《**Original Articles**》

The actual state of impaired glucose tolerance in young Japanese people and its relationship with physique

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Abstract

Purpose: Inappropriate diet among young people has been linked to a greater prevalence of ill health and lifestyle diseases in younger generations. Despite this, health examinations of young people targeting early detection of lifestyle diseases are not being carried out. In particular, there are hardly any reports of the oral glucose tolerance test (OGTT) being performed on young people. We therefore examined the actual state of impaired glucose tolerance (IGT) and its association with body mass index (BMI) and body fat percentage in past data on 75 g OGTT results from university students.

Methods: A total of 1,772 healthy university students (200 men and 1,572 women, mean age of 20.4 ± 0.6 years, BMI of 20.5 ± 2.4 kg/m^2) were given a 75 g OGTT and had their body composition measured.

χ^2 tests and Fisher's exact tests were performed to examine the association between OGTT blood glucose level and BMI as well as body fat percentage. Logistic regression analysis was performed on the factors affecting having a blood glucose level of 180 mg/dl or higher measured one hour after the glucose load (one-hour blood glucose level).

Results: IGT was present in 34.0% of men and 45.1% of women, and the proportion of those with a one-hour blood glucose level of 180 mg/dl or higher was 21.0% for men and 37.8% for women. Both proportions were significantly higher for women. However, no association with BMI or body fat percentage was observed. Logistic regression analysis adjusted for sex, fasting blood glucose level, BMI, and body fat percentage was performed to determine the factors affecting a one-hour blood glucose level of 180 mg/dl or higher and the results revealed an odds ratio of 2.89 (95% confidence interval, 1.84–4.54) for women compared to men.

Conclusion: IGT was observed in about 40% of young people who were not obese, and the risk of IGT was higher for women. However, no association with BMI or body fat percentage was observed. Further studies are needed to determine the factors affecting IGT in young women.

Keywords: impaired glucose tolerance (IGF), young Japanese women, 75g OGTT

I. Introduction

Japan is currently said to be in an age of plenty, and the increase in the number of people with or at risk of lifestyle diseases rooted in obesity is becoming graver. The fiscal year (FY) 2015 National Health and Nutrition Survey for Japan revealed that

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younger generations had greater problems balancing nutrient intake, and it was reported that type 2 diabetes prevalence is increasing among young people[1]. Meanwhile, the problem of "thinness" is also becoming increasingly serious among young women. A challenge concerning lifestyle habits from puberty to adolescence is that Japanese women have a strong desire to be thin and excessive dieting is becoming a social phenomenon among young people. Dieting to achieve thinness has been reported to result in nutrient imbalances, abnormal eating behavior, and subjective feelings of ill health[2-5]. Despite this, young people are not being targeted for health examinations focusing on lifestyle diseases. Studies have been carried out to observe people with glucose metabolism disorders with a focus on relatively younger generations among those receiving a complete physical examination or participating in a group health examination[6], but almost no investigative reports can be found on people around the age of 20.

In light of this, we performed a 75 g oral glucose tolerance test (OGTT) with a simple blood glucose meter on healthy university students. Although their body mass index (BMI) was only about 20 kg/m^2, many of the students exhibited impaired glucose tolerance (IGT). From the perspective of diabetes prevention, it is necessary to identify young people who are at risk of IGT. We therefore examined the association between IGT and BMI as well as body fat percentage in past data on 75 g OGTT results from university students.

II. Methods

1) Study subjects

A 75g OGTT with a simple blood glucose meter (Autodisksensor; Bayer Yakuhin,Ltd., Osaka, Japan and GLUCOCARD; ARKRAY,Inc., Kyoto, Japan) was performed on third year university students at N University. Body composition was measured at the same time using a TBF-210 body composition scale with an automatic height meter (Tanita Corp., Tokyo, Japan). From the sample of 1,954 students obtained from 2005 to 2016, data that were written incorrectly, data that were unreliable, and data with missing values were excluded. In addition, two students in their thirties or older were excluded as the target was young people, and two obese students with a BMI of 30 kg/m^2 or higher were excluded, leaving 1,772 students for the final analyses.

2) Statistical analysis

The associations between blood glucose levels at 0, 30, 60, and 120 minutes during the 75 g OGTT and BMI as well as body fat percentage were tested. The 75 g OGTT results were divided into four categories based on diabetes criteria[7]: (1) normal type: fasting blood glucose level of below 110 mg/dl and two-hour blood glucose level of below 140 mg/dl; (2) borderline type: neither diabetic type nor normal type with a one-hour blood glucose level of below 180 mg/dl; (3) borderline type: neither diabetic type nor normal type with a one-hour blood glucose level of 180 mg/dl or higher; and (4) diabetic type: fasting blood glucose level of 126 mg/dl or higher and two-hour blood glucose level of 200 mg/dl or higher. We classified the borderline type into two groups in order to investigate the number of people of type with high one-hour blood glucose level. In this study, all but the normal type were regarded as IGF.

R version 3.3.3 was used for statistical analysis. χ^2 tests and Fisher's exact tests were performed to compare sex, physique, and blood glucose level. Logistic regression analysis was performed on the factors affecting having a blood glucose level of 180 mg/dl or higher at one-hour blood glucose level of 75g OGTT. P <0.05 was considered significant difference.

3) Ethical considerations

The study protocol was approved by the research ethics committee of Nagoya University of Arts and Sciences. Data for the present study were collected during practical training in a clinical nutrition class by performing 75 g OGTTs with a simple blood glucose meter. Students were then given an oral explanation that the data would be used again for research purposes, that submission of data was voluntary, that they would not suffer any negative consequences to their grades or otherwise, and that submission of data

could be withdrawn at any time. The data were then collected, and submission of data was deemed as providing consent to participate.

III. Results

1) Characteristics of the subjects

Characteristics of the subjects are shown in Table 1. Subjects were 200 men (11.3%) and 1,572 women (88.7%) with a mean age of 20.4 ± 0.6 years. Their mean BMI was 20.6 ± 2.4 kg/m^2 and mean body fat percentage was 24.8 ± 6.6%.

The 75 g OGTT gave a total mean fasting blood

glucose level of 89.5 ± 12.3 mg/dl and blood glucose level of 157.4 ± 44.1 mg/dl at 30 minutes, 167.4 ± 38.4 mg/dl at 60 minutes, and 137.2 ± 30.2 mg/dl at 120 minutes.

2) Associations between sex and physique as well as blood glucose level (Table 2)

Dividing BMI into three groups with cutoff values at 18.5 kg/m^2 and 25 kg/m^2 revealed that there were 266 women (16.9%) in the underweight category of 18.5 kg/m^2 or lower as opposed to only 16 men (8.0%) in the same category, with the proportion of women in the underweight category being signifi-

Table 1　Characteristics of the subjects

		All	Male	Female
n		1,772	200	1,572
age	(years)	20.4±0.6	20.5±0.9	20.4±0.5
height	(cm)	159.7±6.5	169.9±6.1	158.3±5.3
body weight	(kg)	52.6±8.0	61.9±9.7	51.4±7.0
BMI	(kg/m^2)	20.6±2.4	21.4±2.9	20.5±2.4
body fat percentage	(%)	24.8±6.6	16.3±5.0	25.9±5.9
《75g oral glucose tolerance test》				
Fasting BG	(mg/dl)	89.5±12.3	97.3±12.5	88.5±12.0
BG　30 minutes	(mg/dl)	157.4±44.1	159.0±27.4	157.2±45.8
BG　60 minutes	(mg/dl)	167.4±38.4	153.6±31.9	169.2±38.8
BG 120 minutes	(mg/dl)	137.2±30.2	125.9±22.0	138.6±30.8

BMI : body mass index, BG : blood glucose　　　　　　　　　　　　　　　　　　(mean±SD)

Table 2　Association between sex and physique as well as blood glucose level

	Male (200)	Female (1,572)	p value
BMI	n (%)		
<18.5	16 (8.0)	266 (16.9)	
18.5≦ and <25	169 (84.5)	1251 (79.6)	<0.001
25≦	15 (7.5)	55 (3.5)	
75g OGTT result			
Normal type	132 (66.0)	895 (56.9)	
Borderline type (BG 60 mimutes <180 mg/dl)	42 (21.0)	279 (17.7)	
Borderline type (BG 60 mimutes ≧180 mg/dl)	24 (12.0)	331 (21.1)	0.001
Diabetic type	2 (1.0)	67 (4.3)	
BG 60 minutes in the 75g OGTT			
<180 mg/dl	158 (79.0)	978 (62.2)	
≧180 mg/dl	42 (21.0)	594 (37.8)	<0.001

BMI : body mass index, OGTT : oral glucose tolerance test, BG : blood glucose

cantly higher.

Dividing the 75 g OGTT results into four categories showed women to have a significantly higher proportion of diabetic type and borderline type than men, with a combined proportion of 43.1% for women. Women also had a significantly higher proportion of one-hour blood glucose level of 180 mg/dl or higher, at 37.8%.

3) Associations between physique and blood glucose level in women (Table 3–1, Table 3–2)

We then examined the associations of blood glucose level with BMI and body fat percentage in women who had a large proportion of borderline type in the 75 g OGTT. No clear associations were observed between the proportion of that category in the 75 g

OGTT or the proportion of women with a one-hour blood glucose level of 180 mg/dl or higher and BMI. Moreover, no clear associations were observed when dividing the 266 women in the underweight category into two groups using a body fat percentage cutoff value of 20% and performing comparisons again. In other words, physique was not associated with 75 g OGTT results in women.

4) Analysis of the factors associated with a one-hour blood glucose level of 180 mg/dl or higher (Table 4)

Logistic regression analysis adjusted for sex, fasting blood glucose level, BMI, and body fat percentage was then performed to determine the factors affecting a one-hour blood glucose level of 180 mg/dl. The results revealed that there was no effect of BMI

Table 3–1　Association between physique and blood glucose level in women

	BMI			P value
	<18.5	18.5≦ and <25	25≦	
75g OGTT result		n (%)		
Normal type	150 (56.3)	715 (57.2)	30 (54.5)	
Borderline type	101 (38.0)	486 (38.8)	23 (41.8)	0.777
Diabetic type	15 (5.6)	50 (4.0)	2 (3.6)	
BG 60 minutes in the 75g OGTT				
<180 mg/dl	159 (59.8)	786 (62.8)	33 (60.0)	0.610
≧180 mg/dl	107 (40.2)	465 (37.2)	22 (40.0)	

BMI : body mass index, OGTT : oral glucose tolerance test, BG : blood glucose

Table 3–2　Association between body fat percentage and blood glucose level in women (BMI<18.5)

	Body fat percentage		P value
	<20%	≧20%	
BG 60 minutes in the 75g OGTT		n (%)	
<180 mg/dl	159 (59.8)	786 (62.8)	0.610
≧180 mg/dl	107 (40.2)	465 (37.2)	

BMI : body mass index, BG : blood glucose, OGTT : oral glucose tolerance test

Table 4　The Factors related to hyperglycemia at 60 minutes of 75g OGTT by logistic regression analysis

	Odds ratio	(95% CI)	p value
Sex	2.89	(1.84–4.54)	<0.001
Fasting blood glucose	1.02	(1.01–1.03)	<0.001
Body mass index	0.99	(0.94–1.05)	0.758
Body fat percentage	1.00	(0.97–1.02)	0.717

Hyperglycemia represents 180 mg/dl or more of blood glucose level.

OGTT : oral glucose tolerance test

or body fat percentage. However, an association with sex was observed, with an odds ratio of 2.89 (95% confidence interval, 1.84–4.54) for women compared to men.

IV. Discussion

We examined associations between the data from 75 g OGTTs performed with a simple blood glucose meter on healthy university students and sex as well as physique. The results showed that over 40% of women had IGT, in particular, 37.8% had a one-hour blood glucose level of 180 mg/dl or higher. However, no association with BMI or body fat percentage was observed. Moreover, tests to determine the factors affecting having a one-hour blood glucose level of 180 mg/dl or higher revealed an association with sex, with an odds ratio of 2.89 (95% CI, 1.84–4.54) for women compared to men. However, no association with BMI or body fat percentage was observed.

The majority of the subjects of this study were women, with 1,572 women (88.7%) and 200 men (11.3%). Examining physique, both men and women had slightly lower BMIs than the values in the FY2015 National Health and Nutrition Survey[1], but there was no great difference. The values in the present study may therefore be considered to represent the general population of young people in Japan.

The results of the present study showed as much as 40% of students to have IGT. As for studies investigating the prevalence of IGT using the results of employee health examinations for employees aged 40 to 50, Iwahashi *et al.*[8] found that 116 of 939 (12.4%) of subjects who were not obese with a BMI of less than 25 exhibited IGT or diabetic type. Kanazawa *et al.*[9] found that 77 of 230 (33.5%) of subjects with a BMI of 22.9 ± 10.3 mg/dl exhibited IGT or diabetic type. Compared to these studies, emphasis should be given to the finding in the present study that clearly showed a high prevalence of IGT even among healthy young people. Moreover, in a recent study, 99 university students (mean age of about 21, mean BMI of about 21 mg/dl)[10], 13 (15%) had IGT, which was lower than the prevalence observed in the present

study. However, 40 students (40%) tested positive for urinary glucose that was used as an indicator of hyperglycemia in the OGTT. In particular, over half of women tested positive. This result is similar to the finding in the present study of a high prevalence of an OGTT one-hour blood glucose level of 180 mg/dl or higher in young women. Compared to the above studies, the findings in the present study must be considered very carefully, and the affecting factors must urgently be determined.

In the present study, the proportion of subjects with IGT was significantly higher among women. As a factor affecting one-hour blood glucose level of 180 mg/dl or higher, there was an odds ratio of 2.89 (95% CI, 1.84–4.54) for women compared to men. In a study by Miki *et al.*[10] who performed OGTT on university students, there was a higher prevalence of IGT among women. In a previous study[11] examining the effects of pre-test fasting time on OGTT in university students who were not obese, blood glucose levels were higher and the effects of fasting time were larger in women. Some reasons why women are at higher risk may be due to a smaller physique than men, sex differences in the endocrine system, daily diet, and activity level. Further in-depth studies are needed to examine those associations.

The cause of IGT is generally insulin resistance due to obesity. However, the target of the present study was non-obese young people, and their mean BMI was 20.6 kg/m^2 and body fat percentage was 16.3% and 25.9% for men and women, respectively, indicating that they were actually thin. Lean body mass was also not associated with glucose tolerance in this study (not shown in the data). From these results, we assume that the cause of impaired glucose tolerance is not an increase in insulin resistance but a decrease in insulin secretion ability which is not affected by the physique. The cause of insulin secretion reduction may be an inappropriate diet, for example, skipping a meal or eating a low carbohydrate diet. Concerning carbohydrate intake and glucose tolerance, a decrease in insulin secretion volume has been observed during 75 g OGTT even when a low

carbohydrate meal was eaten the night before[12]. Samaha *et al.*[13] found that having 132 obese individuals eat either a high carbohydrate diet (80%) or low carbohydrate diet (10%) for six months resulted in reduced insulin sensitivity during the OGTT in the low carbohydrate diet group. Accordingly, continuing an extreme low carbohydrate diet for a long time from early in life may lead to disuse of beta cells and increase the risk of diabetes later in life. Marshall *et al.*[14] examined dietary intake in 1,317 subjects comprising people with diabetes, people with IGT, and healthy people and stated that the cause of diabetes could be high fat, low carbohydrate diets. In addition, in recent years, studies have found that a low carbohydrate diet pattern is a risk for type 2 diabetes[15,16] and gestational diabetes[17]. Further investigations are needed to examine the effects of a low carbohydrate diet on insulin secretion and sensitivity and associations with diseases in young people.

In the present study, 75 g OGTT blood glucose level was measured with a simple blood glucose meter, therefore, it may not be an accurate value. In addition, data were collected by school year, and there was insufficient analysis of the large changes that occurred in the students' circumstances over the previous ten years. Moreover, we did not examine eating habits the present study, and therefore cannot clearly determine the association between glucose metabolism disorder and diet. Considering that there may also be effects of genetic factors on glucose metabolism disorder, in addition to diet, genetic background must also be examined and those associations analyzed.

However, we analyzed data from about 1,800 students over 12 years in the present study, and the results may be thought to show the actual state of IGT in young people in Japan overall, and therefore present extremely important findings. Further studies are needed to examine diet and other background aspects of young people, and especially young women, to determine the risk factors.

V. Conclusion

IGT was observed in about 40% of young people who were not obese, and the risk of IGT was higher for women. However, no association with BMI or body fat percentage was observed. Further studies are needed to determine the factors affecting IGT in young women.

VI. Acknowledgments

VII. References

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《原著》

日本人若年者における耐糖能異常の実態および体格との関連

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要旨

【目的】若年者の不適切な食生活が健康不良や生活習慣病の若年齢化に関連があるとされているにも関わらず、生活習慣病の早期発見を対象にした若年者の健康診断は実施されていない。特に、若年者を対象にした糖負荷試験（OGTT）の報告は極めて少ない。そこで、これまでに大学生を対象として行った75gOGTT の過去のデータについて、耐糖能異常の実態、さらに BMI および体脂肪率との関連について検討した。

【方法】健康な大学生1772名（男200名、女性1572名、年齢20.4±0.6歳、BMI20.5±2.4kg/m²）を対象に75gOGTT を行い、体組成を測定した。この OGTT の血糖値と BMI および体脂肪率との関連について、χ^2検定と Fisher の正確検定を用いて検討した。さらに、1時間血糖値が180mg/dl 以上に影響を与える要因について、ロジスティック回帰分析を用いて検討した。

【結果】耐糖能異常者は男性と女性でそれぞれ34.0％と45.1％存在し、また1時間値が180mg/dl 以上になる割合は男性と女性でそれぞれ21.0％と37.8％存在した。また、そのどちらも女性の方が有意に高かった。しかしながら、BMI および体脂肪率との関連は認められなかった。さらに、1時間値が180mg/dl 以上になる要因について、性別、空腹時血糖、BMI および体脂肪率で調整したロジスティック回帰分析の結果、男性に対する女性のオッズ比は2.89（95%CI 1.84-4.54）であった。

【結論】肥満でない若年者の約4割に耐糖能異常が認められ、そのリスクは女性の方が高かった。しかし、BMI および体脂肪率に関連は認められなかった。今後、若年女性と耐糖能異常の要因について検討する必要がある。

キーワード：耐糖能異常、若年女性、75g 糖負荷試験

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