Table 2 shows average height, weight, body composition and standard deviation, categorized by grade and sex for obese children with a Kaup index greater than 22. For boys, there were 8 subjects (8.2%) in the

3<sup>rd</sup> grade, 13 (10.2%) in the 4<sup>th</sup> grade, 25 (20.5%) in the 5<sup>th</sup> grade, and 14 (9.5%) in the 6<sup>th</sup> grade. In girls, there were 7 subjects (6.1%) in the 3<sup>rd</sup> grade, 3 (3.8%) in the 4<sup>th</sup> grade, 34 (26.4%) in the 5<sup>th</sup> grade and 32 (26.0%) in the 6<sup>th</sup> grade, with a difference recognized by sex and grade level in the rate of occurrence of obesity. With regards to body composition, with increasing grade level for both boys and girls, there is seen an increase in height, weight, to

Table 1 Average height, weight, body composition and Kaup index with standard deviation.

|                       | N   | BH                | BW           | %BF             | TBF          | LBM           | TBW           | Kaup         |
|-----------------------|-----|-------------------|--------------|-----------------|--------------|---------------|---------------|--------------|
| 3 <sup>rd</sup> grade |     |                   |              |                 |              |               |               |              |
| boys                  | 97  | 130.504± 5.381    | 29.129±5.606 | 19.196±6.027**  | 5.785±3.039  | 23.265±3.178  | 16.908±2.527  | 17.009±2.632 |
| girls                 | 115 | 130.017± 6.147    | 28.453±5.681 | 21.138±3.918    | 6.104±2.214  | 22.344±3.854  | 16.308±2.825  | 16.840±2.638 |
| 4 <sup>th</sup> grade |     |                   |              |                 |              |               |               |              |
| boys                  | 127 | 135.439± 5.682**  | 31.940±6.895 | 20.132±5.957    | 6.628±3.381  | 25.194±4.122  | 18.477±2.894  | 17.355±2.874 |
| girls                 | 105 | 137.580± 7.079    | 32.713±6.862 | 20.045±3.575    | 6.649±2.438  | 26.060±4.811  | 19.036±3.518  | 17.206±2.390 |
| 5 <sup>th</sup> grade |     |                   |              |                 |              |               |               |              |
| boys                  | 122 | 140.649± 5.993*** | 35.948±7.488 | 21.028±6.069    | 7.940±4.190  | 28.008±4.565* | 20.457±3.348* | 18.077±2.793 |
| girls                 | 129 | 144.088± 7.315    | 37.664±7.502 | 21.022±4.151    | 8.081±2.938  | 29.327±5.571  | 21.587±3.727  | 18.137±2.794 |
| 6 <sup>th</sup> grade |     |                   |              |                 |              |               |               |              |
| boys                  | 148 | 147.577± 7.937    | 40.742±9.851 | 19.130±6.085*** | 8.074±4.353* | 32.869±6.623  | 24.003±4.850  | 18.453±3.328 |
| girls                 | 123 | 147.983±13.698    | 41.775±8.196 | 21.510±4.672    | 9.180±3.639  | 32.585±5.231  | 23.801±3.829  | 18.861±3.158 |

N: no. of subjects BH: body height(cm) BW: body weight(Kg) %BF: percent body fat(%) TBF: total body fat(Kg) LBM: lean body mass(Kg)

TBW: total body water(Kg) Kaup: Kaup index

\*:P&lt;0.05 \*\*:P&lt;0.01 \*\*\*:P&lt;0.001

Table 2 Kaup index greater than 22 for obese children categorized by grade level, sex, and average height, weight, and body composition with standard deviation.

|                       | N  | BH            | BW            | %BF          | TBF          | LBM          | TBW          | Kaup         |
|-----------------------|----|---------------|---------------|--------------|--------------|--------------|--------------|--------------|
| Boys                  |    |               |               |              |              |              |              |              |
| Grade 3 <sup>rd</sup> | 8  | 131.275±5.380 | 40.638± 3.351 | 31.138±4.971 | 12.638±2.374 | 28.000±2.979 | 20.450±2.176 | 23.574±1.244 |
| 4 <sup>th</sup>       | 13 | 136.969±5.237 | 45.008± 6.271 | 30.854±3.760 | 13.123±4.029 | 29.962±6.611 | 22.723±3.129 | 23.894±1.965 |
| 5 <sup>th</sup>       | 25 | 144.924±6.694 | 47.608± 6.741 | 28.952±6.288 | 14.384±4.618 | 33.208±5.989 | 24.280±4.383 | 22.691±1.821 |
| 6 <sup>th</sup>       | 14 | 154.936±7.265 | 61.771±11.766 | 27.743±8.316 | 17.571±7.498 | 44.200±6.976 | 32.300±5.113 | 25.649±3.977 |
| Girls                 |    |               |               |              |              |              |              |              |
| Grade 3 <sup>rd</sup> | 7  | 136.843±5.341 | 43.043± 3.797 | 28.000±2.905 | 12.014±1.431 | 31.029±3.265 | 22.686±2.383 | 23.837±1.560 |
| 4 <sup>th</sup>       | 4  | 144.075±7.298 | 49.675± 6.240 | 27.175±1.033 | 13.425±1.217 | 36.250±5.039 | 26.500±3.665 | 24.065±2.015 |
| 5 <sup>th</sup>       | 34 | 147.441±4.782 | 46.524± 5.833 | 24.835±4.106 | 11.735±2.684 | 34.788±3.944 | 25.418±2.890 | 21.913±1.898 |
| 6 <sup>th</sup>       | 32 | 151.103±6.269 | 51.572± 8.285 | 26.506±4.671 | 13.784±3.790 | 37.788±5.559 | 27.606±4.071 | 22.957±3.154 |

N: no. of subjects BH: body height(cm) BW: body weight(Kg) %BF: percent body fat(%) TBF: total body fat(Kg) LBM: lean body mass(Kg)

TBW: total body water(Kg) Kaup: Kaup index

Table 3 %BF greater than 25% for obese children categorized by grade level, sex, and average height, weight, body composition and Kaup index with standard deviation.

|                       | N  | BH            | BW            | %BF          | TBF          | LBM          | TBW          | Kaup         |
|-----------------------|----|---------------|---------------|--------------|--------------|--------------|--------------|--------------|
| Boys                  |    |               |               |              |              |              |              |              |
| Grade 3 <sup>rd</sup> | 16 | 132.881±1.965 | 37.269± 4.308 | 30.713±3.170 | 11.500±2.249 | 25.769±2.523 | 18.813±1.829 | 21.119±2.332 |
| 4 <sup>th</sup>       | 23 | 136.939±5.733 | 40.865± 7.619 | 30.230±2.924 | 12.022±3.679 | 27.757±5.711 | 20.735±3.445 | 21.726±2.974 |
| 5 <sup>th</sup>       | 26 | 144.558±6.699 | 44.158± 8.293 | 30.181±4.724 | 14.027±4.749 | 30.115±5.563 | 22.015±4.084 | 21.191±3.264 |
| 6 <sup>th</sup>       | 25 | 149.676±7.168 | 50.104±14.710 | 29.360±4.357 | 15.428±6.164 | 35.876±7.808 | 26.220±5.720 | 22.669±4.426 |
| Girls                 |    |               |               |              |              |              |              |              |
| Grade 3 <sup>rd</sup> | 17 | 131.288±7.795 | 35.565± 6.385 | 27.947±2.877 | 9.941±2.143  | 25.624±4.637 | 18.712±3.399 | 20.867±2.699 |
| 4 <sup>th</sup>       | 11 | 142.473±5.777 | 43.673± 7.281 | 26.809±1.328 | 11.700±2.047 | 31.973±5.337 | 23.355±3.909 | 21.474±2.672 |
| 5 <sup>th</sup>       | 19 | 144.926±6.096 | 45.258± 8.276 | 28.326±2.189 | 12.847±2.892 | 32.411±5.642 | 23.679±4.143 | 21.764±2.791 |
| 6 <sup>th</sup>       | 23 | 150.017±7.480 | 51.526±10.117 | 29.134±2.685 | 15.062±3.494 | 36.457±7.009 | 26.630±5.123 | 22.737±2.907 |

N: no. of subjects BH: body height(cm) BW: body weight(Kg) %BF: percent body fat(%) TBF: total body fat(Kg) LBM: lean body mass(Kg)

TBW: total body water(Kg) Kaup: Kaup index

body fat and total body water, while a decrease in percent body fat.

Table 3 shows average height, weight, body composition and standard deviation, categorized by grade and sex, for obese children with percent body fat

greater than 25%. For obese children with percent body fat greater than 25%, for boys, there were 16 subjects in the 3<sup>rd</sup> grade (16.5%), 23 (18.1%) in the 4<sup>th</sup> grade, 26 (21.3%) in the 5<sup>th</sup> grade, and 25 (16.9%) in the 6<sup>th</sup> grade. For 3<sup>rd</sup> grade girls as

subjects, there were 17 (14.8%), 11 (10.5%) in the 4<sup>th</sup> grade, 19 (14.7%) in the 5<sup>th</sup> grade, and 23 (18.7%) in the 6<sup>th</sup> grade. There was no clear difference seen in the rate of occurrence of obesity based on grade level or sex. With regards to body composition, for both boys and girls, as grade level increased, height, weight, total body fat, lean body mass, and total body water increased, while the Kaup index also increased slightly.

### Discussion

Percent body fat and body index showed strong correlation, however the obesity degree index, most considered in development, showed a rather low value in comparison with the other two body indices. The Kaup index, equivalent to the BMI, showed strong correlation to percent body fat, and the results of other researchers<sup>4, 5)</sup> agree (figure 1-8). From comparative results of body change categorized by grade level and sex, as grade level increased for both boys and girls, height and weight increased. Along with body development, total body fat, lean body mass, and total body water also reflected increase, with Kaup index also gradually showing a high value. For 3<sup>rd</sup> grade and 6<sup>th</sup> grade boys, percent body fat decreased. This is because, due to the fact that lean body mass is high, total body fat is low relative to weight. This matches reports that reflect this trend from ages 8 to 20<sup>6)</sup>. Also, 4<sup>th</sup> and 5<sup>th</sup> grade girls are taller than boys, the results reflecting values for lean body mass and total body water, and the observance of differences in compositional development between boys and girls (Table 1).

It is recognized that for children judged to be obese with a Kaup index of 22, as their grade level increases, there is an increase in height, weight, total body fat, lean body mass, and total body water. However, percent body fat decreased. Although an increase in weight reflects an increase in total body fat, lean body mass and body composition such as total body water, the decrease in percent body fat with increasing grade level indicates that the total body fat ratio is low and by this, it is suggested that the Kaup index does not reflect percent body fat, but that it strongly estimates weight as a body index. Also, the ratio of occurrence of obesity for 3<sup>rd</sup> and 4<sup>th</sup> graders

was high for boys, trending high for 5<sup>th</sup> and 6<sup>th</sup> grade girls, and depending upon the conditions for development of each sex in the various grade levels, the Kaup index judgment of obesity differed (Table 2).

For obese children with percent body fat greater than 25%, as grade level increased, height, weight, total body fat, lean body mass and total body water increased, while the Kaup index increased slightly. For boys, the 6<sup>th</sup> grade Kaup index value was rather high compared to other grades, however this is only after entering the 6<sup>th</sup> grade that lean body mass and total body water clearly increased, and here, the Kaup index for 6<sup>th</sup> grade boys reflects weight rather than percent body fat. Furthermore, compared to other grades, this indicates a small correlation between percent body fat and Kaup index for 6<sup>th</sup> grade boys. Similarly, the Kaup index increased for 4<sup>th</sup> grade girls while the correlation between percent body fat and Kaup index showed its lowest value for all girls. All of these results show the change in body composition of boys and girls as they approach puberty.

In comparing results for the judgment of obesity according to Kaup index and percent body fat, the average weight of those judged by the Kaup index had a percent body fat greater than 25%, a value much greater than for the average weight of children judged to be obese. Boys were especially high for all grades, with 3<sup>rd</sup> to 5<sup>th</sup> graders around 4 kg and 6<sup>th</sup> graders around 11.5 kg. Girls were not as high as boys. However, the lower the grade level, the higher the difference, with 3<sup>rd</sup> and 4<sup>th</sup> graders showing a difference of as much as 7kg. Moreover, for obesity judged by the Kaup index, for both boys and girls, percent body fat for boys and girls was low, and those with high lean body mass, total body water and heavy weight were judged to be obese. For those judged to be obese by percent body fat, the Kaup index showed a normal range, compared to judgment by the Kaup index, and those with low lean body mass and total body water and high percent body fat were judged to be obese (Table 3). Following, the Kaup index showed a strong correlation to percent body fat. However, in the judgment of obesity, the estimates for body composition showed a clear difference. Here, the expected limitations of body indices through height and weight can be seen<sup>7)</sup>.

## Conclusion

Percent body fat showed a strong correlation to body indices. However, judgment of obesity by percent body fat gives a Kaup index within the normal range for non-obese children, and children with high percent body fat were judged obese. On the other hand, by the judgment of obesity by the Kaup index, heavy children with good physique were judged to be obese. Categorized by sex, from the 6<sup>th</sup> grade, boys, and from the 4<sup>th</sup> grade, girls show a clear change in body composition. It follows that in the field of health in the schools, the results of this study will aid in the realization of the necessity to accurately judge obesity, to detect obesity early and to enact intervention in its early stages.

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## 学童の体脂肪率と体格指数、および体組成との関係

木村留美子

### 要 旨

小学3年生から6年生の児童966名（男子494名、女子472名）を対象に、子どもの肥満判定の検討を目的とし、Kaup指数、Rohrer指数、肥満度の3つの体格指数と体脂肪率の関係を検討した。また、体組成とKaup指数および体脂肪率の関係についても検討を行った。体脂肪率は体格指数と強い相関関係にあったが、Kaup指数による肥満判定は、除脂肪量や体水分量により体重の重い体格のよい肥満ではない子どもも肥満と判定していた。体脂肪率による肥満判定では6年生の男女だけがKaup指数が22以上の肥満であった。