Identification of Type 2 Diabetes Risk Factors Using Phenotypes Consisting of Anthropometry and Triglycerides based on Machine Learning

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***Abstract*—The hypertriglyceridemic waist (HW) phenotype is strongly associated with type 2 diabetes; however, to date, no study has assessed the predictive power of phenotypes based on individual anthropometric measurements and triglyceride (TG) levels. The aims of the present study were to assess the association between the HW phenotype and type 2 diabetes in Korean adults and to evaluate the predictive power of various phenotypes consisting of combinations of individual anthropometric measurements and TG levels. Between November 2006 and August 2013, 11 937 subjects participated in this retrospective cross-sectional study. We measured fasting plasma glucose and TG levels and performed anthropometric measurements. We employed binary logistic regression (LR) to examine statistically significant differences between normal subjects and those with type 2 diabetes using HW and individual anthropometric measurements. For more reliable prediction results, two machine learning algorithms, naive Bayes (NB) and LR, were used to evaluate the predictive power of various phenotypes. All prediction experiments were performed using a tenfold cross validation method. Among all of the variables, the presence of HW was most strongly associated with type 2 diabetes ($p < 0.001$, adjusted odds ratio (OR) = 2.07 [95% CI, 1.72–2.49] in men; $p < 0.001$, adjusted OR = 2.09 [1.79–2.45] in women). When comparing waist circumference (WC) and TG levels as components of the HW phenotype, the association between WC and type 2 diabetes was greater than the association between TG and type 2 diabetes. The phenotypes tended to have higher predictive power in women than in men. Among the phenotypes, the best predictors of type 2 diabetes were waist-to-hip ratio + TG in men (AUC by NB = 0.653, AUC by LR = 0.661) and rib-to-hip ratio + TG in women (AUC by NB = 0.73, AUC by LR = 0.735). Although the presence of HW demonstrated the strongest association with type 2 diabetes, the predictive power of the combined measurements of the actual WC and TG values may not be the best manner of predicting type 2 diabetes. Our findings may provide clinical information concerning the development of clinical decision support systems for the initial screening of type 2 diabetes.**

***Index Terms*—Anthropometric measurements, data mining, hypertriglyceridemic waist (HW) phenotype, machine learning, predictor, triglycerides (TG), type 2 diabetes.**

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I. Introduction

NUMEROUS epidemiological and public health studies regarding the associations between anthropometric measurements and type 2 diabetes have been conducted. These studies have attempted to identify anthropometric measurements that can better predict type 2 diabetes based on ethnicity, gender, and nationality. Anthropometric measurements, such as waist circumference (WC), waist-to-hip ratio (WHR), waist-to-height ratio (WHtR), and body mass index (BMI), have been reported to be strongly associated with type 2 diabetes, and have demonstrated good predictive power in Canada [1], China [2], [3], Mexico [4], France [5], the United States [6], Jamaica [7], Vietnam [8], Hong Kong [9], Australia [10], Korea [11], and multiethnic cohorts [12]. However, the majority of these studies focused on the analysis of only one or several anthropometric measurements and risk factors suitable for the identification of type 2 diabetes.

Recently, a large number of studies exploring the effects and prevalence of the hypertriglyceridemic waist (HW) phenotype, which consists of triglyceride (TG) levels and WC, have been conducted, revealing that the HW phenotype was strongly associated with type 2 diabetes [13]–[15], cardiovascular disease [16]–[18], and metabolic syndrome [19]–[25]. These studies also commonly suggested that the concurrent use of WC and TG levels could be useful in prevalence studies of type 2 diabetes and reported better results compared to the use of WC or TG levels alone. In a previous study, LaMonte *et al.* [22] indicated that HW could be used as a sensitive, simple, and inexpensive predictor in asymptomatic female subjects with diabetes risk profiles and coronary heart disease because women with HW tend to have a higher risk for coronary heart disease than women without HW. Using the criteria established by the National Cholesterol Education Program-Adult Treatment Panel III (NCEP-ATP III) and the International Diabetes Federation (IDF), Blackburn *et al.* [21] compared the ability of HW to identify subjects with cardiometabolic risk factors and found that HW may have a similar discriminative power to the NCEP-ATP III and IDF criteria, which may enable the use of HW as a primary screening tool to detect subjects with higher cardiometabolic risks.

These previous studies have indicated that the HW phenotype is a critical predictor of type 2 diabetes. However, no study has assessed the predictive power of using various phenotypes consisting of individual anthropometric measurements and TG levels and a phenotype that uses the actual TG and WC values as components of the HW phenotype. The objective of the present

study was to assess the association between the HW phenotype and type 2 diabetes and evaluate the predictive power of many phenotypes with combinations of individual anthropometric measurements and TG levels. To our knowledge, this is the first study to analyze the predictive powers of phenotypes consisting of TG levels and other anthropometric indices in identifying type 2 diabetes in Korean adults.

II. Materials and Methods

A. Study Population

A total of 11 937 subjects (4906 males and 7031 females) 31–80 years of age participated in this retrospective cross-sectional study. All subjects were recruited between November 2006 and August 2013 from hospitals in Ansan, Anseong, and other cities in the Korea. All of the data in the present study were obtained from the Korean Health and Genome Epidemiology Study database. Written informed consent was obtained from all participants, and the Korea Institute of Oriental Medicine Institutional Review Board approved the study.

B. Measurement

The fasting plasma glucose (FPG) levels and TG levels of all subjects were measured for the diagnosis of type 2 diabetes and hypertriglyceridemia. All subjects were asked to fast for at least 8 h, and blood samples were subsequently drawn to analyze plasma glucose and TGs (ADVIA 1800, Siemens, USA).

The anthropometric measurements were obtained by well-trained observers using standardized protocols. The heights and weights of the participants were measured to the nearest 0.1 cm and 0.1 kg, respectively, (LG-150; G Tech International Co., Ltd., Uijeongbu, Republic of Korea), with lightweight clothing and without shoes. We measured the circumferences of the forehead, neck, axilla, chest, rib, waist, pelvis, and hip using nonelastic tape. For example, accurate positions of forehead and chest measurements are at the levels of the glabella and occiput and at the levels of the left and right nipples [11], [26]. Additionally, we calculated the ratios between measurements that are commonly used in anthropometry and epidemiology: The exact WHR, WHtR, neck-to-hip ratio (Neck_Hip), rib-to-hip ratio (Rib_Hip), forehead-to-neck ratio (Forehead_Neck), forehead-to-waist ratio (Forehead_Waist), forehead-to-rib ratio (Forehead_Rib), and BMI. Detailed measurement positions and descriptions were described in [11] and [26].

C. Definitions

When diagnosing type 2 diabetes in this study, we used the criteria of the American Association of Clinical Endocrinologists [27] and the 1990 World Health Organization report [28]. In detail, subjects with FPG $>$ 110 mg/dl and/or a physician's diagnosis were diagnosed with type 2 diabetes.

To diagnose subjects with the HW phenotype, we considered recent studies that have defined the HW phenotype. Male subjects with TG $\geq$ 2.0 mmol/L (177 mg/dl) and WC $\geq$ 90 cm [29]–[32] and female subjects with TG $\geq$ 1.5 mmol/L (133 mg/dl) and WC $\geq$ 85 cm [31], [33]–[35] were determined to have the HW phenotype. Male subjects with TG $<$ 2.0 mmol/L (177 mg/dl) and/or WC $<$ 90 cm and female subjects with TG $<$ 1.5 mmol/L (133 mg/dl) and/or WC $<$ 85 cm were defined as normal subjects. Table I lists the basic patient characteristics and brief descriptions. Among the men, 3849 had type 2 diabetes and 1057 were normal subjects; among the women, 6103 had type 2 diabetes and 928 were normal subjects.

D. Experimental Configuration

All statistical analyses and predictive power assessments were conducted using SPSS 19 for Windows (SPSS Inc., Chicago, IL, USA) and the Waikato Environment for Knowledge Analysis data mining tool [36].

Our methodologies focused on two different analyses: statistical analysis of the association between HW phenotype, individual measurements, and type 2 diabetes, and analysis of the predictive powers of individual measurements and various phenotypes. Previous similar studies have only focused on statistical analysis of the association between HW phenotype and type 2 diabetes [13]–[15], [29], [37]–[39]. However, these studies only used the specific range of WC and TG values to diagnosis HW phenotype. A study that is based on the specific range of TG and WC cannot find the better phenotype consisting of individual measurements and TG. We should know the predictive power of individual measurements and phenotypes to find the better predictor of type 2 diabetes. Therefore, we used two machine learning algorithms to reveal the predictive power of all phenotypes and measurements. Specifically, in the HW phenotype and single measurements, a statistical evaluation of the significant differences between the normal individuals and those with type 2 diabetes was performed using binary logistic regression (LR) after standardization was applied to the data (odds ratios [OR] and 95% confidence intervals [CI]). To compare the predictive powers of all phenotypes (single anthropometric measurements and TG levels, individual anthropometric measurements, and TG levels) in the diagnosis of type 2 diabetes, we used two machine learning algorithms, the naive Bayes (NB) algorithm and LR, in order to obtain more reliable and trustworthy results. We selected NB and LR because in preexperiments using several machine learning algorithms, these two machine learning algorithms showed the best predictive power; in addition, NB and LR are widely used for statistical analysis in medical studies because of their unique characteristics.

Two machine learning algorithms (i.e., NB and LR) are generally used to solve association, prediction, or classification problems in medial and epidemiological studies. However, a conceptual problem with NB relates to conditional independence; all features (variables) are independent, given the value of the response variable (class label). In real-world research, conditional independence assumption was unsuitable for such applications [40]. Briefly, the NB classifier estimates $P(Y|X)$ using joint probability $P(X, Y) = P(Y)P(X|Y)$ from training samples, given random variables *X* and *Y*; the weights of each feature are fitted independently (i.e., the generative classifier) [40]–[42].

The number of normal subject is greater than the number of subjects with type 2 diabetes (an unbalanced-class problem).

TABLE I
BASIC PATIENT CHARACTERISTICS AND BRIEF DESCRIPTIONS

Index	Men		Women		Description
	Normal	Diabetes	Normal	Diabetes	
Subjects	3849	1057	6103	928	Number of subjects with and without and type 2 diabetes
HW subjects	431	214	1099	355	Number of subjects with a HW phenotype
Age	55.81 (11.05)	58.49 (9.79)‡	54.39 (11.34)	61.49 (10.36)*	Age
TG	146.6 (96.34)	184.2 (153.53)‡	119.9 (69.06)	158.6 (95.68)*	TG
Glucose	93.57 (8.32)	138.6 (37.26)‡	90.85 (8.3)	140.8 (45.17)*	FPG
SBP	121.4 (15.51)	125.5 (15.78)‡	118.4 (16.73)	125.33 (16.72)*	Systolic blood pressure
DBP	80.09 (10.62)	81.25 (10.17)†	76.74 (10.67)	78.78 (10.67)*	Diastolic blood pressure
Weight	67.93 (9.99)	70.65 (9.90)‡	57.72 (8.17)	60.2 (9.17)*	Weight
BMI	24.1 (2.94)	25.07 (2.96)‡	23.84 (3.21)	25.39 (3.4)*	Body mass index
NeckC	37.56 (2.41)	38.55 (2.56)‡	33.23 (2.13)	34.4 (2.26)*	Neck circumference
ChestC	93.46 (6.30)	96.08 (6.21)‡	90.31 (7.7)	95.19 (7.58)*	Chest circumference
RibC	87.47 (6.57)	90.53 (6.25)‡	79.51 (7.81)	85.07 (7.76)*	Rib circumference
WaistC	86.68 (7.91)	90.3 (7.81)‡	83.89 (8.88)	89.33 (8.82)*	Waist circumference
HipC	93.15 (5.75)	94.16 (5.71)‡	92.92 (5.91)	94.11 (6.26)*	Hip circumference
Neck_Hip	0.4 (0.02)	0.41 (0.02)‡	0.36 (0.02)	0.37 (0.02)*	Neck-to-hip circumference ratio
Rib_Hip	0.94 (0.05)	0.96 (0.05)‡	0.86 (0.06)	0.9 (0.06)*	Rib-to-hip circumference ratio
Waist_Hip	0.93 (0.05)	0.96 (0.05)‡	0.9 (0.07)	0.95 (0.07)*	Waist-to-hip circumference ratio
Forehead_Waist	0.66 (0.06)	0.63 (0.05)‡	0.66 (0.07)	0.62 (0.06)*	Forehead-to-waist circumference ratio
Forehead_Rib	0.65 (0.05)	0.63 (0.04)‡	0.70 (0.07)	0.65 (0.06)*	Forehead-to-rib circumference ratio
Forehead_Neck	1.52 (0.08)	1.48 (0.08)‡	1.66 (0.1)	1.6 (0.09)*	Forehead-to-neck circumference ratio
WHtR	0.4 (0.05)	0.42 (0.05)	0.37 (0.05)	0.39 (0.05)*	Waist-to-height circumference ratio

† $p = 0.0015$ and ‡ $p = <0.0001$ between normal subjects and subjects with diabetes in men, * $p = <0.0001$ between normal subjects and subjects with diabetes in women.

Generally, classes with few subjects are more difficult to predict than those with numerous subjects [11], [26], [43]–[46]. However, in this study, we used an original dataset. We did not use a cost-sensitive sampling method because the characteristics of an original dataset are generally observed in medical or epidemiological studies.

In the assessment of predictive power, the area under the receiver operating characteristic curve (AUC) was used as the primary criterion. All of the prediction experiments for the predictive power measurements were performed using a tenfold cross validation.

III. RESULTS

A. Association of Type 2 Diabetes With the HW Phenotype and Individual Measurements

In the present study, there were 431 male subjects with the HW phenotype in the normal group and 214 in the diabetes group; there were 1099 female subjects with the HW phenotype in the normal group and 355 in the diabetes group. In terms of anthropometry, 14 measurements were used to predict type 2 diabetes, and all variables showed statistically significant difference between the normal group and the diabetes group for men and women, except for DBP in men ($p = <0.0001$).

Tables II and III list the results of the associations of type 2 diabetes with HW and individual anthropometric measurements in men and women. In men, when we considered the association between type 2 diabetes and HW and anthropometric indices, the presence of the HW phenotype displayed the strongest association with type 2 diabetes ($p < 0.001$, OR = 2.01 [95% CI, 1.68–2.41], adjusted OR = 2.07 [1.72–2.49]). Among only the anthropometric measurements, WHR was the most strongly associated with type 2 diabetes; it remained the best predictor after adjusting for age and region ($p < 0.001$, OR = 1.73 [1.60–1.86], adjusted OR = 1.66 [1.54–1.80]). Rib circumference (RibC) ($p < 0.001$, OR = 1.61 [1.50–1.73], adjusted OR = 1.64 [1.52–1.77]) and Forehead_Rib ($p = <0.001$, OR = 0.59 [0.55–0.64], adjusted OR = 0.61 [0.56–0.66]) were also both strongly associated with type 2 diabetes. When comparing WC and TG levels as components of the HW phenotype, the association between WC and type 2 diabetes ($p < 0.001$, OR = 1.59 [1.48–1.71], adjusted OR = 1.60 [1.48–1.72]) was greater than the association between TG levels and type 2 diabetes ($p < 0.001$, OR = 1.34 [1.26–1.44], adjusted OR = 1.38

TABLE II
ANALYSIS OF THE ASSOCIATION BETWEEN TYPE 2 DIABETES AND ANTHROPOMETRIC INDICES IN MEN

Index	Unadjusted		Adjusted	
	p	OR	p^*	OR*
HW phenotype	<0.001	2.01 (1.68–2.41)	<0.0001	2.07 (1.72–2.49)
Weight	<0.001	1.31 (1.22–1.40)	<0.0001	1.56 (1.45–1.68)
BMI	<0.001	1.39 (1.29–1.49)	<0.0001	1.53 (1.42–1.65)
NeckC	<0.001	1.49 (1.39–1.60)	<0.0001	1.61 (1.49–1.73)
ChestC	<0.001	1.51 (1.41–1.62)	<0.0001	1.60 (1.49–1.73)
RibC	<0.001	1.61 (1.50–1.73)	<0.0001	1.64 (1.52–1.77)
WaistC (WC)	<0.001	1.59 (1.48–1.71)	<0.0001	1.60 (1.48–1.72)
HipC	<0.001	1.19 (1.11–1.28)	<0.0001	1.30 (1.21–1.40)
Neck_Hip	<0.001	1.35 (1.26–1.44)	<0.0001	1.33 (1.24–1.43)
Rib_Hip	<0.001	1.63 (1.52–1.76)	<0.0001	1.60 (1.48–1.73)
Waist_Hip (WHR)	<0.001	1.73 (1.60–1.86)	<0.0001	1.66 (1.54–1.80)
Forehead_Waist	<0.001	0.60 (0.56–0.65)	<0.0001	0.62 (0.58–0.68)
Forehead_Rib	<0.001	0.59 (0.55–0.64)	<0.0001	0.61 (0.56–0.66)
Forehead_Neck	<0.001	0.65 (0.60–0.69)	<0.0001	0.64 (0.59–0.69)
WHtR	<0.001	1.36 (1.27–1.46)	<0.0001	1.57 (1.46–1.69)
TG	<0.001	1.34 (1.26–1.44)	<0.0001	1.38 (1.28–1.47)

*Results were obtained after adjustment for age and region (investigation site).

TABLE III
ANALYSIS OF THE ASSOCIATION BETWEEN TYPE 2 DIABETES AND ANTHROPOMETRIC INDICES IN WOMEN

Index	Unadjusted		Adjusted	
	p	OR	p^*	OR*
HW phenotype	<0.001	2.83 (2.44–3.28)	<0.001	2.09 (1.79–2.45)
Weight	<0.001	1.33 (1.24–1.42)	<0.001	1.46 (1.36–1.57)
BMI	<0.001	1.56 (1.46–1.67)	<0.001	1.50 (1.39–1.61)
NeckC	<0.001	1.66 (1.55–1.78)	<0.001	1.63 (1.52–1.76)
ChestC	<0.001	1.85 (1.72–1.98)	<0.001	1.68 (1.56–1.81)
RibC	<0.001	1.95 (1.81–2.09)	<0.001	1.70 (1.57–1.84)
WaistC (WC)	<0.001	1.81 (1.68–1.94)	<0.001	1.54 (1.43–1.67)
HipC	<0.001	1.21 (1.13–1.30)	<0.001	1.21 (1.13–1.30)
Neck_Hip	<0.001	1.42 (1.33–1.52)	<0.001	1.36 (1.27–1.47)
Rib_Hip	<0.001	2.23 (2.07–2.40)	<0.001	1.91 (1.75–2.08)
Waist_Hip (WHR)	<0.001	1.99 (1.85–2.14)	<0.001	1.65 (1.52–1.80)
Forehead_Waist	<0.001	0.49 (0.45–0.53)	<0.001	0.60 (0.55–0.65)
Forehead_Rib	<0.001	0.44 (0.41–0.48)	<0.001	0.53 (0.48–0.58)
Forehead_Neck	<0.001	0.51 (0.48–0.55)	<0.001	0.57 (0.52–0.61)
WHtR	<0.001	1.46 (1.36–1.56)	<0.001	1.49 (1.39–1.60)
TG	<0.001	1.50 (1.41–1.59)	<0.001	1.37 (1.29–1.46)

*Results were obtained after adjusting for age and region (investigation site).

[1.28–1.47]). These associations were not substantially altered after adjusting for age and region.

In women, among all of the variables, the presence of the HW phenotype was most strongly associated with type 2 diabetes ($p < 0.001$, OR = 2.83 [2.44–3.28], adjusted OR = 2.09 [1.79–2.45]). Among the individual indices, Rib_Hip ($p =< 0.001$, OR = 2.23 [2.07–2.40], adjusted OR = 1.91 [1.75–2.08]) and Forehead_Rib ($p =<0.001$, OR = 0.44 [0.41–0.48], adjusted OR = 0.53 [0.48–0.58]) were the most strongly associated with type 2 diabetes, with the exception of the presence of the HW phenotype. These associations were not substantially altered even after adjusting for site and age.

B. Comparison of the Predictive Powers of the Phenotypes

Tables IV and V list the comparative predictive powers of the individual anthropometric measurements and phenotypes using combinations of single measurements and TG levels in men and women. When comparing the predictive power of each of the anthropometric indices for the diagnosis of type 2 diabetes in men, WHR (AUC by NB = 0.647, AUC by LR = 0.648) had the best predictive power, but this power was only slightly higher than that of RibC, Rib_Hip, and Forehead_Rib. Regarding the predictive powers of either WC or TG levels, WC had a strong predictive power (AUC = 0.63), whereas TG did not (AUC by NB = 0.546, AUC by LR = 0.598). The WHR + TG phenotype displayed the strongest predictive power for type 2 diabetes among the phenotypes consisting of individual measurements and TG levels (AUC by NB = 0.653, AUC by LR = 0.661).

In women, Rib_Hip was the best predictor of type 2 diabetes among the indices (AUC = 0.72). When comparing WC and TG as components of the HW phenotype, the predictive power of WC (AUC = 0.672) for type 2 diabetes was superior to that of TG (AUC by NB = 0.634, AUC by LR = 0.657). Among all of the phenotypes, the Rib_Hip + TG phenotype was the best indicator of type 2 diabetes (AUC by NB = 0.73, AUC by LR = 0.735). Additionally, Forehead_Rib + TG, RibC + TG, and Waist_Hip + TG were useful phenotypes for predicting type 2 diabetes.

When predicting type 2 diabetes using the actual TG values in addition to the measurement values, the addition of the TG values to the single measurements resulted in little improvement in the predictive power compared to the single measurements. Although the presence of HW had the strongest association with type 2 diabetes, the predictive power of the combined measurements of WC and TG using their actual values (not the presence of HW) was slightly lower than that of several other phenotypes.

IV. DISCUSSION

The present study assessed the association between the HW phenotype and type 2 diabetes and evaluated the predictive powers of combined anthropometric measurements and TG levels in Korean adults. Our results indicated that among the variables examined, the presence of the HW phenotype was the most strongly associated with type 2 diabetes, even after adjusting for site and age. The findings of the present study were in agreement with those of previous studies, indicating that the presence of the HW phenotype was strongly associated with type 2 diabetes [14], [15], [29], [37]–[39]. Yu *et al.* [14] argued that Chinese men and women with HW were at an increased risk of developing diabetes and hyperglycemia compared to subjects without hypertriglyceridemia and/or abdominal obesity. Similarly, Du *et al.* [15] documented that HW and the visceral adiposity index were useful predictors of diabetes. Lemieux *et al.* [29] indicated that HW was associated with coronary artery disease (CAD) and type 2 diabetes and served as a useful and practical clinical screening tool in patients with CAD and diabetes. Egeland *et al.* [37] indicated that measurements of WC and TG levels were efficient indicators of diabetes in the Inuit people of the Canadian Arctic and noted that using several metabolic syndrome criteria to identify subjects with abnormalities was a time-consuming task. Brisson *et al.* [38] argued that the combined use of WC and TG levels in the first trimester of pregnancy in French–Canadian white women could enhance the ability of an initial screening to detect gestational diabetes. Amini *et al.* [39] documented that men and women with HW tended to have diabetes and women with HW tended to have an impaired glucose tolerance; they also found that HW could be used to detect diabetes and impaired glucose tolerance during the initial stages. They revealed that men with the HW phenotype had greater TG and cholesterol levels and lower high-density lipoprotein cholesterol levels than other groups of men without HW or men with either an enlarged WC or elevated TG levels; women with HW had higher fasting blood sugar levels.

The association between the HW phenotype and type 2 diabetes was stronger in women than in men, and phenotypes consisting of each index and TG levels tended to have higher predictive powers in women than in men. We hypothesize that one of the reasons for this phenomenon is that the relationship between anthropometric indices and type 2 diabetes is stronger in women than in men [11], [47]–[49]. For example,

TABLE IV
PREDICTIVE POWERS OF THE COMBINATION OF ANTHROPOMETRIC VARIABLES AND TGS FOR TYPE 2 DIABETES IN MEN

Index	AUC-NB	AUC-LR	Phenotype	AUC-NB	AUC-LR
Weight	0.578	0.579	Weight + TG	0.602	0.613
BMI	0.594	0.595	BMI + TG	0.612	0.621
NeckC	0.613	0.613	NeckC + TG	0.627	0.635
ChestC	0.621	0.621	ChestC + TG	0.634	0.642
RibC	0.637	0.637	RibC + TG	0.645	0.652
WaistC (WC)	0.63	0.63	WaistC + TG	0.641	0.648
HipC	0.548	0.549	HipC + TG	0.582	0.601
Neck_Hip	0.583	0.584	Neck_Hip + TG	0.6	0.616
Rib_Hip	0.634	0.634	Rib_Hip + TG	0.639	0.649
Waist_Hip (WHR)	0.647	0.648	Waist_Hip + TG	0.653	0.661
Forehead_Waist	0.633	0.633	Forehead_Waist + TG	0.643	0.65
Forehead_Rib	0.639	0.639	Forehead_Rib + TG	0.647	0.654
Forehead_Neck	0.623	0.623	Forehead_Neck + TG	0.635	0.643
WHtR	0.59	0.59	WHtR + TG	0.61	0.619
TG	0.546	0.598			

AUC-NB: The area under the receiver operating characteristic curve by NB; AUC-LR: The area under the receiver operating characteristic curve by LR.

TABLE V
PREDICTIVE POWERS OF THE COMBINATION OF ANTHROPOMETRIC VARIABLES AND TGS FOR TYPE 2 DIABETES IN WOMEN

Index	AUC-NB	AUC-LR	Phenotype	AUC-NB	AUC-LR
Weight	0.576	0.578	Weight + TG	0.643	0.66
BMI	0.633	0.633	BMI + TG	0.67	0.679
NeckC	0.653	0.653	NeckC + TG	0.678	0.688
ChestC	0.679	0.679	ChestC + TG	0.701	0.705
RibC	0.698	0.698	RibC + TG	0.714	0.718
WaistC (WC)	0.672	0.672	WaistC + TG	0.696	0.701
HipC	0.55	0.552	HipC + TG	0.634	0.657
Neck_Hip	0.606	0.606	Neck_Hip + TG	0.648	0.666
Rib_Hip	0.72	0.72	Rib_Hip + TG	0.73	0.735
Waist_Hip (WHR)	0.693	0.693	Waist_Hip + TG	0.711	0.715
Forehead_Waist	0.685	0.685	Forehead_Waist + TG	0.704	0.709
Forehead_Rib	0.713	0.713	Forehead_Rib + TG	0.725	0.729
Forehead_Neck	0.685	0.685	Forehead_Neck + TG	0.699	0.707
WHtR	0.608	0.609	WHtR + TG	0.657	0.669
TG	0.634	0.657			

AUC-NB: the area under the receiver operating characteristic curve by NB, AUC-LR: the area under the receiver operating characteristic curve by LR.

Paek and Chun [47] investigated the association between type 2 diabetes and WC and BMI in Korean adults and revealed that the type 2 diabetes predictive powers of WC and BMI were higher in women than in men. Lee *et al.* [48] studied the association between WC, WHtR, WHR, and BMI and metabolic risks in Korean women and men who participated in the healthy twin study and found that the AUC values of four anthropometric indices in the prediction of high fasting glucose levels were greater in women than in men. In addition, Lee *et al.* [11] carried out an analysis of the predictive powers of 37 anthropometric indices in identifying type 2 diabetes and reported that the majority of the anthropometric indices had better predictive powers in women than in men. Likewise, Ashwell *et al.* [49] conducted a systematic review and metaanalysis of a total of 24 studies for women and 22 studies for men in 18 different countries and reported that the predictive powers of WHtR, WC, and BMI for diabetes were stronger in women than in men. The findings of these previous studies were consistent with the results of the present study, indicating that the predictive powers of anthropometric indices used to screen for type 2 diabetes are better in women than in men.

Regarding WC and TG levels as two components of the HW phenotype, WC was the more important component of the HW phenotype because the association between WC and type 2 diabetes was higher than that of TG levels and type 2 diabetes; the predictive power of WC was also stronger than that of TG levels in both men and women. In addition, this study reported that the association between the HW phenotype and type 2 diabetes was stronger than that of WC or TG levels alone. This finding was consistent with the results of previous studies [13], [47]. For example, Okosuna and Boltrib [13] noted that the HW phenotype was more strongly associated with type 2 diabetes than either hypertriglyceridemia or increased WC. They also noted racial and ethnic differences in the relationship between HW and type 2 diabetes: The association between type 2 diabetes and HW was much higher in black men and women than in white men and women. Sam *et al.* [50] indicated that in non-Hispanic white and non-Hispanic black subjects in Chicago,

WC alone did not predict diabetes in individuals with higher degrees of visceral fat accumulation, even in individuals with type 2 diabetes. They revealed that the relationship between HW and coronary atherosclerosis may be associated with proatherogenic lipoprotein changes related to HW. They also reported that the combined use of fasting TG levels and WC was an accessible and inexpensive tool that could be used to predict the degree of visceral fat, cardiovascular disease, and metabolic risk.

In summary, we demonstrated that the presence of the HW phenotype was the variable that was most strongly associated with type 2 diabetes. The association between WC and type 2 diabetes was stronger than the association between TG levels and type 2 diabetes. When examining the predictive powers of WC and TG levels alone, WC was a good predictor of type 2 diabetes, whereas TG was not. When comparing the various phenotypes (i.e., single measurements and TG levels), the best phenotype for predicting type 2 diabetes differed according to gender; WHR + TG in men and Rib_Hip + TG in women were the best predictors of type 2 diabetes. The main contribution of this study was that although the presence of the HW phenotype was the variable most strongly associated with type 2 diabetes, the predictive power of this phenotype, which consisted of the actual TG and WC values, was slightly lower than that of the other phenotypes. Therefore, the predictive power of the combined measurements of the actual WC and TG values may not be the best method of predicting type 2 diabetes, and the best phenotype for predicting type 2 diabetes differed according to gender. When comparing our study to previous studies, the previous studies only documented the association of the HW phenotype with type 2 diabetes and the effect of the HW phenotype. However, to date, an analysis of the predictive powers of phenotypes consisting of both individual anthropometric measurements and TG levels has not been conducted. To our knowledge, the present study is the first to compare the predictive powers of the combined measurements of each anthropometric index and TG levels in type 2 diabetes. Our findings may provide clinical information that can be used to develop clinical decision support systems for the initial screening of type 2 diabetes.

Our findings have several limitations. The retrospective cross-sectional design of this study does not allow us to establish a cause-effect relationship. To predict type 2 diabetes, the proposed method in this study suggested that the actual TG and WC values be used instead of the range of TG and WC values and various phenotypes consisting of individual anthropometric measurements and TG. This method may easily be used in experiments to identify the best phenotype or predictor of type 2 diabetes in various countries. However, the findings of this study cannot be applied to other populations because the study population included only Korean women and men. Among a single patient cohort, there can exist differences in socio-economic status, race, gender, and nationality. For example, several ethnic groups or nationalities demonstrate different BMI or body shape characteristics. In terms of HW phenotype, the WC criteria should differ by ethnic group or country. Some researchers have suggested that normal WC or BMI ranges for both men and women differ among Europeans or between Americans and Asians [51]–[56]. To predict type 2 diabetes, we must find the optimal cut-off value for each WC and TG based on the ROC curves (AUC) for type 2 diabetes, considering the differences related to nationality, gender, and ethnicity. We must identify the value ranges for normal subjects and subjects with the HW phenotype using the TG and WC cut-off values. Further studies are needed to build and assess a generalized phenotype across world populations.

REFERENCES

[1] P. T. Katzmarzyk, C. L. Craig, and L. Gauvin, "Adiposity, physical fitness and incident diabetes: The physical activity longitudinal study," *Diabetologia*, vol. 50, no. 3, pp. 538–544, Mar. 2007.

[2] Z. Xu, X. Qi, A. K. Dahl, and W. Xu, "Waist-to-height ratio is the best indicator for undiagnosed type 2 diabetes," *Diabetic Med.*, vol. 30, no. 6, pp. e201–e207, Jun. 2013.

[3] R. N. Feng, C. Zhao, C. Wang, Y. C. Niu, K. Li, F. C. Guo, S. T. Li, C. H. Sun, and Y. Li, "BMI is strongly associated with hypertension, and waist circumference is strongly associated with type 2 diabetes and dyslipidemia, in northern Chinese adults," *J. Epidemiol.*, vol. 22, no. 4, pp. 317–323, May 2012.

[4] A. Berber, R. Gómez-Santos, G. Fanghänel, and L. Sánchez-Reyes, "Anthropometric indexes in the prediction of type 2 diabetes mellitus, hypertension and dyslipidaemia in a Mexican population," *Int. J. Obes. Relat. Metab. Disorders*, vol. 25, no. 12, pp. 1794–1799, Dec. 2001.

[5] B. Balkau, D. Sapinho, A. Petrella, L. Mhamdi, M. Cailleau, D. Arondel, and M. A. Charles, D. E. S. I. R. Study Group, "Prescreening tools for diabetes and obesity-associated dyslipidaemia: Comparing BMI, waist and waist hip ratio. The D.E.S.I.R. Study," *Eur. J. Clin. Nutr.*, vol. 60, no. 3, pp. 295–304, Mar. 2006.

[6] I. S. Okosun, K. M. Chandra, S. Choi, J. Christman, G. E. Dever, and T. E. Prewitt, "Hypertension and type 2 diabetes comorbidity in adults in the United States: risk of overall and regional adiposity," *Obes. Res.*, vol. 9, no. 1, pp. 1–9, Jan. 2001.

[7] L. A. Sargeant, F. I. Bennett, T. E. Forrester, R. S. Cooper, and R. J. Wilks, "Predicting incident diabetes in Jamaica: the role of anthropometry," *Obes. Res.*, vol. 10, no. 8, pp. 792–798, Aug. 2002.

[8] N. T. Duc Son le, T. T. Hanh, K. Kusama, D. Kunii, T. Sakai, N. T. Hung, and S. Yamamoto, "Anthropometric characteristics, dietary patterns and risk of type 2 diabetes mellitus in Vietnam," *J. Amer. Coll. Nutr.*, vol. 24, no. 4, pp. 229–234, Aug. 2005.

[9] G. T. Ko, J. C. Chan, C. S. Cockram, and J. Woo, "Prediction of hypertension, diabetes, dyslipidaemia or albuminuria using simple anthropometric indexes in Hong Kong Chinese," *Int. J. Obes. Relat. Metab. Disorders*, vol. 23, no. 11, pp. 1136–1142, Nov. 1999.

[10] M. B. Snijder, P. Z. Zimmet, M. Visser, J. M. Dekker, J. C. Seidell, and J. E. Shaw, "Independent and opposite associations of waist and hip circumferences with diabetes, hypertension and dyslipidemia: The AusDiab study," *Int. J. Obes. Relat. Metab. Disorders*, vol. 28, no. 3, pp. 402–409, Mar. 2004.

[11] B. J. Lee, B. Ku, J. Nam, D. D. Pham, and J. Y. Kim, "Prediction of fasting plasma glucose status using anthropometric measures for diagnosing type 2 diabetes," *IEEE J. Biomed. Health Informat.*, vol. 18, no. 2, pp. 555–561, Mar. 2014.

[12] L. de Koning, H. C. Gerstein, J. Bosch, R. Diaz, V. Mohan, G. Dagenais, S. Yusuf, and S. S. Anand, EpiDREAM Investigators, "Anthropometric measures and glucose levels in a large multi-ethnic cohort of individuals at risk of developing type 2 diabetes," *Diabetologia*, vol. 53, no. 7, pp. 1322–1330, Jul. 2010.

[13] I. S. Okosuna and J. M. Boltrib, "Abdominal obesity, hypertriglyceridemia, hypertriglyceridemic waist phenotype and risk of type 2 diabetes in American adults," *Diabetes Metab. Syndrome*, vol. 2, no. 4, pp. 273–281, Dec. 2008.

[14] Z. Yu, L. Sun, Q. Qi, H. Wu, L. Lu, C. Liu, H. Li, and X. Lin, "Hypertriglyceridemic waist, cytokines and hyperglycaemia in Chinese," *Eur. J. Clin. Invest.*, vol. 42, no. 10, pp. 1100–1111, Oct. 2012.

[15] T. Du, X. Sun, R. Huo, and X. Yu, "Visceral adiposity index, hypertriglyceridemic waist and risk of diabetes: The china health and nutrition survey 2009," *Int. J. Obes. (Lond.)*, vol. 38, no. 6, pp. 840–847, Jun. 2014.

[16] M. Solati, A. Ghanbarian, M. Rahmani, N. Sarbazi, S. Allahverdian, and F. Azizi, "Cardiovascular risk factors in males with hypertriglycemic waist (tehran lipid and glucose study)," *Int. J. Obes. Relat. Metab. Disorders*, vol. 28, no. 5, pp. 706–709, May 2004.

[17] I. Lemieux, A. Pascot, C. Couillard, B. Lamarche, A. Tchernof, N. Alméras, J. Bergeron, D. Gaudet, G. Tremblay, D. Prud'homme, A. Nadeau, and J. P. Després, "Hypertriglyceridemic waist: A marker of the atherogenic metabolic triad (hyperinsulinemia; hyperapolipoprotein B; small, dense LDL) in men?" *Circulation*, vol. 102, no. 2, pp. 179–184, Jul. 2000.

[18] L. B. Tankó, Y. Z. Bagger, G. Qin, P. Alexandersen, P. J. Larsen, and C. Christiansen, "Enlarged waist combined with elevated triglycerides is a strong predictor of accelerated atherogenesis and related cardiovascular mortality in postmenopausal women," *Circulation*, vol. 111, no. 15, pp. 1883–1890, Apr. 2005.

[19] I. F. Gazi, T. D. Filippatos, V. Tsimihodimos, V. G. Saougos, E. N. Liberopoulos, D. P. Mikhailidis, A. D. Tselepis, and M. Elisaf, "The hypertriglyceridemic waist phenotype is a predictor of elevated levels of small, dense LDL cholesterol," *Lipids*, vol. 41, no. 7, pp. 647–654, Jul. 2006.

[20] J. St-Pierre, I. Lemieux, M. C. Vohl, P. Perron, G. Tremblay, J. P. Després, and D. Gaudet, "Contribution of abdominal obesity and hypertriglyceridemia to impaired fasting glucose and coronary artery disease," *Amer. J. Cardiol.*, vol. 90, no. 1, pp. 15–18, Jul. 2002.

[21] P. Blackburn, I. Lemieux, N. Alméras, J. Bergeron, M. Côté, A. Tremblay, B. Lamarche, and J. P. Després, "The hypertriglyceridemic waist phenotype versus the national cholesterol education program-adult treatment panel III and international diabetes federation clinical criteria to identify high-risk men with an altered cardiometabolic risk profile," *Metabolism*, vol. 58, no. 8, pp. 1123–1130, Aug. 2009.

[22] M. J. LaMonte, B. E. Ainsworth, K. D. DuBose, P. W. Grandjean, P. G. Davis, F. G. Yanowitz, and J. L. Durstine, "The hypertriglyceridemic waist phenotype among women," *Atherosclerosis*, vol. 171, no. 1, pp. 123–130, Nov. 2003.

[23] A. Esmaillzadeh, P. Mirmiran, L. Azadbakht, and F. Azizi, "Prevalence of the hypertriglyceridemic waist phenotype in Iranian adolescents," *Amer. J. Prev. Med.*, vol. 30, no. 1, pp. 52–58, Jan. 2006.

[24] S. P. Radenković, R. D. Kocić, M. M. Pešić, D. N. Dimić, M. D. Golubović, D. B. Radojković, and V. M. Cirić, "The hypertriglyceridemic waist phenotype and metabolic syndrome by differing criteria in type 2 diabetic patients and their relation to lipids and blood glucose control," *Endokrynol. Pol.*, vol. 62, no. 4, pp. 316–323, 2011.

[25] D. Yu, J. Huang, D. Hu, J. Chen, J. Cao, and J. Li, "Is an appropriate cutoff of hypertriglyceridemic waist designated for type 2 diabetes among Chinese adults?" *Clin. Nutr.*, vol. 29, no. 2, pp. 192–198, Apr. 2010.

[26] B. J. Lee and J. Y. Kim, "A comparison of the predictive power of anthropometric indices for hypertension and hypotension risk," *PLoS One*, vol. 9, no. 1, p. e84897, Jan. 2014.

[27] World Health Organization, "Definition, diagnosis and classification of diabetes mellitus and its complications: Report of a WHO consultation. Part 1: Diagnosis and classification of diabetes mellitus," Geneva, Switzerland, World Health Org., 1999.

[28] American Association of Clinical Endocrinologists, "The American association of clinical endocrinologists medical guidelines for the management of diabetes mellitus: The AACE system of intensive diabetes self-management—2000 update," *Endocr. Pract.*, vol. 6, no. 1, pp. 43–84, Jan./Feb. 2000.

[29] I. Lemieux, P. Poirier, J. Bergeron, N. Alméras, B. Lamarche, B. Cantin, G. R. Dagenais, and J. P. Després, "Hypertriglyceridemic waist: A useful screening phenotype in preventive cardiology?" *Can. J. Cardiol.*, vol. 23, no. Suppl B, pp. 23B–31B, Oct. 2007.

[30] P. Blackburn, B. Lamarche, C. Couillard, A. Pascot, N. Bergeron, D. Prud'homme, A. Tremblay, J. Bergeron, I. Lemieux, and J. P. Després, "Postprandial hyperlipidemia: Another correlate of the "hypertriglyceridemic waist" phenotype in men," *Atherosclerosis*, vol. 171, no. 2, pp. 327–336, Dec. 2003.

[31] B. J. Arsenault, I. Lemieux, J. P. Després, N. J. Wareham, J. J. Kastelein, K. T. Khaw, and S. M. Boekholdt, "The hypertriglyceridemic-waist phenotype and the risk of coronary artery disease: Results from the EPIC-Norfolk prospective population study," *CMAJ*, vol. 182, no. 13, pp. 1427–1432, Sep. 2010.

[32] J. St-Pierre, I. Lemieux, P. Perron, D. Brisson, M. Santuré, M. C. Vohl, J. P. Després, and D. Gaudet, "Relation of the 'hypertriglyceridemic waist' phenotype to earlier manifestations of coronary artery disease in patients with glucose intolerance and type 2 diabetes mellitus," *Amer. J. Cardiol.*, vol. 99, no. 3, pp. 369–373, Feb. 2007.

[33] P. Blackburn, I. Lemieux, B. Lamarche, J. Bergeron, P. Perron, G. Tremblay, D. Gaudet, and J. P. Després, "Hypertriglyceridemic waist: A simple clinical phenotype associated with coronary artery disease in women," *Metabolism*, vol. 61, no. 1, pp. 56–64, Jan. 2012.

[34] P. M. Janiszewski, R. Ross, J. P. Despres, I. Lemieux, G. Orlando, F. Carli, P. Bagni, M. Menozzi, S. Zona, and G. Guaraldi, "Hypertriglyceridemia and waist circumference predict cardiovascular risk among HIV patients: A cross-sectional study," *PLoS One*, vol. 6, no. 9, p. e25032, Sep. 2011.

[35] P. Blackburn, I. Lemieux, B. Lamarche, J. Bergeron, P. Perron, G. Tremblay, D. Gaudet, and J. P. Despres, "Type 2 diabetes without the atherogenic metabolic triad does not predict angiographically assessed coronary artery disease in women," *Diabetes Care*, vol. 31, no. 1, pp. 170–172, Jan. 2008.

[36] M. Hall, E. Frank, G. Holmes, B. Pfahringer, P. Reutemann, and I. H. Witten, "The WEKA data mining software: An update," *SIGKDD Explor.*, vol. 11, no. 1, pp. 10–18, Jun. 2009.

[37] G. M. Egeland, Z. Cao, and T. K. Young, "Hypertriglyceridemic-waist phenotype and glucose intolerance among canadian inuit: The international polar year inuit health survey for adults 2007–2008," *CMAJ*, vol. 183, no. 9, pp. E553–E558, Jun. 2011.

[38] D. Brisson, P. Perron, S. P. Guay, D. Gaudet, and L. Bouchard, "The "hypertriglyceridemic waist" phenotype and glucose intolerance in pregnancy," *CMAJ*, vol. 182, no. 15, pp. E722–E725, Oct. 2010.

[39] M. Amini, A. Esmaillzadeh, M. Sadeghi, N. Mehvarifar, M. Amini, and M. Zare, "The association of hypertriglyceridemic waist phenotype with type 2 diabetes mellitus among individuals with first relative history of diabetes," *J. Res. Med. Sci.*, vol. 16, no. 2, pp. 156–164, Feb. 2011.

[40] H. Zhang, "The optimality of naive Bayes," in *Proc. 7th Int. Florida Artif. Intell. Res. Soc. Conf.*, 2004, pp. 562–567.

[41] A. Jordan, "On discriminative vs. generative classifiers: A comparison of logistic regression and naive bayes," *Adv. Neural Inform. Process. Syst.*, vol. 14, pp. 841–848, 2002.

[42] J. Halloran, "Classification: Naive bayes vs logistic regression," Univ. Hawaii, Honolulu, HI, USA, Tech. Rep. EE 645, pp. 1–24, 2009.

[43] H. He and E. A. Garcia, "Learning from imbalanced data," *IEEE Trans. Knowl. Data Eng.*, vol. 21, no. 9, pp. 1263–1284, Sep. 2009.

[44] Y. Tang, Y. Q. Zhang, N. V. Chawla, and S. Krasser, "SVMs modeling for highly imbalanced classification," *IEEE Trans. Syst. Man, Cybern. B, Cybern.*, vol. 39, no. 1, pp. 281–288, Feb. 2009.

[45] G. M. Weiss, "Mining with rarity: A unifying framework," *SIGKDD Explor.*, vol. 6, no. 1, pp. 7–19, 2004.

[46] W. J. Lin and J. J. Chen, "Class-imbalanced classifiers for high-dimensional data," *Brief. Bioinformat.*, vol. 14, no. 1, pp. 13–26, Jan. 2013.

[47] K. W. Paek and K. H. Chun, "Sex difference of type 2 diabetes affected by abdominal obesity versus overall obesity," *Yonsei Med. J.*, vol. 51, no. 6, pp. 850–856, Nov. 2010.

[48] K. Lee, Y. M. Song, and J. Sung, "Which obesity indicators are better predictors of metabolic risk?: Healthy twin study," *Obesity (Silver Spring)*, vol. 16, no. 4, pp. 834–840, Apr. 2008.

[49] M. Ashwell, P. Gunn, and S. Gibson, "Waist-to-height ratio is a better screening tool than waist circumference and BMI for adult cardiometabolic risk factors: Systematic review and meta-analysis," *Obes. Rev.*, vol. 13, no. 3, pp. 275–286, Mar. 2012.

[50] S. Sam, S. Haffner, M. H. Davidson, R. B. Sr. D'Agostino, S. Feinstein, G. Kondos, A Perez, and T. Mazzone, "Hypertriglyceridemic waist phenotype predicts increased visceral fat in subjects with type 2 diabetes," *Diabetes Care*, vol. 32, no. 10, pp. 1916–1920, Oct. 2009.

[51] A. Misra, N. K. Vikram, R. Gupta, R. M. Pandey, J. S. Wasir, and V. P. Gupta, "Waist circumference cutoff points and action levels for Asian Indians for identification of abdominal obesity," *Int. J. Obes. (Lond.)*, vol. 30, no. 1, pp. 106–111, Jan. 2006.

[52] R. Huxley, W. P. James, F. Barzi, J. V. Patel, S. A. Lear, P. Suriyawongpaisal, E. Janus, I. Caterson, P. Zimmet, D. Prabhakaran, S. Reddy, and M. Woodward, Obesity in aAsia cCollaboration, "Ethnic comparisons of the cross-sectional relationships between measures of body size with diabetes and hypertension," *Obes. Rev.*, vol. 9, no. 1, pp. 53–61, Mar. 2008.

[53] S. A. Lear, M. M. Chen, J. J. Frohlich, and C. L. Birmingham, "The relationship between waist circumference and metabolic risk factors: Cohorts of European and Chinese descent," *Metabolism*, vol. 51, no. 11, pp. 1427–1432, Nov. 2002.

[54] S. A. Lear, K. H. Humphries, S. Kohli1, and C. L. Birmingham, "The use of BMI and waist circumference as surrogates of body fat differs by ethnicity," *Obesity (Silver Spring)*, vol. 15, no. 11, pp. 2817–2824, Nov. 2007.

[55] C. Snehalatha, V. Viswanathan, and A. Ramachandran, "Cutoff values for normal anthropometric variables in Asian Indian adults," *Diabetes Care*, vol. 26, no. 5, pp. 1380–1384, May 2003.
[56] A. Lev-Ran, "Human obesity: An evolutionary approach to understanding our bulging waistline," *Diabetes Metab. Res. Rev.*, vol. 17, no. 5, pp. 347–362, Sep./Oct. 2001.

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