Original article

Regional adiposity and cardiorespiratory fitness related to fat percentage in amateur cyclists

José Ramón Alvero-Cruz, José Francisco Vico Guzmán

Universidad de Málaga

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Summary

Introduction: Regional adiposity monitoring can detect patterns related to sports performance. The objective of this study is to determine the degree of sensitivity and specificity of skinfolds in relation to a percentage of body fat, estimated as ideal for a particular sport modality, as well as other ergometric variables.
Material and method: Participated in the study 136 male, *amateur* cyclists, ranging 40-60 years old, with a weight: 72.8 ± 8.5 kg, height: 169.5 ± 6.5 cm, BMI of 25.6 ± 2.3 kg/m^2 A total of annual covered km of 8372.9 ± 3429.6. Were analyzed 8 skinfold (tríceps, subscapular, bicipital, crestal, ileospinal, abdominal, anterior thigh and medial calf) under ISAK guidelines. Also were collected the maximum load achieved (W), the VO_{2max} and the ergometric index. Variable associations were performed using the correlation coefficient of Spearman. Ten percent fat mass was established as ideal for this type of athletes. We analyzed the sensitivity and specificity in relation to the percentage of ideal fat using ROC curves, according the best cut-off point by the Youden index.
Results: The values of sensitivity and specificity (S/E) are greater for the subscapular skinfold: 93/89 and ileospinal: 100/78 compared with those of the limbs. There are inverse correlations of fat mass with covered km/year (r=-0.27, p=0.0017), with maximal aerobic power (r=-0.33, p=0.0001), Ergometric index (r=-0.59, p<0.0001) and VO_{2max} (r=-0.28, p=0.0006).
Conclusions: Subscapular and ileospinal skinfolds have a great sensitivity and specificity to discriminate adequate body fat percentage in *amateur* cyclists and are more sensitive the trunk skinfolds than those of the limbs. Also emphasize the body mass index and ergometric index.

Key words:
Fat mass percentage. Skinfolds. Graded exercise test. ROC curves.

Adiposidad regional y *fitness* cardiorrespiratorio en relación al porcentaje de grasa ideal, en ciclistas *amateur*

Resumen

Introducción: La monitorización de la adiposidad regional puede detectar patrones que se relacionan con el rendimiento deportivo. El objetivo del presente trabajo es determinar el grado de sensibilidad y especificidad de los pliegues cutáneos de grasa en relación a un porcentaje de grasa corporal, estimado como ideal para una práctica deportiva determinada, así como otras variables ergométricas.
Material y método: Participaron en el estudio 136 ciclistas *amateur*, varones, entre 40-60 años, con un peso de 72,8 ± 8,5 kg, talla de 169,5 ± 6,5 cm, IMC de 25,6 ± 2,3 kg/m^2 un total de km anuales recorridos de 8.372,9 ± 3.429,6. Se analizaron los datos de los pliegues tricipital, subescapular, bicipital, crestal, ileospinal, abdominal, muslo anterior y medial de la pierna, bajo las recomendaciones de la ISAK. Igualmente se recogieron datos de la carga máxima alcanzada, el VO_{2max} y el índice ergométrico. Se realizaron asociaciones de variables mediante los coeficientes de correlación de Spearman. El valor de 10% de masa grasa fue el establecido como ideal para este tipo de deportistas. Se analizaron la sensibilidad y la especificidad en relación al porcentaje de grasa ideal mediante curvas ROC, designando el mejor punto de corte mediante el índice de Youden.
Resultados: Los valores de sensibilidad y especificidad (S/E) son mayores para los pliegues subescapular: 93/89 e ileospinal: 100/78 comparado con los de los miembros inferiores. Existen correlaciones inversas de la masa grasa con los km recorridos/año (r=-0,27, p=0,0017), con la potencia aeróbica máxima (r=-0,33, p=0,0001), el índice ergométrico (r=-0,59, p<0,0001) y el VO_{2max} (r=-0,28, p=0,0006).
Conclusiones: El pliegue subescapular e ileospinal poseen una gran sensibilidad y especificidad para el diagnóstico discriminante de unos valores adecuados de grasa corporal en ciclistas aficionados y son más sensibles los pliegues del tronco que los de los miembros. Así mismo destacan el índice de masa corporal y el índice ergométrico.

Palabras clave:
Porcentaje de grasa. Pliegues cutáneos. Ergometría. Curvas ROC.

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Correspondence: José Ramón Alvero-Cruz
E-mail: alvero@uma.es

Introduction

Monitoring body composition and particularly regional adiposity can identify patterns related to sports performance. Although body composition can be a reflection of numerous factors not related to physical activity and training, many acknowledge that certain specific conditions of low or high adiposity alone can be influential in many different sports and in the performance of athletes in competitions[1].

Having information on the regional adiposity and body composition profiles of sportsmen and women can be very useful for coaches, for example to improve their athletes' development programmes and permit longitudinal monitoring of changes in their body composition, which may reflect sports fitness. Maintaining an ideal body composition over the year can help ensure performance in an athlete's sport and also serve as a means of controlling his/her health and well-being.

Similarly, long-term aerobic training produces not only physiological changes in the aerobic metabolism, but also general and regional body composition changes, and differences according to sex can be found[2,3]. Improvements and positive effects in fat distribution have also been detected when comparing continuous aerobic exercise with high-intensity exercise routines after 12 weeks of training, this study finding that work capacity improved with both types of exercise, that there were no differences in abdominal or gluteal circumference, and no differences were found in lipid and biochemical variables[4]. According to the 2015 Spanish survey of sport habits, cycling is a very popular activity in the country, with about 22.2% of the population cycling at least once a week[5].

The aim of this study was to determine the degree of association between fat mass and parameters of aerobic condition in non-professional male distance cyclists and to determine the sensitivity and specificity of the fat skinfolds and aerobic fitness factors in relation to a percentage of total body fat estimated as ideal for the type of sport studied.

Material and method

136 amateur male cyclists aged between 40 and 60, weighing 72.8 ± 8.5 kg, measuring 169.5 ± 6.5 cm and with a BMI of 25.6 ± 2.3 kg/m^2, who cycled a total of 8,372.9 ± 3,429.6 km a year took part in this cross-sectional study.

Their anthropometric data were obtained using a sports-medicine study protocol: weight, height and skinfolds (triceps, subscapular, biceps, iliac crest, iliac spine, abdomen, front thigh and medial calf) taken by the same researcher with a Slim guide calliper accurate to 1 mm, following the recommendations of the ISAK[6,7]. Fat mass was estimated by the sum of 4 folds: triceps, subscapular, iliac spine and abdomen, applying Faulkner's equation[8], respecting the recommendations of the consensus document.

Values were also obtained for maximum aerobic power (in watts) and ergometric index (watts/kg), and estimated values of VO_{2max} were arrived at using the heart rate relationship method and Uth's equation[9] following a staged stress test on a Monark 818E mechanical cycle ergometer (Sweden). The stress test consisted of a 10-minute warm-up at 50 W before testing actually began with increases of 25 W/min until exhaustion. The heart rate was determined on a continuous basis simultaneously through an electrocardiographic monitoring system (Hellige, Germany) and a Polar heart rate monitor (Polar, Finland). The ergometric index was calculated using the equation: peak watts reached during ergometry/body weight (kg).

Statistical analysis

The data are expressed as the mean ± standard deviation. The normal distribution of the variables was tested using the Kolmogorov-Smirnov test. Rank correlation between the variables was analysed using Spearman's rho. Sensitivity and specificity were analysed in relation to the ideal fat percentage using ROC curves and designating the optimal cut-off point using the Youden index. The value of 10% fat mass for Faulkner's equation was categorized for subsequent statistical analysis as the value established as ideal for this type of male athlete10. The data were processed using MedCalc version 17.8 for Windows. The accepted level of significance was $p < 0.05$ in all cases.

Results

Fat mass has a low-moderate inverse relationship with km covered annually, VO_{2max}, the ergometric index and maximum aerobic power, all of these relationships being significant ($p<0.05$). Meanwhile, fat mass has a direct relationship with body weight ($p<0.001$) (Table 1).

Correlations with km cycled per year

The trunk skinfolds (iliac crest, iliac spine and abdomen) reveal significant inverse relationships with km covered (r= between -0.24 and 0.34, all $p<0.05$), while no significant correlation was found with the limb skinfolds ($p>0.05$) (Table 2).

Table 1. Spearman's rank correlation coefficients between fat mass and demographic and ergometric variables.

		HRmax (ppm)	Age (years)	km (year)	Weight (kg)	Erg Ind (W/kg)	VO_{2max} (mL/kg/min)	MAP (W)
FM	r	-0.052	0.158	-0.27	0.385	-0.595	-0.289	-0.337
(%)	p	0.551	0.066	0.0017	<0.0001	<0.0001	0.0006	0.0001

r: correlation coefficient; p: level of significance; MAP: Aerobic power in W; Erg Ind: Ergometric index; VO_{2max}: Estimated maximal oxygen uptake (mL/kg/min); FM: fat mass.

Correlations with maximum aerobic power

All the skinfolds showed significant inverse correlations ($p<0.05$), except the medial calf skinfold ($p>0.05$) (Table 2).

ROC curves

Greater sensitivity and specificity values were obtained for the trunk skinfolds than the limb skinfolds. The Youden index values were higher for the trunk skinfolds (Table 3) than the limbs (Figure 1). The subscapular skinfold is particularly worthy of note for its greater sensitivity and specificity (Table 3).

Table 4 shows the sensitivity and specificity values relating to the ROC curves of certain physiological variables. The variables with the highest sensitivity and specificity values are the body mass index and the ergometric index (Figure 1).

Discussion

To our knowledge, this is the first study to analyse the sensitivity and specificity of anthropometric variables, such as individual fatfolds and functional parameters, in order that they be discriminated by an

Table 2. Correlation coefficients and significance between trunk and limb skinfolds and physiological variables.

		Trunk skinfolds				Limb skinfolds			
		SBSC	CRES	SPIN	ABD	TRI	BIC	MCAL	THI
km year	r	-0.086	-0.273	-0.246	-0.341	-0.104	-0.112	-0.148	-0.086
	p	0.3267	0.0015	0.0043	0.0001	0.2345	0.1997	0.0893	0.3293
MAP	r	-0.398	-0.246	-0.262	-0.20	-0.274	-0.303	-0.152	-0.214
	p	<0.0001	0.0039	0.0021	0.0197	0.0013	0.0003	0.0792	0.0128
Erg Ind	r	-0.544	-0.533	-0.442	-0.564	-0.365	-0.469	-0.234	-0.2
	p	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.0064	0.02
VO_{2max}	r	-0.209	-0.283	-0.214	-0.288	-0.19	-0.298	-0.14	-0.126
	p	0.0144	0.0009	0.0122	0.0007	0.0271	0.0004	0.1056	0.1445
FM	r	0.823	0.811	0.893	0.891	0.691	0.742	0.567	0.584
	p	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Weight	r	0.126	0.382	0.325	0.475	0.243	0.262	0.133	0.067
	p	0.1431	<0.0001	0.0001	<0.0001	0.0043	0.002	0.1232	0.435

MAP: Aerobic power in W; Erg Ind: Ergometric index; VO_{2max}: Estimated maximal oxygen uptake (mL/kg/min); FM: fat mass; SBSC: Subscapular; CRES: Iliac crest; SPIN Iliac spine; ABD: Abdomen; TRI: Triceps; BIC: Biceps; MCAL: Medial calf; THI: Front thigh.

Table 3. Sensitivity and specificity of fatfolds for the diagnosis of the ideal percentage of body fat.

Fold	*Cut-off*	Sens	95% CI	Spec	95% CI	+LR	95% CI	-LR	95% CI	*Youden Index*
ABD	>12	85.61	78.4-91.1	88.89	51.8-99.7	7.7	1.2-49.0	0.16	0.1-0.3	0.74
SBSC	>8	93.18	87.5-96.8	88.89	51.8-99.7	8.39	1.3-53.3	0.077	0.04-0.2	0.83
CRES	11	87.88	81.1-92.9	88.89	51.8-99.7	7.91	1.2-50.2	0.14	0.08-0.2	0.77
SPIN	>5	100	97.2-100	77.78	40.0-97.2	4.5	1.3-15.3	0		0.78
TRI	>7.5	55.3	46.4-64.0	100	66.4-100			0.45	0.4-0.5	0.55
BIC	>3	78.03	70.0-84.8	88.89	51.8-99.7	7.02	1.1-44.7	0.25	0.2-0.4	0.67
THI	>10	71.76	63.2-79.3	88.89	51.8-99.7	6.46	1.0-41.1	0.32	0.2-0.5	0.61
MCAL	>5.5	77.69	69.6-84.5	66.67	29.9-92.5	2.33	0.9-5.9	0.33	0.2-0.6	0.44

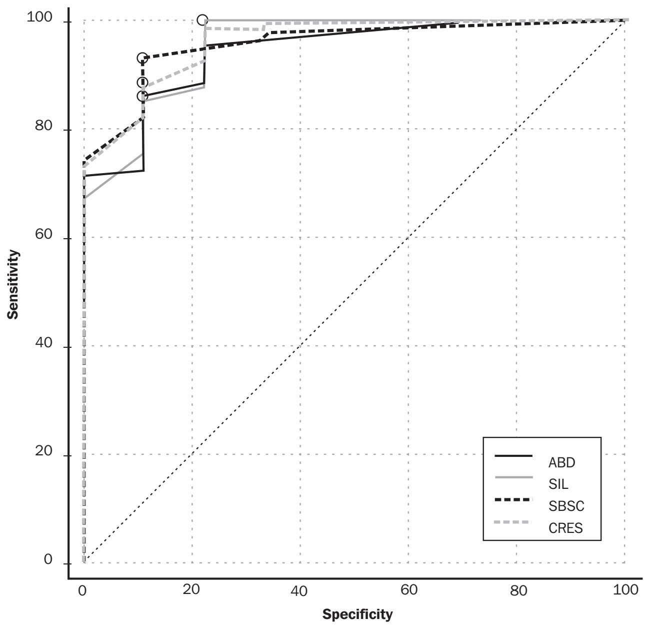
ABD: Abdomen; SBSC: Subscapular; CRES iliac crest; SPIN: Iliac spine; TRI: Triceps; BIC: Biceps; THI: Front thigh; MCAL: Medial calf.

Table 4. Sensitivity and specificity of physiological variables for the ideal percentage of body fat.

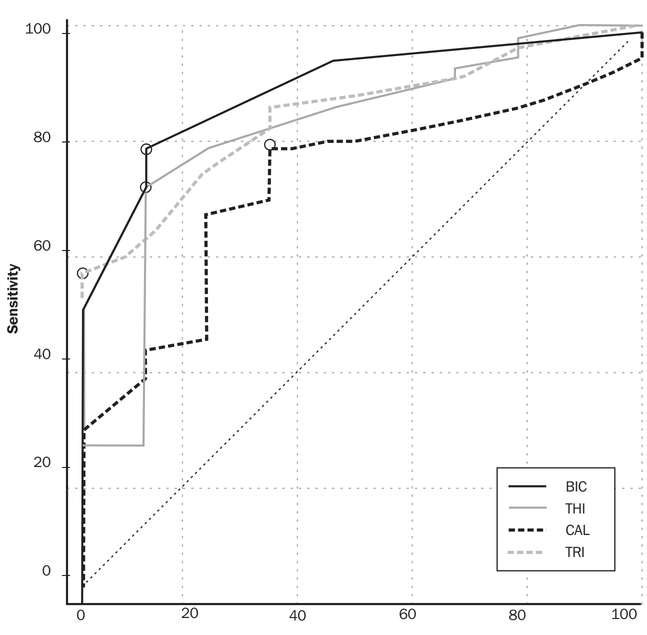
Fold	*Cut-off*	Sens	95% CI	Spec	95% CI	+LR	95% CI	-LR	95% CI	*Youden Index*
km/year	>8000	45.6	36.7-54.7	75	34.9 - 96.8	1.82	0.5-6.2	0.73	0.5-1.1	0.20
VO_{2max}	≤43.59	54.69	45.7-63.5	100	63.1 - 100			0.45	0.4-0.5	0.55
BMI	>23.57	87.5	80.5-92.7	75	34.9 - 96.8	3.5	1.1-11.6	0.17	0.09 0.3	0.62
ERGI	4.98	83.59	76.0-89.5	75	34.9 - 96.8	3.34	1.0-11.1	0.22	0.1-0.4	0.58

VO_2: VO_{2max}; BMI: Body mass index; ERGI: Ergometric index.

Figure 1. Top: ROC curves for the trunk skinfolds (abdomen, supraspinal, subscapular and iliac crest). Bottom: ROC curves for the limb skinfolds (biceps, front thigh, medial calf and triceps).



ABD: Abdomen; SIL: Supra-iliac; SBSC: Subscapular; CRES: Iliac crest



BIC Biceps; THI: Front thigh; CAL: Calf; TRI: Triceps

ideal fat weight value for a highly popular sport and to determine their relationship with aerobic fitness variables.

In this sense, the results can be considered relevant for coaches, technicians and athletes as a way to control changes related to training and physical activity. This cross-sectional study is limited insofar as discovering the influence and effects of the volume of training is concerned, as only a longitudinal intervention study could reach any conclusions in this regard.

The data obtained in this study are an analysis of the relationship between fat mass, individual skinfolds and the performance values obtained in a physiology laboratory, and variables resulting from the effect of the training load on regional body composition variables. We also believe that comparing these same variables with performance variables on flat and rising terrain could be of great interest and could shed light on the relationships between fat deposits and the effects of air resistance (on flat terrain) and those situations in which gravity plays a greater role (uphill terrain). The relationships between adiposity and performance are well known, adiposity explaining many of the associations between physical activity and physical fitness in active men, as well demonstrated by Serrano *et al.*, who showed that adiposity and age were strong predictors of VO_{2max}, and that the energy spent in vigorous activities was inversely proportional to adiposity[11].

This correlational study could provide us with evidence of the effect of continuous exercise and training on total body fat values or regional adiposity patterns. The relationship between skinfolds and fat mass was in all cases both direct and significant, although the correlation values were greater in the trunk skinfolds than the limb skinfolds. We believe that this was due to the fact that the study was carried out on a sample of males and it has been well established that for reasons of sexual dimorphism, there exists a greater fat deposition on the trunk in male subjects[12,13] than on the limbs and, therefore, the distance covered, the maximum aerobic power values and the ergometric index have to some extent a greater relationship with the trunk skinfolds. It would appear that continuous aerobic exercise has a greater effect on the trunk skinfolds than on those on the limbs, with the consequent beneficial effect of lower trunk fat and, as a result, a reduction in the cardiovascular and metabolic risks associated with this factor[14]. Similarly, there exist correlations between skinfolds and body weight for all the skinfolds, those on the trunk being stronger.

In their longitudinal intervention study of physical exercise, Keating et al. compared a form of continuous exercise with a form of high intensity interval training, discovering that continuous exercise performed at an intensity of between 50 and 65% VO_{2max} produced a significant drop in trunk fat and visceral fat, something which was not observed in the HIIT group[4]. These results fall in line with the data obtained in this study, because presumably the type of activity carried out by the subjects of study was performed at low intensities, promoting the chronic activity of lipolysis mediated by hormones over many years, with the subsequent increased availability of fatty acids, in conjunction with a greater metabolism, resulting in a greater uptake and oxidation of fatty acids[15].

Other authors have also found a relationship between training load, fat mass and body weight. A decrease in body weight has been related to a loss of fat weight and an increase in physical activity[16].

Meanwhile, other authors have found no relationship between training load and fat level[2]. Knechtle did not find significant correlations between running time and fat percentage or between fat percentage and the number of km covered per week.

The reduction of fat mass, also known as "non-functional mass", and an increase in fat-free mass is related to enhanced performance and this would be consistent with the data obtained in this study[17].

In the study, age shows direct but not significant correlations with fatfolds. This may be due to the fact that athletes of this kind, highly accustomed to an annual training routine, always maintain very similar regional fat deposit and total body fat values over time[2, 18].

There are no studies of sensitivity and specificity using ROC curves to discriminate ideal body fat values. The most specific and sensitive skinfolds are the subscapular skinfold with a cut-off point of 8 mm and the iliac crest skinfold with 11 mm. Among other variables analysed, the body mass index gave a cut-off point of 23.57 kg/m^2 and an ergometric index of 4.98 W/kg. These associated cut-off points could be considered very suitable values of adiposity and cardiorespiratory fitness for amateur cyclists aged from 40 to 60, and could be used to evaluate cyclists in this age range. Some of the statements made may be speculative and more research into these relationships with longitudinal studies is needed.

Conclusions

The greatest strength of this study lies in the potential usefulness of the different cut-off points for coaches and athletes. The subscapular and iliac crest skinfolds are very sensitive and specific for discriminating appropriate body fat values and body mass and ergometric indices in amateur cyclists. This correlational study provides us with evidence of the effect of continuous training exercise on body fat values.

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