Correlations between Anthropometrics and Electrocardiographic Variables in Japanese University Students: Investigation by Annual Health Screening

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Authors' contributions

This work was carried out in collaboration between all authors. Author TM had the initial research concept, and made the manuscript writing and revision. Authors NY, KK, RT and YM performed the health screening and data acquisition. Authors JN and MI made the advice on statistics. Authors AI and KY managed the annual health screening protocol and data extraction. Author KU is the team leader and supervised the team collaboration. All authors read and approved the final manuscript.

Original Research Article

ABSTRACT

Aims: Anthropometrics provide important health and fitness indicators in University students and have potential impacts on electrocardiographic (ECG) abnormalities leading to cardiac events. However, the correlations between anthropometrics and ECG data are controversial in young adults. This study aimed to investigate the effects on ECG of body mass index (BMI) in Japanese University students which shows unique distribution differing from that in the western youths.
Place of the Study: Infirmaries of Kyushu University Campus, Fukuoka, Japan.
Methodology: Participants (n = 6,786) were recruited from legal Annual Health Screening Program

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of a Japanese University (2014 and 2015), and 6,649 participants (4,693 males and 1,956 females) were the subjects of the study protocol. Anthropometric and blood pressure (BP) measurements and ECG recording were conducted.

Results: This study demonstrated age-matched gender difference of BP, anthropometrics and ECG, i.e., PR interval and QRS duration in males were longer than corresponding parameters in females but the opposite was found in the QT interval corrected by heart rate (QT_c). BP and some ECG variables were dependent on BMI but the dependence of each ECG parameter on BMI differed individually in regression analyses. Positive linearity was found in PR interval and QRS duration, and negative linearity was obtained in frontal QRS axis, i.e., lengthening of PR interval and QRS duration and leftward shift of QRS axis were observed by BMI increment. Concaved parabolic correlation between QT_c and BMI may indicate that lean and high BMI groups with relative QT_c prolongation require lifestyle intervention.

Conclusions: The findings obtained by this mass screening are helpful in healthcare management of Japanese University students showing anthropometrics quite different from those in westerners.

1. INTRODUCTION

The standard twelve-lead electrocardiogram (ECG) remains the key item to detect cardiovascular diseases. To date, computerized ECG interpretation algorithm is a practical tool for cardiac healthcare and mass-screening of University students. Digital ECG diagnosis is characterized by many borderline diagnoses, so-called 'normal variant'. Although individual ECG finding is subnormal, cumulative impacts of such ECG findings on the long-term health outcomes are not negligible [1,2]. ECG parameters are sensitive to anthropometric background, which changes dramatically during the whole periods of time in the University campus life. Moreover, nutrition, food affordability and weight regulation in Japanese University students are fundamentally different from those in Western University students.

There have been many problems in eating behavior among Japanese University students. Solo-eating and rapid eating cause body fat accumulation [3] and skipping breakfast underlies chronic fatigue, malnutrition, menstrual disorder and future osteoporosis [4]. Such unfavorable dietary habits stem from inaccurate own weight perception leading to negative health outcomes in overweight or underweight youths [5]. Nevertheless, the effects of anthropometrics on cardiac structure and function reflected by ECG have not been fully investigated in the University students in Japan. Therefore, this study aimed to investigate the relationship between anthropometrics and ECG findings in Japanese University students undergoing Annual Health Screening Program.

2. METHODOLOGY

2.1 Participants

This study was conducted in Annual Health Screening of Kyushu University (Fukuoka, Japan) between April 2014 and April 2015 in accordance with the updated Declaration of Helsinki (2008), and 6,649 participants aged 19.9 ± 3.6 years ranging from 17 to 32 years (4,693 male and 1,956 female) were the subjects of the study protocol. Annual Health Screening Program includes taking histories and physical findings by physicians working at the University Campus Infirmaries or the Kyushu University Hospitals, the anthropometric measurements of body height (BH: cm), body weight (BW: kg) and body fat percentage, blood pressure (BP: mmHg) measurements, urinalysis, chest X-ray and electrocardiogram (ECG) recordings. BP was measured automatically in sitting position after taking a few minutes rest (Kentaro HBP-9021, Omron-Colin Healthcare, Tokyo, Japan). Body mass index (BMI) was calculated automatically by dividing BW (kg) by square of BH (m). Body fat (%) was estimated using bio-impedance method simultaneously with BH and BW measurements (TANITA DC-250, Tokyo, Japan). Thereafter, interviews concerning lifestyle were performed by public health nurses for the students with their BMI ≥ 25.0 or BMI < 18.5. Demographic variables of the enrolled participants were extracted from health screening personal cards. General exclusion criteria included the evident thyroid, liver, or kidney diseases under medication, and the presence of congenital heart diseases either operated or not. Anthropometrics yields four different BMI groups,

i.e., lean BMI group (BMI < 18.5), moderate BMI group (18.5 ≤ BMI < 25.0), overweight group (25.0 ≤ BMI < 30.0), and obese group (30.0 ≤ BMI). For rarity in obese Japanese, three groups were set depending on different BMI, i.e., lean BMI group (BMI < 18.5), moderate BMI group (18.5 ≤ BMI < 25.0), and high BMI group (25.0 ≤ BMI) in this study.

2.2 ECG Recordings

Twelve-lead ECG was recorded in supine position using digital ECG recorder (CARDISUNY C310, FUKUDA ME, Tokyo, Japan), and was printed if required at a paper speed of 25 mm/sec and amplitude of 10 mm/mV or 5 mm/mV as appropriate. PR interval was defined as the time period from the beginning of the P wave to the beginning of the QRS complex. QRS duration was defined as the interval from the beginning to the end of the QRS complex. QT interval was measured from the beginning of the QRS complex to the end of the T wave. QT interval was corrected by heart rate (HR: bpm) using the Bazett's formula (QT_c: msec) where $QT_c = QT/RR^{1/2}$. ECG data were diagnosed based on Minnesota code, transferred using A/D converter, and stored automatically to a personal computer (VAIO, model SVP132A16N, SONY®, Tokyo, Japan). Thereafter, all ECG recordings were reviewed by cardiologists in a blind manner. ECG exclusion criteria were documented arrhythmias, manifest WPW syndrome, bundle branch block, and atrioventricular block with its degree of second or more. Participants recruited at the beginning of Annual Health Screening program were 6,786 university students including 4,801 males and 1,985 females. According to the two-step exclusion criteria, 6,649 participants aged 19.9 ± 3.6 years ranging from 17 to 32 years (4,693 male and 1,956 female) were the subjects of the study protocol. Participants were divided into three groups based on BMI, i.e., group of lean participants (BMI < 18.5, n = 785), that of participants with moderate stature (18.5 ≤ BMI < 25, n = 5157), and that of obese participants (BMI ≥ 25, n = 707).

2.3 Statistical Analysis

All data were continuous and expressed as means ± standard deviation (SD). Data sets were examined by Kolmogorov-Smirnov test and Shapiro-Wilks test for normality. Optimal regression analyses were performed by the standard least squares method and considered as a regression showing the highest Pearson's product-moment correlation coefficient (*r*), whichever primary regression line or quadratic regression curve was fitted. When considering intergroup comparison, Student's *t* test or one-way analysis of variance (ANOVA) was used for parametric variables and Mann-Whitney analysis or Kruskal-Wallis analysis was performed for other variables. Intergroup comparisons, Spearman's multiple correlation and partial correlation analysis were performed using Predictive Analytics Software (PASW) version 18.0 for Windows (Statistical Package for Social Science (SPSS), Inc., IBM, Chicago, IL, USA).

3. RESULTS

3.1 Baseline Characteristics and Gender Difference

Baseline demographics and ECG data of all the participants (n = 6,649) are detailed in Table 1. All the listed continuous variables did not show normality except for BH. Mean age in males did not differ from that in females (p = 0.113). Unintended age-matched comparison yielded gender difference, i.e., BH, BW and BMI in male students were greater than those in female students (p < 0.001), whereas body fat in females was greater than that in males (p < 0.001). Both systolic and diastolic BPs in males were higher than respective BPs in females (p < 0.001). Gender difference was found also in ECG variables, i.e., PR interval and duration of QRS complex in males were greater than respective parameters in females (p < 0.001), whereas QT_c interval in females was longer than that in males (p < 0.001).

3.2 Correlation between BMI and Other Characteristics

Concerning crude multiple correlation analyses, BMI had positive correlation with body fat and both systolic and diastolic BPs in male and female participants (p < 0.001). BMI affects also ECG variables profoundly. Concerning QRS complex, positive correlations between BMI and duration of QRS complex and negative correlations between BMI and frontal axis of QRS complex were obtained in both male and female participants (p < 0.001). Positive correlation between BMI and PR interval was also observed in both genders. ECG variables are generally influenced by BMI and BP, and BP is also influenced by BMI. Therefore, partial

correlation analysis was performed with systolic and diastolic BPs as control variables. Adjustment for BP made the correlation between BMI and other variables clearer, i.e., BP-adjusted partial correlation yielded association of BMI with body fat, HR, PR and QT_c intervals, QRS duration and axis in both genders (Table 2).

Comparisons among three groups with different BMI were demonstrated in Table 3. BP showed differences depending on BMI range in both male and female participants, i.e., the greater BMI caused the higher BP ($p < 0.001$). HR was lowest in the group of moderate stature in males ($p < 0.001$). With respect to ECG variables, PR interval, QRS duration and QRS axis revealed difference depending on BMI range in males ($p < 0.001$), but such difference was limited in QRS axis in females ($p < 0.001$). QT_c interval showed no intergroup difference in both male and female subjects.

3.3 Regression Analyses of BMI and ECG Variables

To analyze the correlation between BMI and other characteristics in more detail, regression analyses were performed including all participants. Correlation between BP and BMI was clearly fitted by quadratic function showing that both systolic and diastolic BPs elevated as BMI increased (Fig. 1). HR as a function of BMI was fitted by quadratic function showing weak concaved parabola (Fig. 2). Individual ECG variable demonstrated different BMI-dependence. PR interval and QRS duration were weakly fitted by respective positive linear function (Fig. 3). On the other hand, negative linear correlation between BMI and frontal QRS axis was obtained, and the correlation between BMI and QT_c interval was weakly fitted by quadratic function showing concaved curve with a large flat bottom (Fig. 4).

Table 1. Baseline characteristics and electrocardiographic variables of enrolled subjects

	Total (n = 6,649)	Male (n = 4,693)	Female (n = 1,956)	p value
Age (years)	19.9 ± 3.6	19.9 ± 3.7	19.8 ± 3.6	0.113
Height (cm)	167.3 ± 8.0	171.1 ± 5.7	158.4 ± 5.2	< 0.001
Weight (kg)	60.3 ± 10.7	63.9 ± 9.9	51.5 ± 6.9	< 0.001
Body fat (%)	21.0 ± 6.2	19.1 ± 5.6	25.6 ± 5.2	< 0.001
Body mass index (kg/m^2)	21.4 ± 3.0	21.8 ± 3.1	20.5 ± 2.5	< 0.001
Systolic blood pressure (mmHg)	123.6 ± 16.3	127.0 ± 15.9	115.3 ± 13.9	< 0.001
Diastolic blood pressure (mmHg)	72.1 ± 10.0	73.5 ± 9.9	68.6 ± 9.4	< 0.001
Heart rate (beats per minutes)	75 ± 14	74 ± 14	75 ± 13	0.013
PR interval (msec)	143 ± 19	144 ± 19	139 ± 18	< 0.001
QRS duration (msec)	85 ± 11	87 ± 11	79 ± 9.3	< 0.001
QRS axis (degree)	68 ± 27	68 ± 28	67 ± 23	< 0.001
QTc interval (msec)	386 ± 22	384 ± 23	392 ± 20	< 0.001

Data given as mean ± standard deviation.

Table 2. Multiple correlations between body mass index and baseline characteristics including electrocardiographic variables

	SBP	DBP	body fat	heart rate	PR interval	QRS duration	QRS axis	QTc interval
Male (r)	0.363	0.261	0.830	0.016	0.100	0.102	-0.229	-0.030
(p value)	<0.001	<0.001	<0.001	0.279	<0.001	<0.001	<0.001	0.039
(r)	—	—	0.817	-0.108	0.067	0.081	-0.180	-0.082
(p value)	—	—	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Female (r)	0.231	0.133	0.901	-0.001	0.059	0.093	-0.192	-0.009
(p value)	<0.001	<0.001	<0.001	0.957	0.009	<0.001	<0.001	0.690
(r)	—	—	0.904	-0.131	0.046	0.079	-0.165	-0.051
(p value)	—	—	<0.001	<0.001	0.043	<0.001	<0.001	0.024

SBP, systolic blood pressure; DBP, diastolic blood pressure. The upper figures mean standard or partial correlation coefficients and the lowers mean the probabilities.
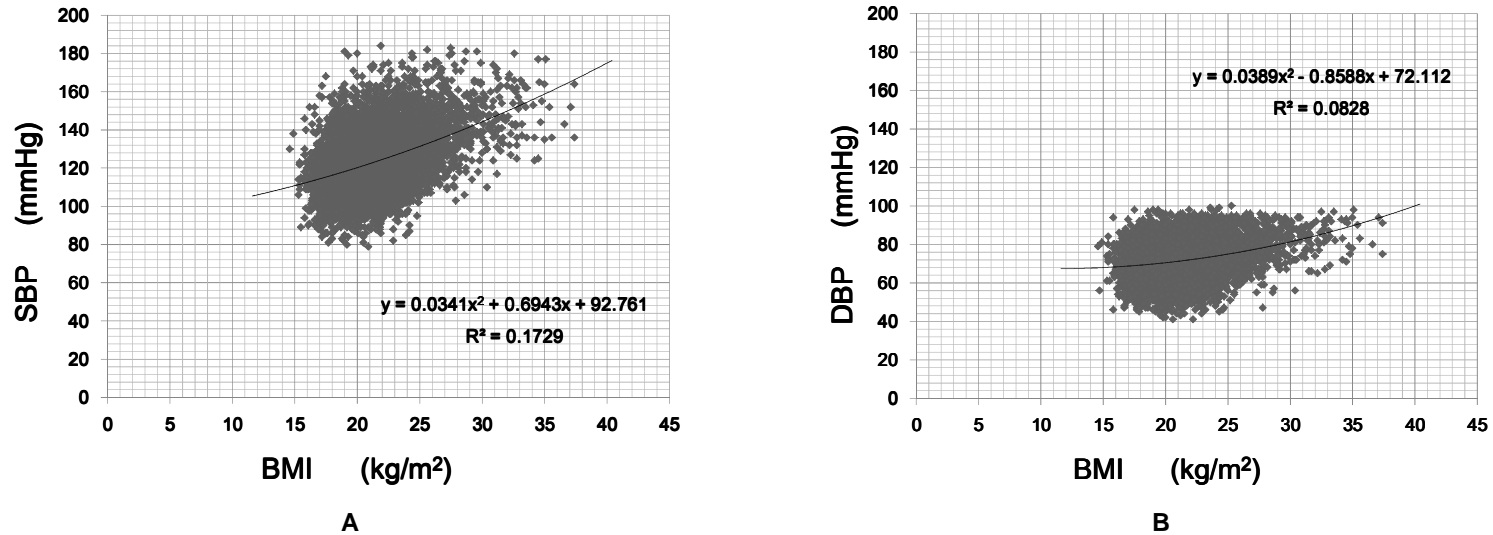
A   B

Fig. 1. Plotting of systolic (A) and diastolic (B) blood pressure (SBP and DBP: mmHg) as a function of body mass index (BMI: kg/m^2). Both showed positive correlations.

Table 3. Differences of blood pressure and electrocardiographic variables between three groups with different body mass index

	(n)	SBP	DBP	heart rate	PR interval	QRS duration	QRS axis	QTc interval
Male	4693							
BMI < 18.5	426	119.0 ± 14.2	70.5 ± 9.3	76 ± 15	140 ± 19	85 ± 9.7	76 ± 25	386 ± 23
18.5 ≤ BMI < 25	3658	125.7 ± 14.7	72.7 ± 9.5	74 ± 14	144 ± 19	87 ± 11	69 ± 28	384 ± 23
25 ≤ BMI	609	140.9 ± 16.4	80.7 ± 9.9	77 ± 15	147 ± 18	88 ± 11	57 ± 31	385 ± 22
p value	—	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.185
Female	1956							
BMI < 18.5	359	111.9 ± 13.0	67.7 ± 9.0	75 ± 14	138 ± 18	78 ± 9.7	72 ± 24	393 ± 21
18.5 ≤ BMI < 25	1499	115.1 ± 13.4	68.2 ± 9.3	75 ± 13	140 ± 19	79 ± 9.2	67 ± 23	392 ± 20
25 ≤ BMI	98	130.4 ± 13.7	76.8 ± 9.4	78 ± 15	143 ± 15	79 ± 9.0	57 ± 24	390 ± 19
p value	—	<0.001	<0.001	0.279	0.022	0.155	<0.001	0.531

BMI, body mass index; SBP, systolic blood pressure; DBP, diastolic blood pressure. Data given as mean ± standard deviation.
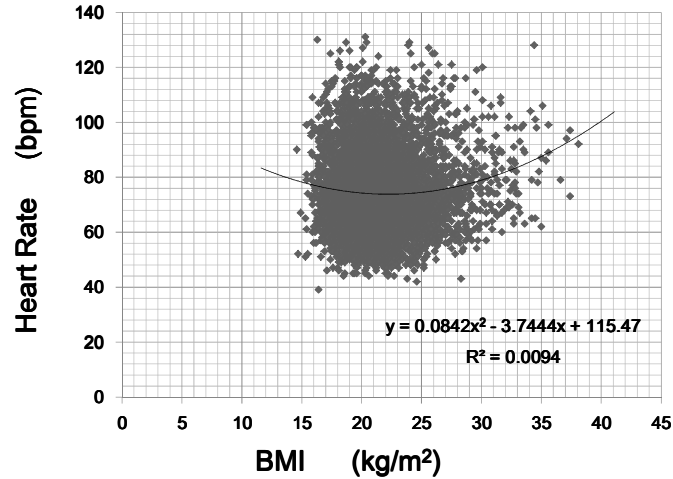
The scatter plot shows: $y = 0.0842x^2 - 3.7444x + 115.47$, $R^2 = 0.0094$

Fig. 2. Plotting of heart rate (bpm) as a function of body mass index (BMI: kg/m^2) showing concaved parabolic relation.

4. DISCUSSION

The main findings of this study are 1) age-matched gender difference of BP, anthropometrics and some ECG variables, 2) BMI-dependent difference in BP and ECG variables in both genders, and 3) lengthening of PR interval and QRS duration and leftward shift of frontal QRS axis according to an increase in BMI.

Anthropometrics such as body size and composition are important health and fitness indicators, and, therefore, these evaluations are of healthcare benefit especially for the University students. It has been recognized that systemic obesity as assessed by BMI influences BP and ECG findings profoundly. Overweight (30 > BMI ≥ 25.0) and obesity (BMI ≥ 30.0) have significant impact on sustaining high BP in Japanese epidemiology (1980 - 2010) [6], which was confirmed in this study (Fig. 1). In spite of worldwide trend toward an increase in BMI, Japanese children and adolescents have demonstrated no evidence of a major rise in the prevalence of obesity as expressed by mean BMI [7]. This is possibly caused by strong desire to and social pressure against thinness in Japanese adolescents who may have erroneous ideal BW and body image [8]. This speculation is supported by unique distribution of BW showing that average, median, and mode of BW are scattered in males (63.9, 62.6 and 58.8 kg, respectively) and females (51.5, 50.8 and 46.9 kg, respectively) leading to the positive skewness

(1.072 in males and 1.050 in females). This is probably the major reason for many data not distributed normally.

BMI also has significant impacts on ECG data. PR interval indicates intra-atrial and atrioventricular conduction time, and QRS duration means intra-ventricular conduction time. These ECG intervals showing narrow reference ranges strictly regulate cardiac performance. It is reported from the last century that BMI increment is associated with PR lengthening, QRS widening and leftward shift of frontal QRS axis [9 − 13]. These findings were confirmed in our study (Fig. 3 & 4), and gender was certainly a factor affecting on ECG variables (Table 1). PR lengthening observed in high BMI group is probably due to increased intra-atrial conduction time rather than atrioventricular conduction delay, because increased left atrial size is one of the features of subclinical cardiac remodeling observed in obese youth [14]. Leftward QRS frontal axis deviation is associated with cardiac geometry altered by obesity, whereas QRS widening is reportedly due to enlarged ventricles due to increased hemodynamic overload [15]. Cardiac remodeling in obese adolescents is recognized as so-called 'obesity cardiomyopathy', which is based on insulin resistance, enhanced renin-angiotensin system, low-grade inflammation and oxidant stress [16 − 18]. Weak but credible concaved curves of HR-BMI relation (Fig. 2) and QT$_c$ -BMI relation (Fig. 4) may be compatible to this concept.
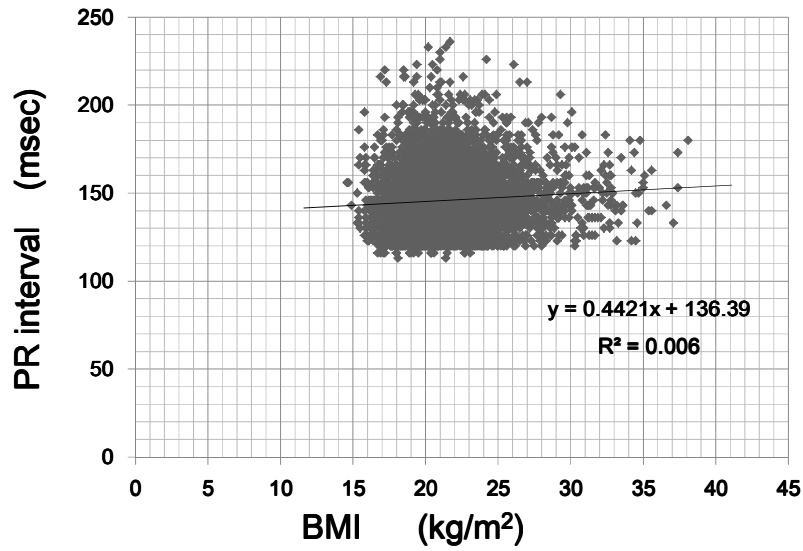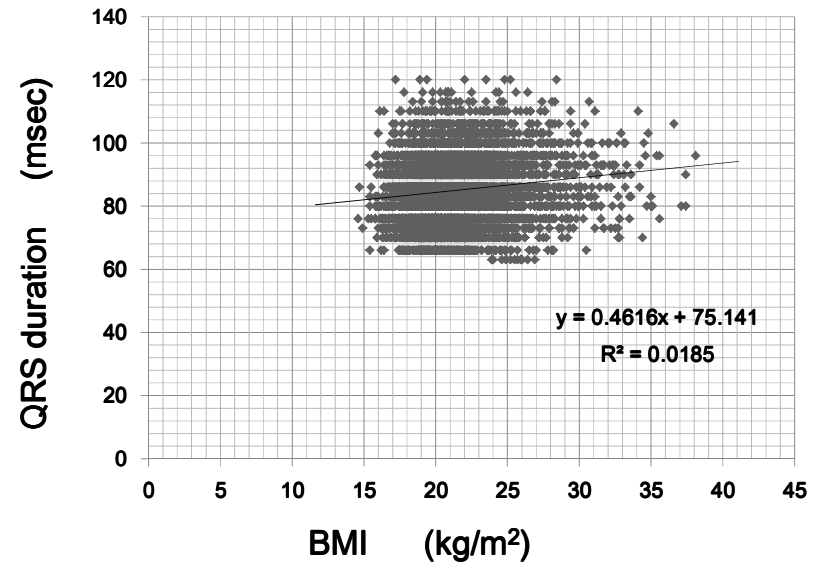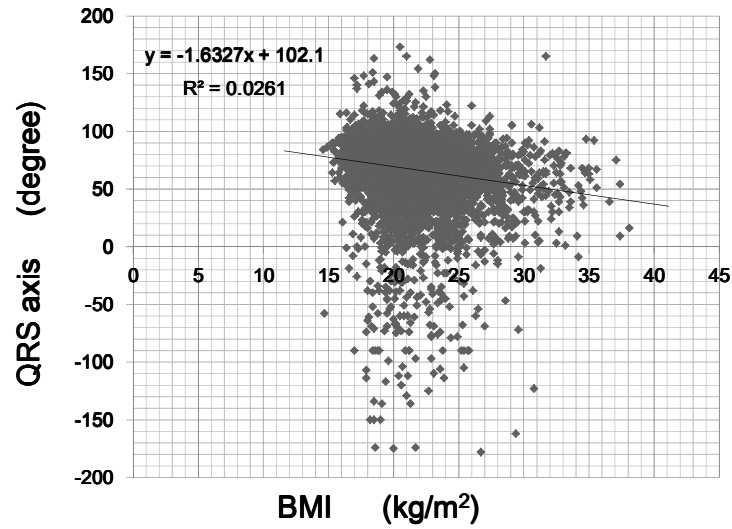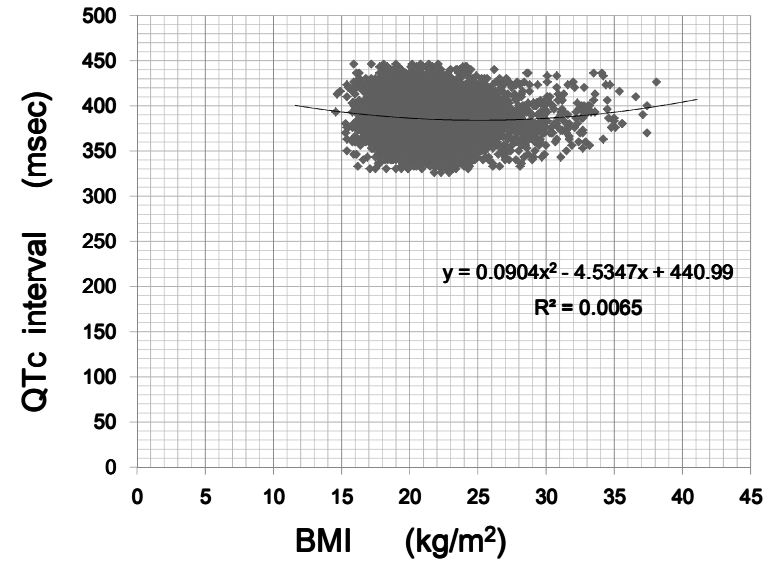
Fig. 3. Plotting of PR interval (msec) in A and QRS duration (msec) in B as a function of body mass index (BMI: kg/m^2). Both showed weak positive linearity

A

B

Fig. 4. Plotting of QRS axis (degree) in A and QTc interval (msec) in B as a function of body mass index (BMI: kg/m^2). The former showed negative linearity (A) and the latter showed weak concaved parabolic relation (B).

QT interval depends deeply on HR and influenced by body temperature, autonomic nervous activity, electrolyte balance, sex hormone, modifier genes and many pathophysiological factors, and adolescents with QT_c ranging from 440 to 470 msec are diagnosed as borderline QT prolongation [19,20]. Reportedly, the correlation between BMI and QT_c interval has been conflicting especially in children and adolescents, i.e., Nasir et al. reported significant (p < 0.0001) difference in QT_c intervals in relation to four different BMI groups (lean (BMI < 18.5), moderate (18.5 ≤ BMI < 25.0), overweight (25.0 ≤ BMI < 30.0) and obese (30.0 ≤ BMI) groups), although the effects of BMI are minimal causing the intergroup difference of QT_c interval < 5 msec [12]. Sun et al. also demonstrated no difference of QT_c intervals among the three different BMI groups (i.e., normal, overweight and obese groups) [13]. The present study supports the findings of the former study. Such discrepancy is derived perhaps from the lean BMI group, i.e., study by Nashir et al did but that of Sun et al did not include the lean BMI group (BMI < 18.5), which may have a trend of muscle shortage, malnutrition or autonomic nervous instability. BP adjustment yielded negative correlation between BMI and HR and between BMI and QT_c interval in both genders (Table 2), indicating that lean BMI group shows relative tachycardia which underlies tendency toward QT prolongation. Lean group sometimes includes preclinical eating problems such as low-calorie diet, mild anorexia nervosa and electrolytes imbalance such as hypokalemia or hypomagnesemia leading to QT prolongation [21–25], which is known as cardiac electrical instability causing life-threatening arrhythmia triggered by stress-induced autonomic nervous activity [26,27].

The association of QT prolongation with severe obesity is known from the last century and is reported to be independent of age, sex and BP [8,9]. QT prolongation correlates to the increased left ventricular (LV) mass in high BMI group (BMI ≥ 25.0) [28]. This prolongation is associated with increased risk of sudden cardiac death in several prospective studies, although it is uncertain whether that is mediated by fatal arrhythmia or not [29,30]. QT_c interval prolonged in obesity is a surrogate of subclinical insulin resistance, low-grade inflammation and atherosclerosis or an outcome of altered sex hormone metabolism observed in adiposity [31–35]. The assessment of QT_c interval behavior as a function of BMI is of importance especially in the University students

with high physical activity to prevent sudden cardiac death. The main reasons for the trend of negative correlation between BMI and QT_c interval are the rarity of severe obesity in Japanese youths and premature age for risk factors to influence QT_c interval. The present study of mass screening ECG helps promote healthcare in Japanese University students showing unique BMI distribution.

5. LIMITATIONS

The findings of this observational study should be interpreted carefully due to some limitations. First of all, comorbidities of obesity such as sleep apnea, diabetes and dyslipidemia were not investigated. Second limitation is the bias attributed to BMI distribution, which does not show normality, i.e., positive skewness (1.072 in males and 1.050 in females) may indicate desire to be thinner in Japanese University students. However, correlations between Box-Cox transformed BMI and study variables did not demonstrate substantial changes relative to the outcomes shown in Table 2 (not shown). The cross-sectional nature of the present study is the third limitation. Single ECG should not predict health risk [20], and the association of ECG variables with cardiac remodeling and reversibility of BMI-related ECG variables are the matters of future study using cohort with lifestyle intervention.

6. CONCLUSION

It is worth investigating correlation between anthropometrics and ECG findings in Japanese University students who seem resistant to the current environment causing obesity in the Western countries. Although some limitations permits, the present study demonstrated 1) age-matched gender differences of BP, anthropometrics, and ECG parameters where PR and QRS intervals in males were longer whereas QT_c interval in males was shorter than the respective ECG intervals in females, 2) association of BMI with BP and ECG variables such as PR interval and QRS duration, and 3) concaved curve of HR and QT_c interval as a function of BMI increment, indicating that QT_c lengthening in lean and high BMI groups may imply respective systemic or cardiac subclinical abnormalities. Intervention to the University students with lean and high BMI by dietary lifestyle counseling is required.

CONSENT

Health data extraction was informed to all the participants on the day of health screening. Furthermore, participants were allowed to opt out of data extraction if they offered.

ETHICAL APPROVAL

Annual health screening is mandatory in terms of the Japanese School Health and Safety Act. All procedures performed in this study involving University students were in accordance with the ethical standards of our institutional and/or national research committee and with the updated Declaration of Helsinki (2008).

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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