Available online at www.sciencedirect.com

SciVerse ScienceDirect

Journal of Electrocardiology 45 (2012) 646–651

JOURNAL OF Electrocardiology

www.jecgonline.com

The effects of body mass index on surface electrocardiograms in young adults☆

Javed M. Nasir, MD,* Bernard J. Rubal, PhD, Samuel O. Jones, MD, MPH, Anand D. Shah, MD

Department of Cardiology, SAMMC, San Antonio, TX, USA

Received 10 April 2012

Abstract

Introduction: While BMI is known to affect ECG measurements, these effects have not been well characterized in young adults.

Methods: We retrospectively reviewed all ECGs performed in adults 18 to 35 years old at a single institution over a 30 year period. ECG measurements were derived electronically and stratified by WHO BMI category.

Results: A total of 55,218 ECGs were included. Increasing BMI led to increased P wave duration and decreasing P, R, and T wave axes. Additionally, while increasing BMI led to less R wave voltage, J point elevation, and T wave amplitude in patients with a BMI $\geq 18.5\,kg/m^2$, there was also a decrease in the measured parameters in patients with a BMI $<18.5\,kg/m^2$.

Discussion: BMI had significant effects on ECG measurements. For accurate assessment of ECGs, these data should be incorporated into established nomograms. Further investigation into the effects of BMI on the ECG is warranted.

Published by Elsevier Inc.

Keywords: Electrocardiogram; Body mass index; ECG; BMI

Introduction

Since the invention of the galvanometer by Einthoven in 1901, the electrocardiogram (ECG) has become the most commonly performed cardiac procedure, with an estimated 20 million ECGs performed annually in the United States (US).[1] The ECG has become ubiquitous in modern medicine and is essential for the diagnosis, treatment, and screening for cardiovascular diseases. While most ECG readers consider the patient's baseline demographics (e.g., gender, age, ethnicity, and body composition) during ECG interpretation, the effects of these variables have not been fully characterized.

For more than three decades, San Antonio Military Medical Center (SAMMC) has collected and electronically stored ECGs obtained from active duty and dependent personnel from diverse segments of the US population. This large electronic repository provides a unique opportunity to assess for demographical differences in ECG measurements in a young adult population unlikely to have comorbid conditions. Here we analyze and report the effects of the body mass index (BMI) on ECG waveform measurements and assess the interaction of BMI with gender, age, and ethnicity. Although there are limitations in the accuracy of BMI for reporting adiposity, BMI is the most prevalent index of obesity and is used as an index of cardiovascular risk.[2]

Methods

Study design

For this project we queried all the ECGs stored in SAMMC's MUSE (General Electric Healthcare) database between 1980 and 2010 in subjects 18 to 35 years old. We limited our search to ECGs that had been verified as a "normal ECG" after interpretation by a member of the Cardiology department, had heart rate of 60 to 100 bpm, a QRS duration <120 ms, a PR interval greater than 110 ms, and a QRS axis between −30° and 90°. Computerized analysis of all waveforms was performed with Marquette

☆ Disclaimer: The opinions expressed on this document are solely those of the authors and do not represent an endorsement by or the views of the United States Air Force, the Department of Defense, or the United States Government.

* Corresponding author. Department of Cardiology, 81st MDOS/SGOMC, Keesler AFB, MS 39564, USA.

E-mail address: javed.nasir@us.af.mil

0022-0736/$ – see front matter. Published by Elsevier Inc.
http://dx.doi.org/10.1016/j.jelectrocard.2012.07.022

Table 1
Baseline demographics.

	All (n=55,218)	Male (n=34,101)	Female (n=21,117)
Mean age (years)	25.9±5.4	25.8±5.3	26.1±5.4
Ethnicity (%)			
- Caucasian (n=40,255)	72.9	77.5	65.5
- African American (n=8666)	15.7	11.7	22.1
- Hispanic (n=2281)	4.13	3.9	4.5
- Other (n=4016)	7.27	6.9	7.9
Height (cm)	171.5±9.9	176.6±7.4	163.2±7.6
Weight (kg)	73.3±13.5	78.5±11.1	65.0±12.5
Mean BMI (kg/m^2)	24.9±3.9	25.2±3.2	24.4±4.7
BMI category (%)			
- BMI <18.5 kg/m^2 (n=1300)	2.4	1.0	4.5
- BMI 18.5 to <25 kg/m^2 (n=29,054)	52.6	47.7	60.5
- BMI 25 to <30 kg/m^2 (n=19,875)	36.0	44.3	22.6
- BMI ≥30 kg/m^2 (n=4989)	9.0	7.0	12.4

This figure illustrates the baseline demographics of the study cohort. When males were compared to females, there were significant differences ($p \leq 0.001$) in all demographic data.

12SL (General Electric Healthcare), and demographic data were collected by ECG technicians when the ECG was acquired. BMI was calculated as weight/body surface area^2 (kg/m^2) and classified into four categories using the World Health Organization (WHO) BMI criteria:[3] underweight (<18.5 kg/m^2), normal (18.5 to <25 kg/m^2), overweight (25 to <30 kg/m^2), and obese (≥30 kg/m^2). For this analysis, age was classified into two groups, 18 to ≤25 years or >25 to 35 years, while ethnicity was categorized dichotomously as Caucasian or non-Caucasian.

Waveform data were collected from all leads, but we have limited this analysis and report to select, clinically relevant measures. ECG measurements are reported and analyzed for the P wave duration, P wave amplitude (lead II), axes (P, R, and T wave), R wave amplitude, T wave amplitude, and J point elevation. More specifically, R wave amplitude was summed and examined in three categories: all leads, the precordial leads, and the frontal leads. T wave amplitude was treated as an absolute value and examined in four separate categories: maximal T wave amplitude, summed from all leads, summed from the precordial leads, and summed from the limb leads. J point elevation was also summed and examined in five categories: all leads, inferior leads (II, III, aVF), lateral leads (I, V_{4-6}), high lateral leads (I, aVL) and anterior leads (V_2–V_4).

Details of the derivation and validity of ECG waveform measurements from 12SL are available elsewhere.[4] In general, amplitudes are measured in each lead individually, and the interval measurements (e.g., P wave duration, PR interval, QRS interval, and QT interval) are measured simultaneously across all leads using a median complex. These measurements have been validated against electrocardiographic common standards, and many of the measurements have been validated independently in the scientific literature.[4]

Statistical analysis

Data are presented as means±standard deviations (SD), percentages, or graphically as box-and-whisker plots to indicate the dispersion of data about the median. The whiskers of the box plot represent 1.5× the lower and upper inner quartiles limits or limits of the data if data are <1.5× quartile limit. To improve clarity, the box-and-whisker plots are displayed without outliers. A Student's t-test was employed to assess differences between genders in scalar demographic data, and a Z-test was used to assess difference in population frequencies. A fixed-effect linear model ANOVA (IBM SPSS Version 19.0) was employed to assess the difference in the ECG characteristic among WHO BMI categories and the significance of interaction between BMI and age, gender, and ethnicity. The Bonferroni post hoc test was applied for multiple group comparisons. All statistical tests were two-tailed with p values considered significant if <0.05.

Results

Our MUSE database contained 99,499 ECGs that met the inclusion criteria specified above. Due to limitations in MUSE's export function, completed data collection was achieved for 93,218 of these subjects. After exclusion of 14,586 duplicates and 23,414 subjects with incomplete or inaccurate demographical data, 55,218 subjects remained in our final cohort.

Subject characteristics

The demographics for the final cohort are presented in Table 1. The subjects were predominately Caucasian (72.9%) and male (61.8%), with the entire cohort having a mean age of 25.9±5.4 years. The mean BMI was 24.9±2.9 kg/m^2 with 52.6% of the subjects having a normal BMI, 36.0% were overweight, 2.4% were underweight, and 9.0% were obese.

P wave

In this cohort, the mean P wave duration was 98.3± 14.1 ms. As illustrated in Table 2, with increasing BMI there was a significant increase in the P wave duration (p<0.0001). Significant differences were observed between all BMI categories ($p \leq 0.001$), and no significant interactions were observed between BMI and gender, ethnicity or age. The mean P wave amplitude was 0.12±0.04 mV. While BMI had a statistically significant effect on the amplitude (p<0.0001), the differences in the amplitudes was minimal (<0.004 mV) and unlikely to be clinically significant.

PR interval

The mean PR interval was 148±19 ms. As illustrated in Table 2, increasing BMI was associated with a significant increase in the PR interval (p<0.0001). Comparison between groups showed a significant difference among all BMI categories (p<0.0001), except when overweight subjects were compared to obese subjects (p=0.24), and there were significant interactions of BMI with gender (p=0.0001) and ethnicity (p=0.02).