Relationship between abdominal obesity and facial characteristics

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Abstract. Abdominal obesity is a significant predictor of disease risk and mortality, and facial characteristics of patients provide medical cues related to health complications. In this study, we examine the relationship between abdominal obesity and facial characteristics and suggest a prediction method for abdominal obesity using only interpretable facial features. On the basis of the analysis of 2003 Korean individuals, we found that many characteristics are statistically significant in distinguishing between abdominal obesity and non-abdominal obesity in gender groups. The area under the receiver operating characteristics curve (AUC) and kappa values in female group were 0.793 and 0.347, respectively, and AUC and kappa values in male group were 0.842 and 0.456, respectively. Our results may provide useful clues for alternative diagnosis of abdominal obesity in situations of emergency medicine and telemedicine.

Keywords: Abdominal obesity, Facial feature, Relationship, Data mining

1 Introduction

The prevalence of obesity is growing rapidly worldwide. Abdominal obesity is intimately associated with cardiovascular disease (CVD), type 2 diabetes, sleep apnea, dyslipidemia, metabolic syndrome, and lipid disorders [1-4], and it is an important factor in the diagnosis of the these diseases.

Recently, several studies have focused on the relationship between facial features and abdominal obesity, and these studies have shown that face adiposity is associated with health complications [5-10]. Adipose tissue accumulation in an individual's face may serve as a reliable indicator of general adiposity and reveal clinical information about future health conditions [5]. For instance, Coetzee et al. [8] have suggested that facial adiposity is strongly associated with cardiovascular health, based on the finding that individuals with higher perceived facial obesity have significantly higher blood pressures. Levine et al. [9] have noted that abdominal obesity and upper body fat distribution are associated with type 2 diabetes mellitus, hypertension, dyslipidemia, and insulin resistance. Through observations of the development of moon face and increased abdominal fat in patients with Cushing's syndrome, the authors proposed that chubby cheeks might be among the facial characteristics of patients at

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higher risk of the metabolic complications of obesity. In observing the relationship between craniofacial differences, obstructive sleep apnea syndrome, and obesity, Paoli et al. [10] have suggested that the anterior floor of the cranial base of non-obese patients is shorter than that of obese patients, the horizontal ramus of the mandible of non-obese patients is shorter than that of obese patients, and the maxillomandibular discrepancy of non-obese patients is greater than that of obese patients. Detailed findings about morphological facial characteristics and obesity-related diseases were described [5].

2 Materials and methods

2.1 Subjects and anthropometric measurements

A total of 2003 subjects participated in this study. Frontal and profile photographs of subjects' faces with neutral expressions were acquired using a digital camera with a ruler (Nikon D700 with an 85-mm lens), and data including name, age, gender, weight, height, blood pressure, pulse, and waist circumference were recorded. A total of 56 features were extracted from images of the participants based on feature points designated by physicians. All points designated in frontal and profile images are shown in Figure 1, and all of the extracted features and brief descriptions are given in Table 1.

Fig. 1. All points designated by physicians in the facial

image Table 1. All features with brief descriptions

Feature	Brief description
FD n_1_ n_2	Distance between point n_1 and n_2 in a frontal or profile image
FDH *ni_n2*	Horizontal distance between n_1 and n_2 in an image
FDV *ni_n2*	Vertical distance between n_1 and n_2 in a frontal or profile image
FA n_i n_2 n_3	Angle of 3 points n_1, n_2, and n_3 in an image
FA *ni_n2*	Angle between the line through 2 points n_1 and n_2 and a horizontal line
FRO2psu	FD(17,26)/FD(18,25)
FRO3psu	(FD[18,25] + FD[118,125])/FDH(33,133)
FR05jsu	FDH(33,133)/FD(43,143)
FRO6psu	FDH(33,133)/FDV(52,50)
FRO8psu	FD(43,143)/FDV(52,50)
FArea02	Area of the contour formed by the points 53,153, 133, 194, 94, 33, and 53 in an image
FArea03	Area of the contour formed by the points 94, 194, 143, 43, and 94
Fh_Cur Max_Distan	Distance between points 7 and 77

Feature	Brief description
Fh_Angle_ n_i_n_2	Angle between the line through 2 points, n_1 and n_2, and a horizontal line
Nose_Angle_ n_i_ n_2	Angle between the line through 2 points, n_l and n_2, and a horizontal line
Nose_Angle_ n_i_n_2	Angle of 3 points $n1$, $n2$, and n_3
_n_3 SA $n_/$ n_2	Angle between the line through 2 points, n_i and n_2, and a horizontal line
Fh Cur Max R79 69	FD(77,9)/FD(6,9)
Nose Area n_1 $n2$ $n3$	Area of the triangle formed by 3 points, $n1$, $n2$, and n_3, in an image

2.2 Experimental design

For cut-off values for waist circumference (WC), we have followed the suggestions of other reports [11-13] to assign a cut-off value for waist circumference for the diagnosis of abdominal obesity. The proposed cut-off values for abdominal obesity in this study are defined as WC >90 cm for men and >85 cm for women.

For classification of gender-specific findings, all subjects were divided into 2 groups: Female-20-50 (women aged 21-50 years) and Male-20-50 (men aged 21-50 years). The numbers of normal subjects and abdominal obesity subjects in female group were 800 and 266, respectively, and were 663 and 274 in male group, respectively. The mean (± standard deviation) age in the 2 groups was 40.24 ± 8.93 years in Female-20-50 and 39.54 ± 9.74 years in Male-20-50.

All statistical analyses were conducted using SPSS version 19 for Windows (SPSS Inc., Chicago, **IL,** USA). Normal group and abdominal obesity group subjects in gender groups were compared by the unpaired t-test, and a p-value less than 0.05 was considered statistically significant. Thus, features used in each group were different due to the distinction of gender.

In the normal/abdominal obesity classification, the analysis was performed in 2 ways: (1) only features with a p-value < 0.05 were included in classification experiments with an applied normalization (scale 0-1 value); and (2) we additionally performed a wrapper-based feature subset selection using logistic regression with greedy search strategy (backward elimination) with applied normalization and the entropy-based multi-interval discretization introduced by Fayyad and Irani [14] based on features with a p-value < 0.05. All classification experiments were performed using logistic regression in the WEKA software [15], and all of the experimental results are based on a 10-fold cross-validation method.

3 Results and Discussion

3.1 Prediction results

AUC and kappa values of two gender groups according to performance evaluation criteria are presented in Figure 2.

In classification by the first method (using features with a p-value < 0.05), our models showed AUC values ranging from 0.775 to 0.822 and kappa values ranging from 0.326 to 0.456 for two groups, and AUC values ranging from 0.793 to 0.842 with kappa values ranging 0.347 to 0.440 in classification by the second method (using feature selection and unpaired t-test). The good classification accuracy for normal/abdominal obesity diagnosis was achieved in the Male-20-50 group in comparison with the Female-20-50 group.

Our results demonstrated that the classification performance of the second method with unpaired t-test and feature selection was better than that of the first method with only the unpaired t-test. However, in the Male-20-50 group, the kappa value of classification based on unpaired t-test was only slightly higher than that of the classification based on feature subset selection and unpaired t-test.

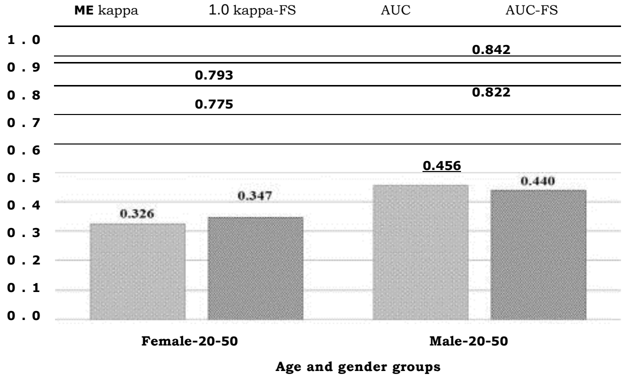

Fig. 2. Performance results using AUC and kappa in comparison of the first method (classification based on unpaired t-test, called kappa and AUC) and the second method (classification based on feature subset selection and unpaired t-test, called kappa-FS and AUC-FS) in gender groups

3.2 Statistical analysis

In this study, features with p-values <0.05 were considered statistically significant, and are described in Tables 2 and 3. Features with p-values <0.0001 were considered highly statistically significant. Thus, for the following analysis results, we only considered features that satisfied the above conditions (p-value) in each group. The statistical data are expressed as mean ± standard deviation.

In the Female-20-50 group (Table 2), there were 34 features with statistically significant differences between normal and AO (abdominal obesity) classes ($p < 0.05$), and 18 of these features showed highly significant differences ($p < 0.0000$). As an example, the FA18_25_43 feature exhibited highly significant differences. This means that angle between the ends (points 18 and 25) of the left eye and the mandibular ramus (point 43) in abdominal obesity (100.1 ± 5.435) is greater than that in non-abdominal obesity (97.35 ± 5.292) (t= -7.290, p = 0.0000). This feature is related to chubby cheeks or the horizontal distance around bucca, including FD43_143, FD94_194, and FArea03.

In the Male-20-50 group (Table 3), differences in 25 of 36 features with p-values less than 0.05 were highly significant ($p < 0.0000$). For instance, forehead angle (the angle between the line through 2 points, 73 and 72, and a horizontal line in profile, called Fh_Angle_73_72) of abdominally obese subjects was higher than that of normal subjects (t = 3.329, p = 0.0009).

Table 2. Female-20-50 (Std: standard deviation; * p < 0.05; ** p < 0.01; *** p < 0.001; **** p < 0.0001)

Feature	Class	Mean (Std.)	t	Feature	Class	Mean (Std.)	t
FD17_26	Normal	9.09 (1.381)	5.63****	FA18_17_43	Normal	79.15 (6.326)	-6.835****
	AO	8.531 (1.463)			AO	82.52 (7.172)	
FD117_126	Normal	9.105 (1.372)	5.519****	FA118_117_143	Normal	79.4 (6.699)	-7.925****
	AO	8.568 (1.378)			AO	83.18 (6.883)	
FDH25_125	Normal	95.86 (4.828)	-4.81****	FA17_25	Normal	20.98 (4.323)	2.189*
	AO	97.54 (5.226)			AO	20.31 (4.318)	
FDH36_136	Normal	24.15 (2.325)	-2.986**	FA117_125	Normal	21.84 (4.249)	2.378*
	AO	24.64 (2.354)			AO	21.12 (4.321)	
FDV52 81	Normal	44.96 (3.288)	2.217*	FA17_18	Normal	32.38 (5.158)	3.32**
	AO	44.45 (3.251)			AO	31.03 (5.887)	
FD18 25	Normal	30.09 (2.514)	-3.456***	FA117_118	Normal	32.06 (5.559)	4.218****

Feature	Class	Mean (Std.)	t	Feature	Class	Mean (Std.)	t
	AO	30.71 (2.626)			AO	30.4 (5.506)	
FD17_25	Normal	18.39 (2.21)	-3.401^{***}	FRO2_psu	Normal	0.303 (0.044)	6.988^{****}
	AO	18.92 (2.29)			AO	0.279 (0.049)	
FD43_143_aD	Normal	126.8 (7.142)	-13.52^{****}	FRO5_psu	Normal	1.161 (0.052)	5.907^{****}
	AO	133.7 (7.225)			AO	1.14 (0.047)	
FD53_153_aD	Normal	144.7 (5.905)	-9.833^{****}	FRO6_psu	Normal	2.031 (0.112)	-9.586^{****}
	AO	148.9 6.326)			AO	2.108 (0.117)	
FD94_194_aD	Normal	141.3 (6.056)	-15.1^{****}	FRO8_psu	Normal	1.754 (0.145)	-9.661^{****}
	AO	147.8 (6.09)			AO	1.853 (0.148)	
FDH33_133_aD	Normal	147 (5.677)	-12.66^{****}	FArea02_aD	Normal	6395 (599.1)	-3.462^{***}
	AO	152.2 (5.952)			AO	6544 (620.2)	
FA18_17_25	Normal	126.6 (6.744)	-3.813^{***}	FArea03_aD	Normal	3733 (384.6)	-8.63^{****}
	AO	128.7 (7.679)			AO	3968 (389.8)	
FA118_117_125	Normal	126.1 (7.381)	-4.539^{****}	FDV12_14	Normal	33.41 (3.115)	2.818^{**}
	AO	128.5 (7.412)			AO	32.77 (3.45)	
FA18_25_43	Normal	97.35 (5.292)	-7.29^{****}	FDV14_21	Normal	12.82 (1.65)	-1.989^{*}
	AO	100.1 (5.435)			AO	13.05 (1.685)	
FA118_125_143	Normal	98.08 (5.121)	-7.976^{****}	Nose_Angle_14_12	Normal	59.97 (4.348)	2.499^{*}
	AO	101 (5.361)			AO	59.2 (4.381)	
FA17_25_43	Normal	121.4 (5.808)	-3.087^{**}	Fh_Cur Max R79_69	Normal	0.528 (0.115)	-2.013^{*}
	AO	122.7 (5.727)			AO	0.545 (0.133)	
FA117_125_143	Normal	122.7 (5.552)	-3.184^{**}	PDH44_53	Normal	88.7 (5.734)	
	AO	124 (5.669)			AO	89.93 (6.042)	

Table 3. Male-20-50 (Std: standard deviation; $^{*}p < 0.05$; $^{**}p < 0.01$; $^{***}p < 0.001$; $^{****}p < 0.0001$)

Feature	Class	Mean (Std.)	t	Feature	Class	Mean (Std.)	t
FD17_26	Normal	8.162 (1.265)	4.73^{****}	FA17_18	Normal	27.24 (5.218)	4.617^{****}
	AO	7.727 (1.324)			AO	25.51 (5.234)	
FD117_126	Normal	8.3 (1.315)	5.555^{****}	FA117_118	Normal	27.21 (5.455)	4.824^{****}
	AO	7.815 (1.173)			AO	25.36 (5.101)	
FDH25_125	Normal	99.71 (5.669)	-7.679^{****}	FRO2_psu	Normal	0.259 (0.043)	7.618^{****}
	AO	102.8 (5.504)			AO	0.235 (0.041)	
FDH36_136	Normal	27.03 (2.719)	-2.11^{*}	FRO5_psu	Normal	1.148 (0.056)	9.176^{****}
	AO	27.44 (2.757)			AO	1.116 (0.045)	
FD18_25	Normal	31.72 (2.566)	-6.478^{****}	FRO6_psu	Normal	2.026 (0.121)	-9.656^{****}
	AO	33 (2.818)			AO	2.113 (0.136)	
FD17_25	Normal	18.52 (2.231)	-6.257^{****}	FRO8_psu	Normal	1.77 (0.16)	-10.931^{****}
	AO	19.55 (2.415)			AO	1.898 (0.168)	
FD43_143_aD	Normal	135.2 (8.869)	-16.489^{****}	FArea02_aD	Normal	7116 (726.4)	-6.966^{****}
	AO	145.8 (9.056)			AO	7477 (707.2)	
FD53_153_aD	Normal	151.9 (7.149)	-12.477^{****}	FArea03_aD	Normal	4197 (482.1)	-9.578^{****}
	AO	158.2 (6.888)			AO	4552 (530.3)	
FD94_194_aD	Normal	149.7 (7.805)	-17.517^{****}	FDV7_9	Normal	28.11 (10.74)	2.508^{*}
	AO	159.4 (7.444)			AO	26.03 (11.8)	
FDH33_133_aD	Normal	154.9 (7.16)	-14.758^{****}	FDV9_12	Normal	28.78 (3.919)	-4.412^{****}
	AO	162.5 (6.98)			AO	30.05 (4.192)	
FA18_17_25	Normal	134.2 (6.799)	-4.709^{****}	FDV12_14	Normal	36.29 (3.833)	2.993^{**}
	AO	136.6 (7.419)			AO	35.47 (3.639)	
FA118_117_125	Normal	133 (13.114)	-3.569^{***}	FDV14_21	Normal	13.58 (1.857)	-2.325^{*}
	AO	135.9 (6.704)			AO	13.89 (1.892)	
FA18_25_43	Normal	98.78 (5.718)	-8.639^{****}	Fh_Angle_73_72	Normal	69.2 (6.345)	3.329^{***}
	AO	102.3 (5.461)			AO	67.66 (6.629)	
FA118_125_143	Normal	99.57 (5.675)	-8.933^{****}	Nose_Angle_14_12	Normal	58.01 (4.609)	2.933^{**}
	AO	103.2 (5.498)			AO	57.03 (4.668)	
FA17_25_43	Normal	119.9 (6.319)	$-4.094^{**,*}$	Nose_Angle_14_21	Normal	45.43 (5.729)	-2.424^{*}
	AO	121.8 (6.411)			AO	46.42 (5.606)	
FA117_125_143	Normal	121.2 (6.543)	-4.274^{****}	SA12_09	Normal	85.54 (5.864)	-2.737^{**}

Feature	Class	Mean (Std.)	t	Feature	Class	Mean (Std.)	t
	AO	123.2 (6.02)			AO	86.68 (5.639)	
FA18_17_43	Normal	84.89 (6.686)	-9.122^{****}	Fh_Cur Max_R79_69	Normal	0.532 (0.196)	2.137^{*}
	AO	89.29 (6.778)			AO	0.5 (0.215)	
FA118_117_143	Normal	85.2 (6.951)	-9.205^{****}	PDH44_53	Normal	94.53 (7.702)	-2.978^{**}
	AO	89.74 (6.692)			AO	96.1 (6.306)	

3.3 Summary

In this paper, we determined the relationship between abdominal obesity and facial characteristics in Korean adults and demonstrated the potential to predict abdominal obesity from morphological facial features of individuals. Even though there are several problems to be addressed in perfecting the classification of abdominal obesity, our results may provide useful clues for alternative diagnosis of abdominal obesity, as well as offering new contributions to medical science.

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