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A Body Shape Index (ABSI) and Hip Index (HI) Adjust Waist and Hip Circumferences for Body Mass Index, But Only ABSI Predicts High Cardiovascular Risk in the Spanish Caucasian Population

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Abstract

Background: Our aim in this study was to investigate if Hip index (HI) improves the identification of cardiovascular risk (CVR) beyond that achieved with either the waist-to-height ratio (WHtR) or body mass index (BMI)-adjusted waist circumference (A body shape index [ABSI]) in the Spanish Caucasian population.
Methods: Three thousand eight hundred forty-four subjects (1754 males, response rate 75.8%) were included. Anthropometric indices (AIs) included were HI, ABSI, and WHtR. CVR was estimated using the Framingham, Systematic COronary Risk Evaluation (SCORE), and American College of Cardiology/American Heart Association (ACC/AHA) charts. Areas under the receiver operating characteristic curve (AUC) were obtained to evaluate the performance of AIs in detecting CVR. We also estimated the AIs' standardized Z-scores and compared them against the CVR.
Results: AUC demonstrated that the best AI in males to estimate higher CVR according to Framingham and ACC/AHA charts was WHtR. In females, WHtR also achieved good performance and showed higher prediction capacity than the other AIs. After transforming to Z-scores, ABSI was the best linear predictor for CVR according to SCORE and ACC/AHA, although WHtR also proved to be good. HI did not associate with the measures of CVR.
Conclusions: HI does not predict high CVR in the Spanish Caucasian Population. However, ABSI is directly and linearly related to high CVR, with a higher performance than WHtR when standardized and evaluated as a linear predictor.

Keywords: a body shape index, hip index, waist-to-height ratio, cardiovascular risk, standardized analysis

Introduction

Excess body fat is a well-known risk factor for cardiovascular (CV) diseases.[1] Recently, two anthropometric indices (AIs) have been introduced with potential benefits for the diagnosis of excess fat and to improve health risk assessments: A body shape index (ABSI) and Hip index (HI).[2] Previously, multiple AIs based on circumferences have been examined as predictors of abnormal adiposity and abdominal fat as well as the development of insulin resistance and/or higher cardiovascular risk (CVR).[2–4]

Many efforts have been directed to improve the diagnosis of abnormal abdominal shape beyond body mass index (BMI) and waist circumference (WC), which are the most widely used AIs. It is well known that BMI does not distinguish between fat locations, while WC, highly predictive

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of CVR, is more sensitive to fat percentage and distribution.[5] Moreover, BMI, WC, and hip circumference (HC) were found to be poor predictors of internal body fat compartments according to magnetic resonance imaging (MRI),[6] which can be considered the *Gold Standard*. Furthermore, the intercorrelations between BMI, WC, and HC are ~0.9,[2] so joint consideration should take into account the large overlap between these measures' information content. Motivated by this, ABSI normalizes WC to be uncorrelated with BMI. Similarly, HI normalizes HC to be uncorrelated with BMI. ABSI and HI also have little intercorrelation.[2] Further, transformation of AIs to Z-scores relative to an age and sex specific mean and standard deviation puts them on a common scale and removes the potential for spurious associations due to the dependence of an AI on basic demographic parameters.[2]

We previously demonstrated that overall, the best (AI) identifying Spanish males and females who are at high risk for developing CV diseases is waist-to-height ratio (WHtR), but that ABSI is also a good AI to predict high CVR in Spanish males, while for Spanish females, WC and waist-to-hip ratio are also good AIs.[7] By contrast, there is limited research published evaluating HI as a predictor of CVR,[2] none in Spanish population.

Accordingly, our aim in this study was to investigate if HI, an allometric anthropometric that transforms HC to be statistically independent of BMI and ABSI, adds to identifying CVR in the Spanish Caucasian population.

Methods

Details of recruitment and study protocols of these two well-characterized population-based surveys were previously described and the general characteristics of these populations were then reported.[7] We used standard procedures adapted from the WHO MONICA protocol and excluded subjects older than 65 years as well as participants with diabetes mellitus. All participants gave written informed consent to be included in our study and the protocol was approved by the corresponding Institutional Review Board. A total of 3844 subjects (response rate 75.8%) completed the study, 1754 males and 2090 females, with no differences in their mean age (48 years). Sitting blood pressure was averaged from three attended measurements, performed after a 10-min seated rest. Total cholesterol, triglycerides, and high-density lipoprotein cholesterol (HDL-C) were determined by enzymatic methods, and low-density lipoprotein cholesterol (LDL-C) by the Friedewald formula. Obesity prevalence according to BMI (≥30 kg/m^2) was 27.5%, while overweight prevalence (BMI 25–29.99 kg/m^2) was 45.3%.

The AIs included in the study herein presented are ABSI and HI according to Krakauer and Krakauer[2,8,9] and WHtR.

To estimate CVR, we used CVR charts for 10-year risk of atherosclerotic CV disease. The 2008 D'Agostino chart was derived from 8491 Framingham CVR Score (FR) study participants[10]; it was specifically designed for primary care and estimates 10-year absolute CV events risk. The Systematic COronary Risk Evaluation (SCORE) risk chart[11] assembled a pooled dataset of European cohort studies and offers 10-year direct estimation of total fatal CVR, while the most recent American College of Cardiology/American Heart Association (ACC/AHA) guide[12] was created with follow-up data from community-based cohorts of adults, with adjudicated endpoints for coronary heart disease death, nonfatal myocardial infarction, and fatal or nonfatal stroke over a 10-year period. The FR chart has a sensitivity of 48% and 58% in men and women, respectively, and a specificity of 85% and 83%, respectively. The SCORE risk chart has a 35% sensitivity and 88% specificity for both genders considered together. The ACC/AHA guide has a sensitivity that ranges from 71% to 82%. Estimated CVR ≥20%, ≥5%, and ≥7.5% classify subjects as high CVR individuals according to the FR, SCORE, and ACC/AHA guides, respectively. Finally, participants with diabetes mellitus were excluded for the purpose of this study because diabetes subjects are directly classified as high CVR subjects according to the SCORE guide, but not with the other charts, for which diabetes is "only" a major risk factor.

Statistical analysis

Areas under the receiver operating characteristic curve (AUC) with 95% confidence intervals (CIs) were obtained

Table 1. Characteristics of the Population

	Males n = *1582*	*Females* n = *1874*	*Total* N = *3456*†	
	X (SD)	*X (SD)*	*X (SD)*	P*
Age (years)	48.57 (8.61)	48.83 (8.52)	48.71 (8.56)	0.378
Weight (kg)	77.88 (11.78)	67.76 (12.60)	72.40 (1323)	<0.001
BMI (kg/m^2)	27.42 (3.60)	27.59 (4.82)	27.51 (4.30)	0.247
WHtR	0.56 (0.06)	0.54 (0.07)	0.55 (0.07)	<0.001
ABSI	0.09 (0.01)	0.08 (0.01)	0.08 (0.01)	<0.001
HI	95.69 (5.69)	103.79 (5.62)	100.07 (6.94)	<0.001
SBP (mmHg)	125.66 (18.27)	124.83 (20.19)	125.21 (19.34)	0.211
Total cholesterol (mg/dL)	222.24 (41.10)	217.03 (40.47)	219.41 (40.83)	<0.001
Triglycerides (mg/dLl)	131.03 (85.11)	95.08 (51.41)	111.50 (71.17)	<0.001
HDL-Cholesterol (mg/dL)	47.90 (13.56)	57.14 (15.08)	52.92 (15.12)	<0.001
LDL-Cholesterol (mg/dL)	148.13 (37.97)	140.95 (36.87)	144.23 (37.54)	<0.001
Smoking habit (%)	694 (43.87%)	353 (18.85%)	1047 (30.30%)	<0.001
Treated hypertension (%)	301 (20.32%)	459 (25.51%)	760 (23.17%)	<0.001

†Type 2 DM subjects excluded (n = 388). *Comparison: Males versus Females. Results are expressed in means (standard deviation) except for smoking habit and treated hypertension, which are expressed in number (percentage).

ABSI, a body shape index; BMI, body mass index; HDL-cholesterol, high density lipoproteins, HI, Hip index; LDL-cholesterol, low-density lipoproteins, SBP, systolic blood pressure; WHtR, waist-to-height ratio.

Table 2. Areas Under the Receiver Operating Characteristic Curves of Anthropometric Body Fat Indices According to the Three Estimated Cardiovascular Risk Scores

	WHtR	*95% CI*	*Cut-off*	*ABSI*	*95% CI*	*Cut-off*	*HI*	*95% CI*	*Cut-off*
FR (≥20%)									
Males	**0.687**	**0.655–0.720**	**0.564*****	0.653	0.617–0.689	0.089	0.610	0.575–0.645	93.74
Females	**0.826**	**0.790–0.862**	**0.546**[†]	0.637	0.571–0.703	0.081	0.611	0.550–0.672	103.89
Total	0.734	0.710–0.758	0.545	0.748	0.721–0.774	0.086	0.568	0.539–0.596	99.89
SCORE (≥5%)									
Males	0.653	0.605–0.701	0.557	0.665	0.615–0.715	0.090	0.668	0.623–0.713	94.76
Females	0.733	0.603–0.863	0.546[¥]	0.625	0.428–0.822	0.083	0.532	0.385–0.680	104.48
Total	0.685	0.646–0.725	0.558	0.789	0.753–0.824	0.086[β]	0.565	0.528–0.603	95.07
ACC/AHA (≥7.5%)									
Males	**0.687**	**0.657–0.717**	**0.558**[¶]	0.631	0.599–0.664	0.089	0.578	0.545–0.611	100.86
Females	**0.699**	**0.670–0.728**	**0.537**[Φ]	0.609	0.576–0.643	0.081	0.578	0.545–0.611	96.26
Total	0.691	0.673–0.710	0.538	**0.750**	**0.731–0.766**	**0.083**[γ]	0.645	0.625–0.664	101.95

Highest AUC are highlighted with bold and their cutoff points sensitivity (S) and specificity (Sp) are: *S: 69%, Sp: 59%; [†]S: 95%, Sp: 58%; [¥]S: 83%, Sp: 56%; [β]S: 78%, Sp: 67%; [¶]S: 59%, Sp: 69%; [Φ]S: 74%, Sp: 58%; [γ]S 75%; Sp: 64%.

95% CI, 95% confidence interval; ACC/AHA, American College of Cardiology/American Heart Association chart; AUC, areas under the receiver operating characteristic curve; CVR, cardiovascular risk; FR, Framingham CVR Score; SCORE, Systematic COronary Risk Evaluation.

to evaluate the performance of the nonstandardized WHtR, ABSI, and HI in detecting high CVR by comparing AUC. Subsequently, we compared in pairs the areas under the AUC using DeLong comparisons.

To further compare AIs performances, we computed normalized Z-scores (differences between the original values and age- and sex-specific means, divided by the standard deviations) of the AIs (WHtR, ABSI, and HI). CVR estimated by the three CVR scales was then recalculated for the Z-score transformed data. The results were expressed as nonlinear functions for each of the AIs.

The level of significance was set at 0.05 for all analyses. Analyses were performed using Windows SPSS software (version 20.0; SPSS, Inc., Chicago, IL).

Results

The characteristics of subjects can be seen in Table 1. According to the AUC results (Table 2), the best AI in males to estimate CVR was WHtR, using the FR and ACC/AHA charts. With the SCORE chart, ABSI and HI had slightly better performances than WHtR. In females, WHtR also performed well, surpassing the other AIs according to all three CVR charts. DeLong comparisons (Table 3) favored WHtR against other AIs in both sexes, except for the comparisons in females with the SCORE chart, where WHtR was only favored against HI ($P = 0.045$). Nevertheless, discrepancies were found when comparing WHtR and ABSI according to FR and ACC/AHA in females by this method, as ABSI was superior ($P < 0.0001$ in all cases), and in a similar manner, according to ACC/AHA in males ($P = 0.0133$). For both sexes, ABSI showed according to SCORE and ACC/AHA charts better sensitivity and specificity compared to all the other AIs, including WHtR ($P < 0.0001$).

To better compare WHtR and ABSI as AI predictors, we then computed their standardized Z-scores, showing that the most powerful AI progressively evaluating the CV risk was ABSI (Fig. 1). ABSI outperformed WHtR, although WHtR proved to be a good AI according to SCORE and ACC/AHA. HI Z-score, however, was not correlated significantly with CVR and did not show progressive or linear increase with the estimated CVR.

Discussion

In this report, we analyze for the first time in a Spanish Caucasian population the potential role for predicting higher CVR of two allometrically defined AIs, HI, and ABSI. We have found that ABSI performs well in estimating CVR according to the three most widely used CVR score charts, while HI does not. In addition, after standardization for age and sex, ABSI showed a progressive increase in the CVR according to the CVR charts, while HI did not. On the contrary, we found that although WHtR outperformed ABSI in a ROC analysis, subsequent analysis, showed a stronger and progressive relationship of standardized ABSI with the CVR, which is consistent with analyses of other cohorts.[9]

BMI is widely used in population studies as the main body size index, but does not differentiate between lean and fat tissue, hence it does not portray a clear picture of the body composition nor fat distribution. Thus, other indices have become more useful for assessing body composition,

Table 3. Comparison of the Anthropometric Indices According to Sex

	Males	*Females*	*Total*
FR ≥20%			
WHtR—HI	**0.001**	**<0.0001**	**<0.0001**
ABSI—WHtR	0.164	**<0.0001**	0.454
ABSI—HI	0.091	0.566	**<0.0001**
SCORE ≥5%			
WHtR—HI	0.655	**0.045**	**<0.0001**
ABSI—WHtR	0.727	0.703	**<0.0001**
ABSI—HI	0.939	0.457	**<0.0001**
ACC/AHA ≥7.5%			
WHtR—HI	**<0.0001**	**<0.0001**	**0.001**
ABSI—WHtR	**0.0133**	**<0.0001**	**<0.0001**
ABSI—HI	**0.0235**	**0.002**	**<0.0001**

P-value according to DeLong method. For any *P*-value, when $P < 0.05$ (highlighted in bold) favor the left side. For example, WHtR has significant better CVR performance than HI in both sexes, considered alone or together.

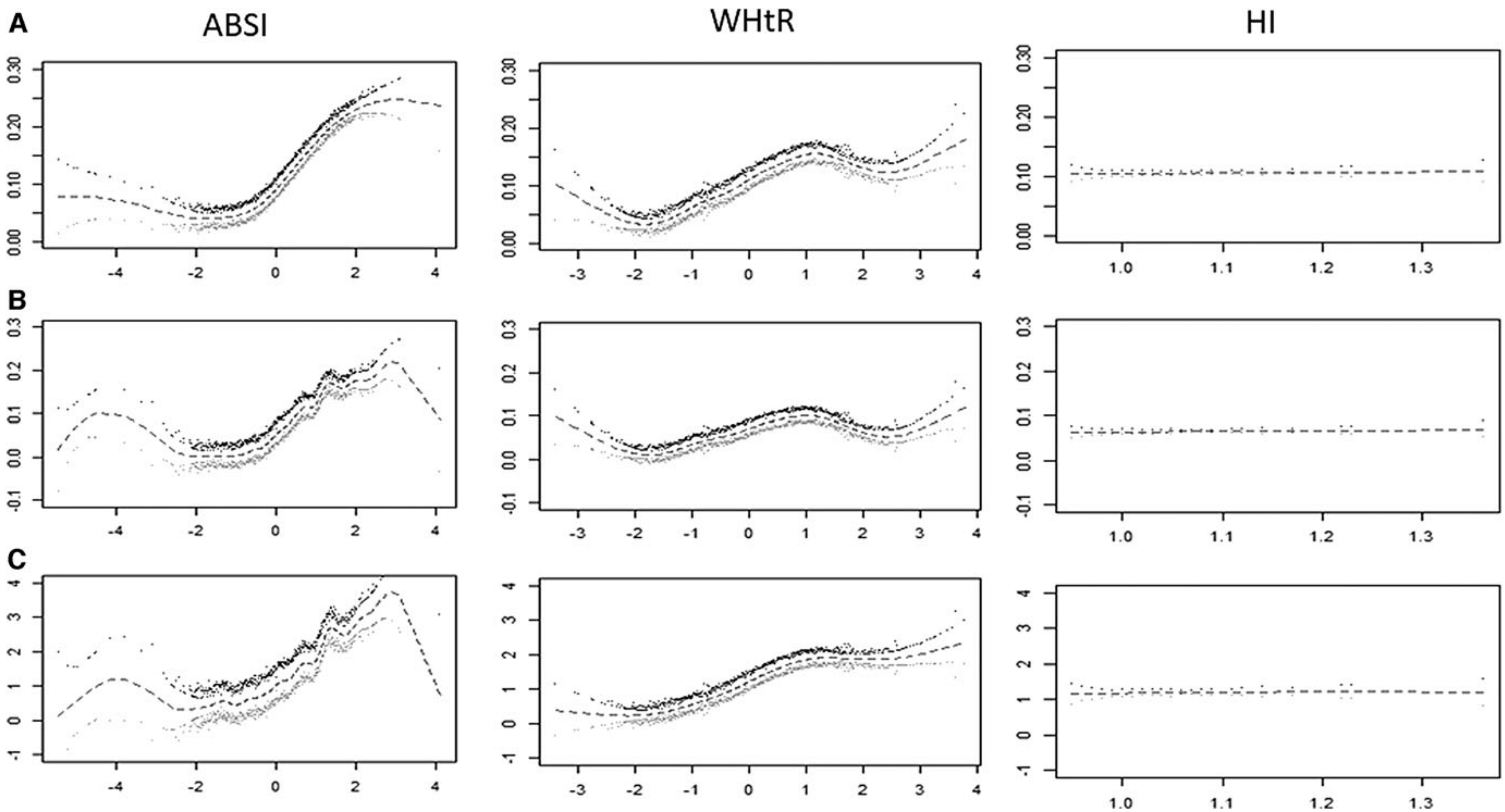

FIG. 1. Estimated high CVR in the cohort according to CV risk charts, as a nonlinear function of anthropometric indices. WHtR, waist-to-height ratio; ABSI, a body shape index; HI, Hip index. ACC/AHA, American College of Cardiology/American Heart Association chart **(A)**; FR, Framingham CVR Score; **(B)**, SCORE, Systematic COronary Risk Evaluation **(C)**. *Dotted lines* indicate 95% confidence intervals. Percentiles and Z-scores are based on the cohort. CVR, cardiovascular risk.

including anthropometry, dual-energy X-ray absorptiometry (DEXA), and computed tomography (CT) scanning.[13] Nevertheless, DEXA and CT are costly and time-consuming procedures, hence difficult to perform in study populations. Regarding the recently described anthropometric index HI, it was developed as a transformation of HC intended to be uncorrelated with BMI and ABSI. HI was found to be a significant mortality predictor in the U.S. population (with a U-shaped association), although weaker than BMI or ABSI.[2,9] Otherwise, there have been few studies of the association of HI with outcomes other than mortality. In a study from China, HI was not a significant risk factor for developing diabetes mellitus.[14] In a pediatric population of overweight and obese children and adolescents, HI was linearly correlated with only one cardiometabolic risk marker, whereas BMI and ABSI were correlated with 7 and 5 out of 12, respectively.[15] Consistent with the aforementioned studies, our study supports that there is no association in the Spanish population between HI and CVR, suggesting that measuring HC may not add information to CVR assessment beyond that available from weight and WC measurements.

That ABSI predicts CVR in the Spanish population is not surprising, as a variety of studies in different populations have shown correlation of ABSI with total as well as CV mortality.[8,16–20] Further, a European study including nearly 50,000 subjects from various countries found a linear relationship between ABSI and CV and total mortality, while, by contrast, BMI and WC showed J-shaped associations with total mortality.[21] The linear relationship of ABSI with CVR found in our population suggests that it can be used to help clinicians in making patient treatment decisions, together with the routinely used BMI.

This study has some limitations. First, its cross-sectional design does not allow to make causal inferences. As well, we do not have data on actual CV events, relying instead on CVR charts that are widely used by physicians and investigators. These surrogate measures have demonstrated adequate performance, although sensitivity is recognized to be low in intermediate risk populations. Second, our cohort is primarily of Caucasian ethnicity, which does not represent the current diversity of the Spanish population, as Spain has received significant immigration in recent years. Large and long-term population studies are therefore needed to better establish the value of these new indices in the Spanish non-Caucasian population, mainly from Latin American and East European ethnicities. Third, the age of our study population was composed of subjects within 35 and 65 years old, so our study might, therefore, not be generalizable to younger or older populations.

In summary, HI did not predict high CVR in the Spanish Caucasian population. ABSI was found directly and linearly related to high CVR, with a higher performance than WHtR when standardized for age and sex. However, we believe that the combined consideration of ABSI and BMI may extend the ability to detect CV risk beyond single, often highly intercorrelated AIs.

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Ethics Approval

The Spanish Insulin Resistance Study (SIRS) and the Segovia Insulin Resistance Study included in this analysis were approved by the Ethics Committee of San Carlos Clinic Hospital in Madrid (Spain).

Availability of Data and Material

The datasets generated and analyzed during the current study are available from the corresponding author on reasonable request.

Authors' Contributions

The first author (A.C.-A.) is responsible for the design of the study, data interpretation and preparation of the first draft of the article. The second (J.C.K.) and fourth (N.Y.K.) authors participated in data analyses, writing, and critical revision of the article. The third author (I.S.-G.) extracted the data and take responsibility together with the first author (A.C.-A.) for the integrity of the analyses. The fifth (M.T.M.-L.) and corresponding (M.S.-R.) authors participated actively in the design and development of the field studies. The sixth author (M.S.-R.) gave final approval of the article to be published.

Author Disclosure Statement

No conflicting financial interests exist.

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