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Originales

Data mining of key anthropometric variables in elite and non-elite wrestlers using principal component analysis



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ABSTRACT

Objective. To identify the key anthropometric variables that characterise elite and non-elite wrestlers by means of principal component analysis, and to compare the anthropometric profile of both competitive levels.

Method. Sixty male Iranian wrestlers (30 elite, 30 non-elite) underwent an anthropometric assessment including height, body mass, body mass index, eight skinfolds, two bicondylar breadths, eleven girths, body fat percentage, body fat mass, skeletal muscle index and total-body skeletal muscle mass. Principal component analysis was applied to the 27 variables in order to identify the most representative ones. Independent t-tests compared both groups and Cohen's d was calculated as effect size.

Results. Anthropometric features were reduced to two principal components explaining 76.3% of the total variance. The first component (50.7%) showed high loadings for girth measurements and muscular properties, whereas the second (25.5%) was associated with skinfold thicknesses and body fat properties. Elite wrestlers were taller, showed larger girths (shoulders, chest, biceps, forearm, thigh, knee and wrist), thinner skinfolds (triceps, calf, chest and front thigh), lower body fat percentage, lower skeletal muscle index and greater total-body skeletal muscle mass ($p < .05$). No differences were found for body mass index, bicondylar breadths or body fat mass.

Conclusions. Principal component analysis is a useful tool to detect representative anthropometric variables in wrestlers. Girth measurements and muscular properties emerged as the most informative dimension, which may support a more efficient variable selection process for talent identification and strength and conditioning programming in wrestling clubs.

Keywords: Body composition; Muscle; Big data; Sport science; Data mining.

Minería de datos de las variables antropométricas clave en luchadores de élite y no élite mediante análisis de componentes principales

RESUMEN

Objetivo. Identificar las variables antropométricas clave que caracterizan a los luchadores de élite y no élite mediante el análisis de componentes principales, y comparar el perfil antropométrico de ambos niveles competitivos.

Método. Sesenta luchadores iraníes varones (30 de élite y 30 no élite) fueron evaluados antropométricamente: talla, masa corporal, índice de masa corporal, ocho pliegues cutáneos, dos diámetros bicondíleos, once perímetros, porcentaje de grasa corporal, masa grasa, índice de masa muscular esquelética y masa muscular esquelética total. Se aplicó un análisis de componentes principales a las 27 variables para identificar las más representativas. Se emplearon pruebas t para muestras independientes y se calculó la d de Cohen como tamaño del efecto.

Resultados. Las características antropométricas se redujeron a dos componentes principales que explicaron el 76.3% de la varianza total. El primer componente (50.7%) presentó cargas elevadas en los perímetros y las propiedades musculares, mientras que el segundo (25.5%) se asoció a los pliegues cutáneos y a las propiedades de la grasa corporal. Los luchadores de élite fueron más altos, presentaron mayores perímetros (hombros, tórax, bíceps, antebrazo, muslo, rodilla y muñeca), menores pliegues cutáneos (triceps, pantorrilla, tórax y muslo anterior), menor porcentaje de grasa corporal, menor índice de masa muscular esquelética y mayor masa muscular esquelética total ($p < .05$). No se hallaron diferencias en el índice de masa corporal, los diámetros bicondíleos ni la masa grasa.

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Conclusiones. El análisis de componentes principales resulta útil para detectar variables antropométricas representativas en luchadores. Los perímetros y las propiedades musculares emergieron como la dimensión más informativa, lo que puede favorecer una selección de variables más eficiente en los procesos de detección de talentos y en la programación del entrenamiento de fuerza en los clubes de lucha.

Palabras clave: Composición corporal; Músculo; Macrodatos; Ciencias del deporte; Minería de datos.

Mineração de dados das variáveis antropométricas-chave em lutadores de elite e não elite por meio da análise de componentes principais

RESUMO

Objetivo. Identificar as variáveis antropométricas-chave que caracterizam lutadores de elite e não elite por meio da análise de componentes principais e comparar o perfil antropométrico de ambos os níveis competitivos.

Método. Sessenta lutadores iranianos do sexo masculino (30 de elite e 30 não elite) foram avaliados antropometricamente: estatura, massa corporal, índice de massa corporal, oito dobras cutâneas, dois diâmetros bicondilares, onze perímetros, percentual de gordura corporal, massa gorda, índice de massa muscular esquelética e massa muscular esquelética total. Aplicou-se a análise de componentes principais às 27 variáveis para identificar as mais representativas. Foram utilizados testes t para amostras independentes e calculou-se o d de Cohen como tamanho de efeito.

Resultados. As características antropométricas foram reduzidas a dois componentes principais que explicaram 76.3% da variância total. O primeiro componente (50.7%) apresentou cargas elevadas nos perímetros e nas propriedades musculares, enquanto o segundo (25.5%) associou-se às dobras cutâneas e às propriedades da gordura corporal. Os lutadores de elite foram mais altos, apresentaram maiores perímetros (ombros, tórax, bíceps, antebraço, coxa, joelho e punho), menores dobras cutâneas (tríceps, panturrilha, tórax e coxa anterior), menor percentual de gordura corporal, menor índice de massa muscular esquelética e maior massa muscular esquelética total ($p < .05$). Não foram encontradas diferenças no índice de massa corporal, nos diâmetros bicondilares nem na massa gorda.

Conclusões. A análise de componentes principais é uma ferramenta útil para detectar variáveis antropométricas representativas em lutadores. Os perímetros e as propriedades musculares emergiram como a dimensão mais informativa, o que pode favorecer uma seleção de variáveis mais eficiente nos processos de detecção de talentos e na programação do treinamento de força em clubes de luta.

Palavras-chave: Composição corporal; Músculo; Big data; Ciências do esporte; Mineração de dados.

INTRODUCTION

Multiple factors may contribute to predicting the future success of wrestlers, yet most of them are difficult to control. Kaynar reported that coaches ($n = 165$) based talent identification mainly on competition observation and technical characteristics (27.9%), the physical structure and wrestling tendencies of the athletes (24.9%), basic motor features (20%), previous success (15.8%) and intelligence (11.5%).¹ In the literature there is consistent evidence of a connection between anthropometric and body composition factors and the attainment of high-level wrestling performance.^{2,3} Pallarés et al. showed that elite female wrestlers were older (8-10%) and had more fat-free mass (3%) than amateur wrestlers.⁴ As such, measuring physical factors is imperative for those working within talent identification systems in order to evaluate and monitor athletes and to establish short- and long-term goals.⁵ Therefore, identifying which variables provide the most relevant information about the physical features of wrestlers can be considered a critical component of future success.

In order to reduce large sets of variables into key features, several statistical methods, such as principal component analysis (PCA), single value decomposition and factor analysis, have been developed within sports performance research.⁶⁻⁸ Previous studies on talent identification⁹ and athlete monitoring¹⁰ revealed that PCA can reduce the dimensionality of a dataset and identify its most relevant variables. PCA is an unsupervised technique used for the reduction of high-dimensional data that transforms many correlated variables into a smaller number of new variables, or principal components (PC), while minimising information loss.¹¹ Thus, as a data reduction technique, PCA can distinguish the most significant variables and highlight performance indicators in various sports.

Physical and anthropometric variables have been explored using PCA in sports such as rugby,¹⁰ hockey¹² and basketball.¹³ For example, McCormack et al. examined the physical qualities of academy and international youth rugby league players using PCA, and their findings suggested that this technique can help identify overall differences between playing levels.¹⁴ PCA has also been used to explore an anthropometric, growth and maturity index in soccer and its relationship with players' physical attributes, fitness, motivation and skills.¹⁵ Given the several applications of PCA in performance analysis as a data reduction method, identifying key body-related differences between wrestlers of different competitive levels can be expected; however, this hypothesis has not been assessed in wrestling yet.

Considering the importance of talent identification in wrestling, determining the optimum physical features at an early stage might play a relevant role in planning, performance analysis and coaching. Therefore, the main goal of this study was to identify the key anthropometric variables that predict wrestlers' future success using PCA. Secondly, the overall differences in anthropometric features between elite and non-elite wrestlers were examined.

METHODS

Participants

Sixty male Iranian wrestlers took part in this cross-sectional study: 30 elite (age 18.73 ± 4.48 years; body mass 69.56 ± 15.50 kg; height 171.67 ± 8.74 cm) and 30 non-elite (age 14.27 ± 3.43 years; body mass 57.32 ± 16.88 kg; height 161.25 ± 15.91 cm). The elite group trained at least six days a week, involving considerable skill and fitness sessions (up to 10 per week, 60-90 minutes per session), and

Instruments and procedures

Statistical analysis

The first and second PCs were extracted for further analysis, as they explained the most variance in the dataset and had eigenvalues > 1 , a typical threshold for determining which PCs to extract. Using these PC, a scatter plot of the first two components was created for each group (MATLAB PCA toolbox). To assist in visualising the groups, convex hulls were plotted around each group. The scree plot of the explained variance of each PC and the contribution of the anthropometric variables to PC1 and PC2 were also depicted.

Descriptive data are presented as mean and standard deviation. Independent t-tests were used to compare anthropometric data between elite and non-elite wrestlers, with the level of significance set at $p \leq .05$. To evaluate the magnitude of the differences, Cohen's effect size (d) was calculated and interpreted as very small ($0.00 < 0.20$), small ($0.20 < 0.50$), medium ($0.50 < 0.80$) and large (≥ 0.80).²⁰

Figure 1A displays the scree plot of the PCA, depicting the variance explained by each PC. PC1 (50.7%) and PC2 (25.5%) accounted for 76.3% of the variance in the dataset, whereas PC3 to PC27 only added 23.7%. The contribution of the physical features to PC1 and PC2 is shown in Figures 1B and 1C, respectively. Table 2 displays the component loadings of each variable for PC1 and PC2, which demonstrate the contribution of each physical feature to each of the PC.

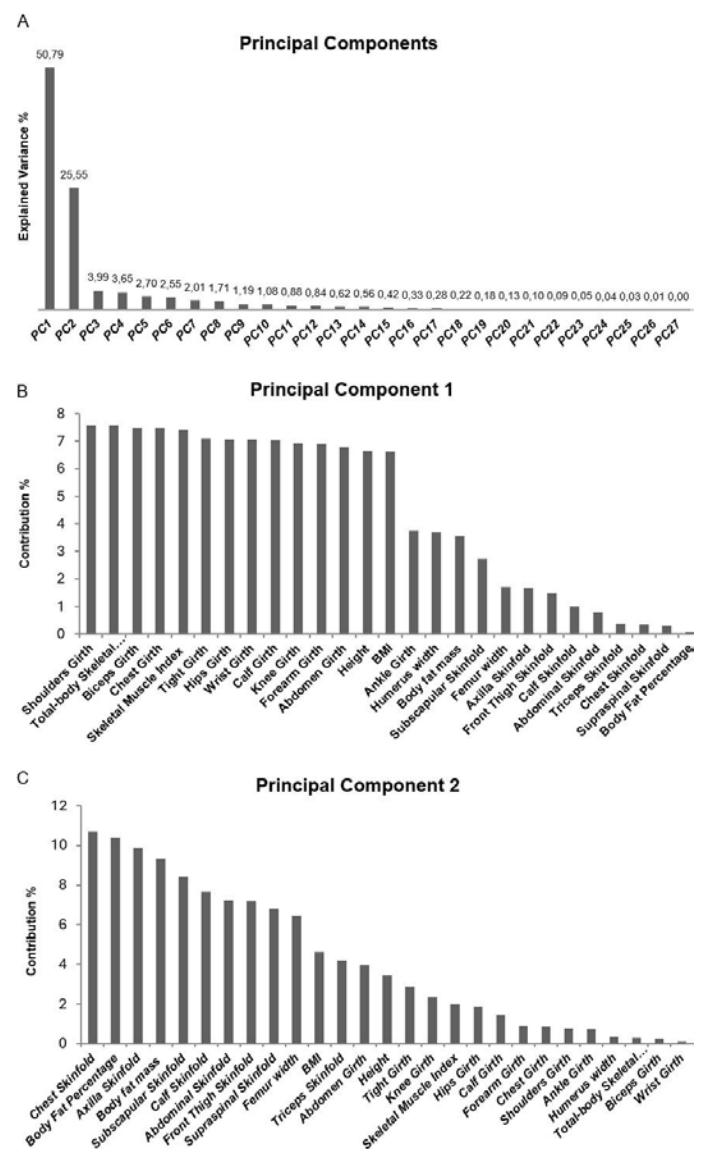


Figure 1. (A) Scree plot for the principal component analysis and the fractional variance attributed to each principal component. (B) Contribution

Table 1. Mean and standard deviation values of the anthropometric measurements and differences between elite and non-elite wrestlers.

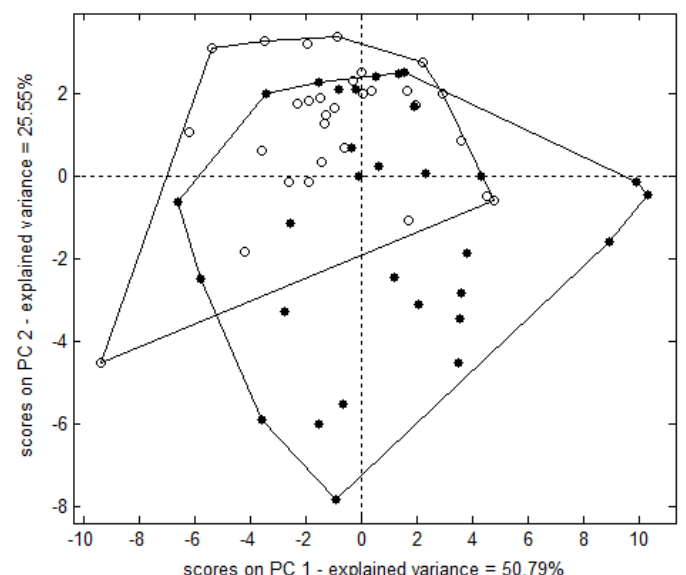
Variable	Elite (n = 30)	Non-elite (n = 30)	p	95% CI	Cohen's d
Height (cm)	171.67 ± 8.74	161.25 ± 15.91	0.003*	3.70 / 17.50	0.81 (large)
Body mass index (kg/m ²)	23.38 ± 3.86	21.53 ± 3.72	0.064	-0.11 / 3.80	0.48 (small)
Triceps skinfold (mm)	8.13 ± 2.64	10.80 ± 5.15	0.015*	-4.77 / -0.54	0.65 (medium)
Subscapular skinfold (mm)	9.24 ± 2.64	9.93 ± 3.47	0.415	-2.35 / 0.98	0.22 (small)
Supraspinal skinfold (mm)	6.71 ± 2.67	8.28 ± 4.13	0.086	-3.36 / 0.22	0.45 (small)
Calf skinfold (mm)	7.49 ± 3.55	10.34 ± 4.90	0.013*	-5.06 / -0.63	0.66 (medium)
Chest skinfold (mm)	6.15 ± 2.30	8.95 ± 4.61	0.004*	-4.67 / 0.91	0.76 (medium)
Abdominal skinfold (mm)	10.81 ± 4.80	13.48 ± 6.20	0.067	-5.53 / 0.19	0.48 (small)
Front thigh skinfold (mm)	10.86 ± 3.77	14.52 ± 6.44	0.009*	-6.38 / -0.92	0.69 (medium)
Axilla skinfold (mm)	8.42 ± 3.37	9.71 ± 4.55	0.217	-3.36 / 0.78	0.32 (small)
Shoulders girth (cm)	109.58 ± 11.22	98.48 ± 13.08	0.001*	4.80 / 17.39	0.91 (large)
Chest girth (cm)	94.32 ± 11.42	85.35 ± 11.97	0.004*	2.92 / 15.01	0.76 (medium)
Biceps girth (cm)	32.87 ± 3.86	29.00 ± 4.77	0.001*	1.62 / 6.10	0.89 (large)
Forearm girth (cm)	27.40 ± 3.04	24.36 ± 3.57	0.001*	1.32 / 4.75	0.91 (large)
Thigh girth (cm)	54.00 ± 5.30	49.90 ± 6.75	0.011*	0.96 / 7.23	0.67 (medium)
Calf girth (cm)	35.12 ± 3.32	33.63 ± 3.98	0.122	-0.41 / 3.37	0.40 (small)
Abdomen girth (cm)	76.97 ± 8.67	73.58 ± 8.97	0.143	-1.17 / 7.94	0.38 (small)
Hips girth (cm)	86.42 ± 8.73	82.00 ± 10.22	0.077	-0.49 / 9.32	0.46 (small)
Knee girth (cm)	36.63 ± 2.64	34.95 ± 3.62	0.044*	0.45 / 3.32	0.53 (medium)
Ankle girth (cm)	26.18 ± 2.57	25.38 ± 3.06	0.278	-0.66 / 2.26	0.28 (small)
Wrist girth (cm)	16.88 ± 0.93	16.09 ± 1.54	0.019*	0.13 / 1.45	0.62 (medium)
Humerus breadth (cm)	7.16 ± 0.86	6.63 ± 1.18	0.054	-0.01 / 1.05	0.51 (medium)
Femur breadth (cm)	8.77 ± 0.49	8.91 ± 1.01	0.486	-0.55 / 0.26	0.17 (very small)
Body fat (%)	7.11 ± 2.77	10.14 ± 5.44	0.009*	-5.26 / -0.79	0.70 (medium)
Skeletal muscle index (%)	44.06 ± 4.07	47.49 ± 5.89	0.011*	-6.04 / -0.80	0.67 (medium)
Body fat mass (kg)	5.15 ± 3.12	5.87 ± 3.49	0.407	-2.42 / 0.99	0.21 (small)
Total-body skeletal muscle mass (kg)	30.07 ± 4.20	26.35 ± 5.46	0.004*	1.20 / 6.24	0.76 (medium)

CI: confidence interval.

* Statistically significant difference between elite and non-elite wrestlers (p < .05).

of the variables to the first principal component. (C) Contribution of the variables to the second principal component.

Figure 2 shows the scatter diagram of the component scores for the first and second principal components, which together explain 76.3% of the total amount of information. Elite wrestlers are marked with white circles and non-elite wrestlers with black circles. Despite evident overlap between the two groups, which is common in anthropometric features due to experimental variability, the plot highlights a potential trend toward separation and a systematic distribution of samples with respect to anthropometric values.

**Figure 2.** Scatter plot of the first two principal component scores. Elite wrestlers are marked with white circles and non-elite wrestlers with black circles.

DISCUSSION

To our knowledge, this is the first report identifying key anthropometric variables that contribute to successful wrestling. The main results of the present study were that (1) anthropometric measures were reduced to two PC explaining 76.3% of the variance,

Table 2. Component loadings of each variable for the first and second principal components.

Variable	PC1	PC2
Height	.845	-.311
Body mass index	.844	.419
Triceps skinfold	-.048	.379
Subscapular skinfold	.349	.759
Supraspinal skinfold	.037	.613
Calf skinfold	-.126	.693
Chest skinfold	-.043	.964
Abdominal skinfold	.102	.653
Front thigh skinfold	-.188	.650
Axilla skinfold	.214	.891
Shoulders girth	.965	-.068
Chest girth	.955	.076
Biceps girth	.956	.024
Forearm girth	.878	-.079
Thigh girth	.903	.256
Calf girth	.898	.130
Abdomen girth	.866	.357
Hips girth	.901	.170
Knee girth	.882	.213
Ankle girth	.479	.065
Wrist girth	.901	-.011
Humerus breadth	.469	.030
Femur breadth	.217	.582
Body fat percentage	.007	.939
Skeletal muscle index	-.943	-.181
Body fat mass	.454	.842
Total-body skeletal muscle mass	.964	-.029

PC: principal component. Loadings ≥ |.75| are shown in bold.

with PC1 (50.7%) influenced by girth measurements and muscular properties (shoulders, biceps, chest, thigh, hips, wrist, calf, knee, forearm, abdomen, skeletal muscle index and total-body skeletal muscle mass) and PC2 (25.5%) influenced by skinfold thicknesses and body fat properties (subscapular, supraspinal, calf, chest, abdominal, front thigh and axilla skinfolds, body fat percentage and body fat mass); and (2) independent t-tests indicated significant differences ($p \leq .05$) between elite and non-elite wrestlers in height, several skinfold thicknesses (triceps, calf, chest and front thigh), most girth measurements (shoulders, chest, biceps, forearm, thigh, knee and wrist), skeletal muscle index, body fat percentage and total-body skeletal muscle mass.

Within PC1, girth measurements (except for ankle girth) and muscular properties (total-body skeletal muscle mass and skeletal muscle index) had higher contributions than the remaining variables. These findings suggest that girth measurements and muscular properties should be monitored, as they appear to be associated with wrestlers' performance. It is accepted that strength is related to muscle size, and previous studies have reported that isometric strength is one of the most important factors of wrestling success.²¹ Therefore, developing girth measurements and muscular properties may be an important factor in achieving success in wrestling.

One of the major findings of the present study was that girth measurements, both muscular and non-muscular components, were higher in elite than in non-elite wrestlers (Table 1). Few researchers have examined girth measurements separated into muscular and non-muscular components in wrestlers of different skill levels. The chest, hip, biceps, forearm, thigh and calf girths of the non-elite wrestlers in the present study were lower than those previously reported for Colombian elite male wrestlers,²² which could be related to the fact that our participants were younger. However, these results

were higher than those reported for wrestlers between 7 and 18 years old.²³ Consequently, it is likely that the differences observed in girth measurements may be partly explained by differences in the strength and conditioning programmes used by elite and non-elite wrestlers.

Concerning muscular properties, and as expected, elite wrestlers demonstrated greater total-body skeletal muscle mass than non-elite wrestlers. This information may be useful for creating optimal strength training programmes for wrestlers with varying levels of strength. However, a distinctive finding of the present study was that non-elite wrestlers had higher skeletal muscle indices than elite wrestlers. Because this variable is directly dependent on total body mass and the magnitude of total-body skeletal muscle mass, this result may be due to various factors, including the contribution of non-skeletal muscle tissues.

Basic measurements such as height and BMI may be relevant factors for achieving success in wrestling. In both PC1 and PC2, BMI and height contributed moderately compared with other variables. Considering that these variables do not account for differences in body composition, they might not be accurate indicators of long-term future success. In agreement with previous research, no significant differences in BMI were detected between elite and non-elite groups.²⁴ However, the wrestlers in our study showed lower mean BMI values than Olympic wrestlers²⁵ and than the values reported by other studies.^{24,26} In contrast, height values were significantly higher in elite than in non-elite wrestlers, and the mean height of our elite wrestlers was rather similar to that of Olympic wrestlers.²⁵ These results suggest that height may be a better indicator than BMI to identify differences between elite and non-elite wrestlers and to predict future success.

Regarding skinfold thicknesses and body fat percentage, our PCA showed that these variables had lower contributions to PC1 and

higher contributions to PC2 than other variables. Consistent with our results, Horswill found no relationship between body fat percentage and competitive success.²⁷ Body fat percentage is influenced by genetics, age, nutritional strategy, prior training history and physical exercise level, so these variables may not be predictive of longer-term functional outcomes.

When comparing elite and non-elite wrestlers, our results indicated that elite wrestlers had lower mean values in the sum of skinfolds. Our elite wrestlers' skinfold values are lower than those reported by Ramírez-Vélez et al.²² Compared with Olympic wrestlers under 18 years of age, the elite wrestlers of the present study had lower values for all skinfold thicknesses except calf and axilla.²⁵ In contrast, Olympic wrestlers over 18 years old had lower values for all skinfold thicknesses, except calf and subscapular, than our elite wrestlers.²⁵

In line with the skinfold results, body fat percentage was significantly lower in elite than in non-elite wrestlers. Yoon suggested that a wrestler's ideal body fat percentage should be between 7% and 10%,²⁸ and our findings are relatively similar to those described by Zaccagni, who determined the body fat percentage of Italian national team elite wrestlers by weight category as 7.1% (55 kg), 8.6% (60 kg), 10.5% (66 kg), 9.5% (74 kg), 9.4% (84 kg) and 15.5% (96 kg).² However, the mean body fat percentage values of the wrestlers in the present study are slightly lower than those previously described by other studies,^{22,29} a discrepancy that may be explained by differences in the training programs.

Lastly, femur and humerus breadths contributed relatively little to both PC1 and PC2, so these variables may not be important factors in predicting future success in wrestlers. In agreement with this finding, no significant differences were found for humerus and femur breadths between groups. Yaşar and Sağır evaluated the humerus and femur breadths of 21 elite Turkish wrestlers and reported higher values in all three weight categories, except for humerus breadth in lightweight wrestlers, compared with our study.³⁰ These differences may be due to the measurement method and to age differences.

The two-dimensional scatter plot of the PC1-PC2 scores (Figure 2) indicated that the clustering trends of elite and non-elite wrestlers were not fully satisfactory and that a partial overlap existed between both groups, possibly because of the lower variance contribution rate. Nevertheless, it shows a systematic distribution of elite and non-elite wrestlers with respect to anthropometric values, with greater dispersion among non-elite wrestlers.

Limitations

This study did not consider physiological factors related to success in wrestling, such as maximal dynamic strength, isometric strength, explosive strength and strength endurance. As this was the first approach to identify key anthropometric variables in wrestling through PCA, several limitations should be mentioned. The most important is the sample size, which means that the data are specific to the study population and cannot be generalised to all wrestlers. In addition, the key anthropometric variables were not calculated separately for elite and non-elite wrestlers. Accordingly, we suggest that future research focuses on the sample sizes required for coaches to confidently identify talented athletes, and compares the key anthropometric variables between elite and non-elite wrestlers.

CONCLUSIONS

PCA proved a useful data-reduction technique for identifying key anthropometric variables in elite and non-elite wrestlers. Anthropometric measures were reduced to two PC explaining 76.3% of the variance: girth measurements and muscular properties influenced PC1 (50.7%), whereas skinfold thicknesses and body fat variables contributed to PC2 (25.5%). These findings emphasise

the importance of girth measurements and muscular properties within the talent identification process in wrestling. Elite wrestlers were taller, had larger girth measurements and greater total-body skeletal muscle mass, and had lower skinfold thicknesses, body fat percentage, and skeletal muscle index than non-elite wrestlers, with similar BMI, bicondylar breadths, and body fat mass. Consequently, these findings may support a more efficient variable selection process in wrestling clubs.

AUTHOR CONTRIBUTIONS

Conceptualisation: M.A., M.E. and D.R.-V.; methodology: M.A., M.E. and D.R.-V.; investigation and data collection: M.A. and M.E.; formal analysis and data curation: M.A., B.A.B.-P. and D.R.-V.; visualisation: M.A. and D.R.-V.; writing, original draft: M.A. and B.A.B.-P.; writing, review and editing: all authors.

CONFLICT OF INTEREST

The authors declare that they have no competing interests.

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