ORIGINAL ARTICLE

Predictors of performance on world-level arm wrestlers

MAURO PASCOA[1] ✉, MIRTES STANCANELLI[2], THIAGO F. LOURENÇO[3], VIRGINIA TESSAROTTO[2], GIL GUERRA-JUNIOR[1], FERNANDA L. LAZARIM[2]

[1]*Laboratory of Growth and Development. Center for Investigation in Pediatric. State University of Campinas. Campinas, Brazil.*

[2]*Minian Medical & Health Group. São Paulo, Brazil.*

[3]*Brazilian Paralympic Centre. São Paulo, Brazil.*

ABSTRACT

This study aims to explore predictors of performance ascertaining the optimal body composition for world-level arm wrestlers in a competitive environment. Athletes underwent body composition assessments and their final competition classifications were noted. Athletes had a pairwise comparison percentile groups for relative fat mass (FM%), scattered by country, fat-free mass (FFM%) clustered by final classification, and comparison of the final classifications, grouped by country. A total of 220 elite, male competitors from 33 countries showed a mixed classification by country for FM% percentiles (p = .089) with values ranging from the 10th percentile (FM = 7.1%) to above the 90th percentile (FM = 16.1%). Extreme values (FM = 4.5%) and country of origin did not predict the classification of the athletes, although the athletes´ ranking <75th did suggest a tendency towards classification (FFM% = 27.3%). Thus, world-level arm wrestlers revealed nutritional issues concerning values for body composition components in a competition environment.

Keywords: Performance analysis, Body composition, Wrestling, Wrestler profile.

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✉ **Corresponding author.** *Laboratory of Growth and Development, Center for Investigation in Pediatric, State University of Campinas. Adress: Tessalia Vieira Camargo - 126, Campinas, SP 13083 – 887 - Brazil.*
E-mail: pascoawaf@gmail.com
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INTRODUCTION

Arm wrestling is a weight-sensitive sport branded by physical strength capabilities and perceptual skills (Akpınar et al., 2013; Bajkowski and Cynarski, 2024; Podrihalo et al., 2020). Several factors such as physical training, nutritional behaviour, health and body composition are crucial for predicting outcomes in weight-sensitive sports, combined with risk factors such as the effects of rapid weight loss on health and physical performance (Castor-Praga et al., 2021; Maksimovic et al., 2024; Ranisavljev et al., 2022).

Arm wrestling involves the action of forcing down the opponent's hand to the losing position on the surface of a special table (Akpınar et al., 2013; Yonca et al., 2017) and compete according to specific weight classes ("*Rules WAF*," 2024). It suggests that relationship between weight and body composition are the main factors in the improvement of performance in weight-sensitive sports (Bajkowski and Cynarski, 2024; Silva, 2019). Thus, we aimed to ascertain the best body composition profile for world-level arm wrestlers, taking into account predictors of performance in a competitive environment. Furthermore, we provided baseline reference data for coaches and athletes, embracing body composition, health and nutritional issues, and physical training programs.

MATERIALS AND METHODS

Subjects

All the volunteers were informed about the study, and signed a free and informed consent form, in accordance with the Helsinki Declaration (1964), and approved by the local Ethical Committee. The inclusion criteria consisted of selecting male athletes above 18 years old, only from the Senior division, during World Arm-wrestling Championships.

Interventions

Athletes underwent body composition assessment, applying a cross-validated equation (Evans et al., 2005) to obtain relative fat mass (FM%), based on the sum of abdomen, thigh, and triceps skinfolds thicknesses (3SKF), as a reference value: FM% = 8.997 + 0.24658*(3SKF) − 6.343*(gender) − 1.998*(race). The 3SKF sites were measure according to the international standards *("Isak - The International Society for the Advancement of Kinanthropometry,"* n.d.). The relative differences of FM provided values to fat free mas (FFM%). Measures comprised total body mass (BM) with a digital floor scale (seca 803, 0.1 kg); height, employing a vertical portable stadiometer (EST-223 Balmak, 0.1 cm); age of the athletes; measures of 3SKF using a Lange™ skinfold calliper (Beta Technology Inc., Cambridge, Maryland, USA, 10 g/mm^2 and an accuracy of 0.5 mm. Anthropometric values had control through technical error of measurement (TEM) verifying the intra-class correlation coefficient (ICC). The athletes' ranking after the awards provided reference values of physical performance.

Statistical analysis

Data outcomes represent the median and interquartile range (IQ = 25th-75th percentiles) to compare athletes' performance in the final classification groups: 1st, 2nd, 3rd, 4th, 5th, and Below (i.e., all those below 5th place). Body composition was analysed by percentile groups: <10th, <25th, <50th, <75th, <90th, >90th (above 90th), and estimated the relative FM and FFM. The data analysis used the Statistical Package for the Social Sciences (SPSS, Inc., Chicago, IL, USA, version 25.0). A Shapiro-Wilk test verified the distribution and the differences between the athletes' performance and evaluated percentile groups using a Kruskal-Wallis test with Bonferroni's post-hoc correction. A radial matrix (Acan, 2017) (chord diagram) permitted multiple comparisons between body composition and classification. A dot-plot diagram represented a cluster distribution of the final classification of the athletes, by country. A level of significance of $p < .05$ was used for all analyses.

RESULTS

Two hundred and twenty top-level male competitors (aged 29.5 ± 5.6 years, height 179.1 ± 8.7 cm, body mass 89.4 ± 20.7 kg) from thirty-three countries, participated in this study. Technical error of measurement (TEM) (value (min-max); percentage value (min; max)) verified the intraclass correlation coefficient (ICC) provided by the two evaluators, through One-Way ANOVA per 20 subjects: TEM = 0.24 (0.13-0.37), 0.37 (0.22-0.64); percentage = 1.92 (0.19-2.81), 3.46 (2.18-6.19); ICC = 1.00, 0.86; respectively. The classification groups (n = 6) provided the effect size (f = 0.25), considering limits for α = .05, and determined the power analysis (1-β err prob = .82) of this study (Figure 1; Table 1).

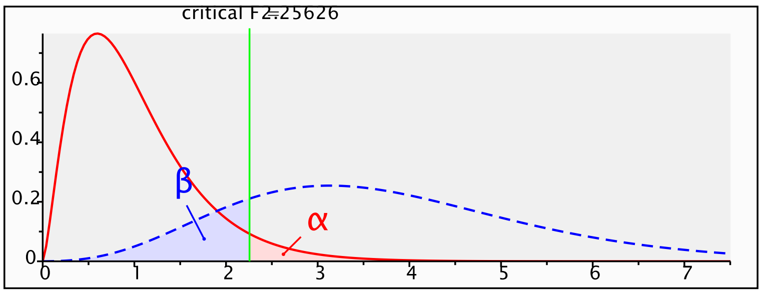


Figure 1. Central and noncentral distribution analysed by G*Power software.

Table 1. Protocol of power analysis.

F tests - ANOVA: Fixed effects, omnibus, one-way			
Analysis:	Post hoc: Compute achieved power		
Input:	Effect size f	=	0.25
	α Error probability	=	0.05
	Total sample size	=	220
	Number of groups	=	6
Output:	Noncentrality parameter λ	=	13.750000
	Critical F	=	2.2566566
	Numerator df	=	5
	Denominator df	=	214
	Power (1-β Error probability)	=	0.8196686

Note. F: the critical Type-I error value; df: degrees of freedom.

Athletes' participation by country (Figure 2) showed a mixed classification of FM% percentiles ($p = .089$) with values ranging from the 10th percentile (FM = 7.1%) to above the 90th percentile (FM = 16.1%).

To results involved controlling the mathematical effect of the confounding factors in the athletes' final classification. Height was not a factor ($p = .569$) but age was. Statistical differences were adjusted with Bonferroni's post-hoc correction ($p = .027$, $p > .164$, respectively) via the Kruskal-Wallis test (Figure 3, Table 2).

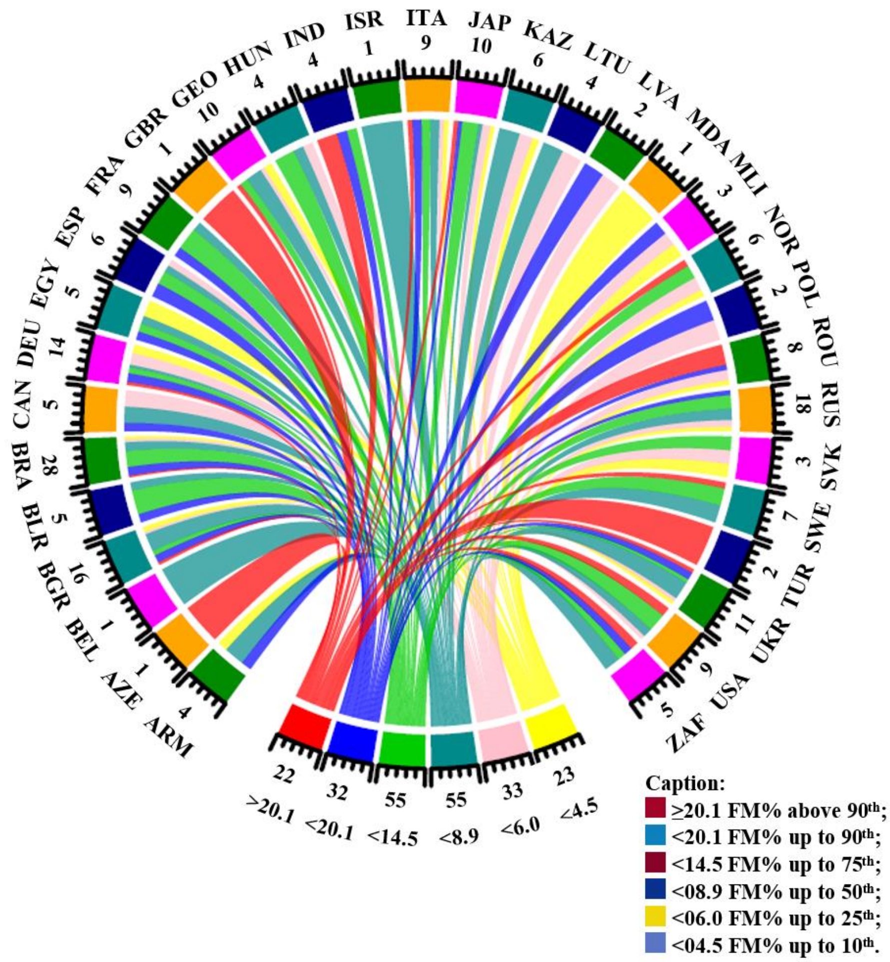
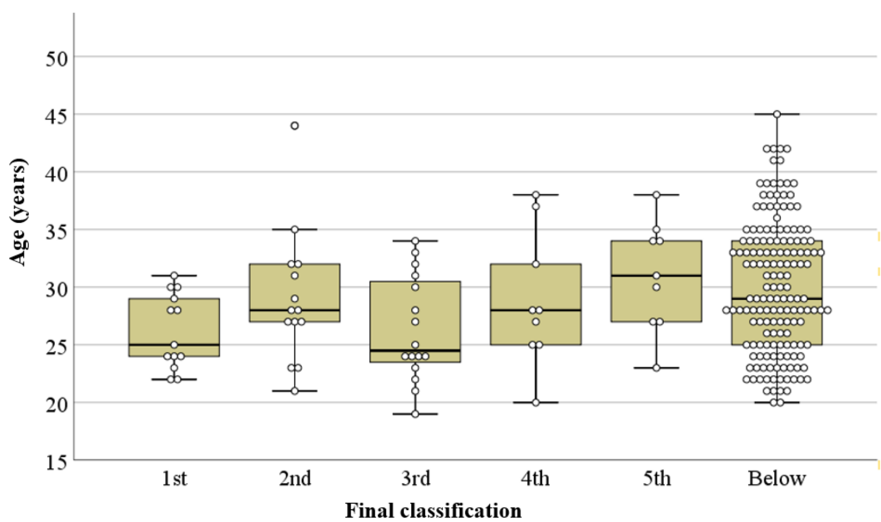


Figure 2. Interrelationship between the FM% percentiles according to the athletes´ participation, by country.



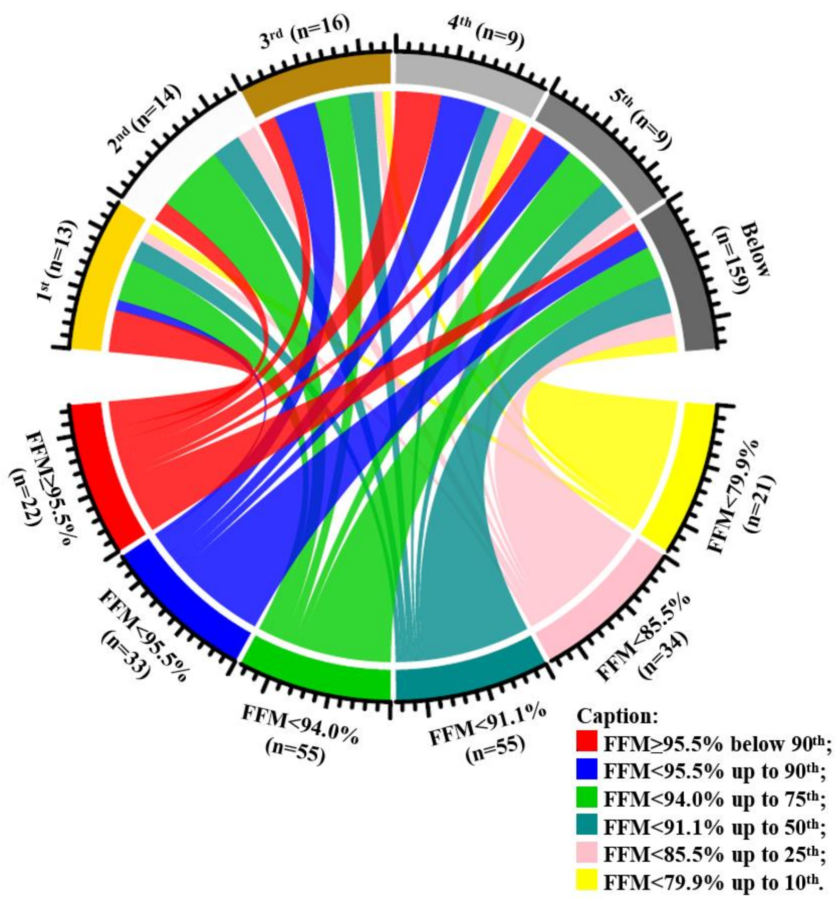
Note. Age: years (decimal); final classification: 1st-3rd: podium; Below: 6th place and below (until the 30th).

Figure 3. Post hoc Bonferroni correction by Independent-sample Kruskal-Wallis test.

Table 2. Pairwise comparison of Age by Classification adjusted by Bonferroni correction.

Age/Class.	Test Statistic	Standard Error	Standard Test Statistic	Sig.	Adj. Sig.
1-3	-2.050	23.722	-0.086	.931	1.000
1-2	-29.448	24.470	-1.203	.229	1.000
1-4	-31.158	27.549	-1.131	.258	1.000
1-6	-44.442	18.326	-2.425	.015	0.230
1-5	-57.491	27.549	-2.087	.037	0.553
3-2	27.397	23.250	1.178	.239	1.000
3-4	-29.108	26.471	-1.100	.272	1.000
3-6	-42.392	16.663	-2.544	.011	0.164
3-5	-55.441	26.471	-2.094	.036	0.543
2-4	-1.710	27.143	-0.063	.950	1.000
2-6	-14.994	17.711	0.847	.397	1.000
2-5	-28.044	27.143	-1.033	.302	1.000
4-6	-13.284	21.768	-0.610	.542	1.000
4-5	-26.333	29.949	-0.879	.379	1.000
6-5	13.049	21.768	0.599	.549	1.000

Note. Total N = 220; test statistic (12.611) DF = 5; asymptotic signal (2-sided test).



Note. FFM fat free mass; (1st - 5th, and Below) ranking distribution.

Figure 4. Interrelationship between final classification of the athletes according to relative fat free mass distribution.

Table 3. Athletes' final classification by fat free mass (FFM) percentiles.

Placing	<10	<25	<50	<75	<90	>90	Total
1st	1 (<79.9)	1 (<85.5)	2 (87.4-87.7)	4 (92.4-93.1)	1 (< 95.5)	4 (95.8-98.2)	13
2nd		2 (81.2-82.5)	3 (87.3-90.8)	7 (91.2-93.8)		2 (96.1-97.4)	14
3rd	1 (<79.9)	1 (<85.5)	3 (87.8-90.8)	4 (91.2-93.9)	5 (94.1-95.4)	2 (95.9-97.3)	16
4th	1 (<79.9)	1 (<85.5)	1 (<91.1)		3 (94.5-95.3)	3 (95.8-96.1)	9
5th		1 (<85.5)	2 (88.9-89.6)	3 (92.1-93.7)	2 (94.1-94.6)	1 (≥95.5)	9
Below 5th	19 (67.6-79.9)	27 (80.0-85.5)	44 (85.5-91.1)	37 (91.1-94.0)	23 (94.0-95.5)	9 (95.6-96.6)	159
Total	22	33	55	55	34	21	220

Note. Values are frequency and specific FFM percentage (min; max); Below: classification between 6th and 30th place; FFM percentiles according to final classification groups: <10th: up to 79.9% of fat free mass; <25th: up to 85.5%; <50th: up to 91.1%; <75th: up to 94.0%; <90th: up to 95.5%; >90th: Above.

Table 4. Pairwise comparison of FFM percentage by classification.

Sample 1-Sample 2	Test Statistic	Standard Error	Standard Test Statistic	Significance	Adjust Significance
6-2	19.655	17.745	1.108	.268	1.000
6-5	32.560	21.810	1.493	.135	1.000
6-1	37.380	18.362	2.036	.042	0.627
6-3	37.476	16.695	2.245	.025	0.372
6-4	41.782	21.810	1.916	.055	0.831
2-5	-12.905	27.195	-0.475	.635	1.000
2-1	17.725	24.517	0.723	.470	1.000
2-3	-17.821	23.294	-0.765	.444	1.000
2-4	-22.127	27.195	-0.814	.416	1.000
5-1	4.821	27.602	0.175	.861	1.000
5-3	4.917	26.522	0.185	.853	1.000
5-4	9.222	30.006	0.307	.759	1.000
1-3	-0.096	23.767	-0.004	.997	1.000
1-4	-4.402	27.602	-0.159	.873	1.000
3-4	-4.306	26.522	-0.162	.871	1.000

Note. Pairwise comparison of FFM percentage by ranking classification (1-5: 1st - 5th; 6: bellowed classification until the 30th place).

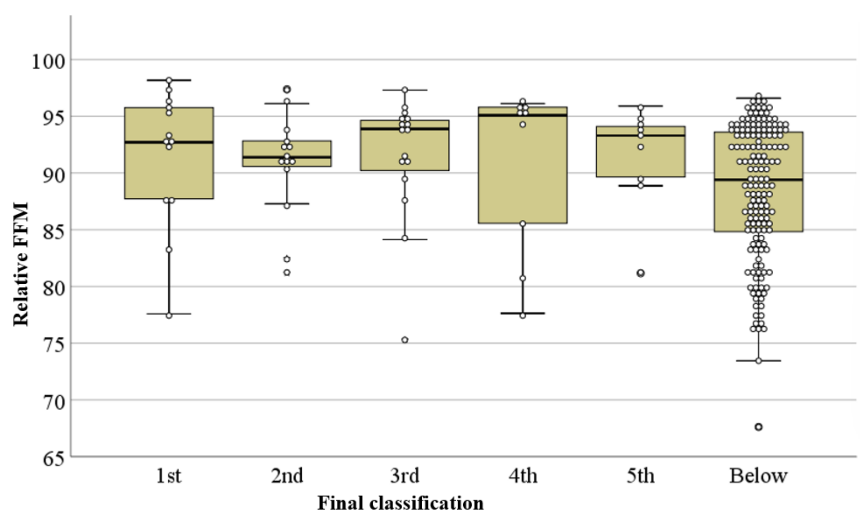
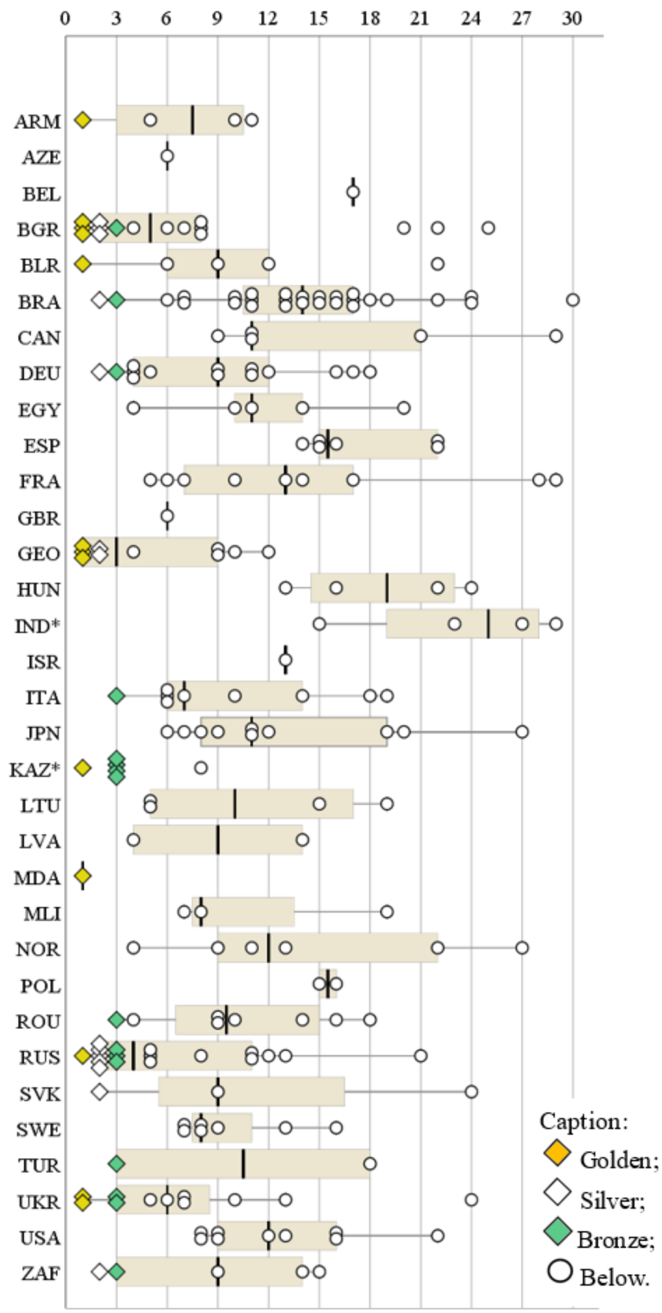


Figure 5. Post hoc Bonferroni correction by Independent-sample Kruskal-Wallis test of the FFM percentage; 1st-3rd: podium; Below: 6th place and below (until the 30th place).

Figure 4 shows the FFM% percentiles distributed by final classification. Values ranged from below 79.9% (up to the 10th percentile), to over 95.5% (the over 90th percentile), with a median of 91.1%. We discarded Differences (*p* = .025) found in the final classification groups after post-hoc correction (*p* > .372). Up to the 3rd place on the podium, athletes from the <10th percentile (FFM up to 79.9%) achieved two classifications (=9.1%). On the other hand, athletes with the >90th percentile (FFM over 95.5%) achieved eight classifications (=36.4%). We also found a trend in the <75th with 15 classifications (=27.3%) between <94.0% and >91.1%, compared to the <50th, which achieved 8 classifications (=14.5%) up to 3rd position. The Supplement displays FFM values according to the final classification of the athletes (Tables 3-4; Figure 5).



*Note. Diamond-shaped graph: podium classification 1st to 3rd place; * Kruskal-Wallis test.*

Figure 6. Athletes' classification by country.

Final competition results showed that sixty athletes participated on just one day, thirty-five of whom competed with their left arm the day before. Another five athletes competed on four consecutive days, alternating arms, and in two divisions. In this regard, the classification of the athletes showed that fifteen countries achieved podium finishes (Figure 6). The largest team in this study was Brazil (n = 28, 12.7%), followed by Russia (n = 18, 8.2%), Bulgaria (n = 16, 7.3%), Germany (n = 14, 6.4%), Ukraine (n = 11, 5.0%), Georgia (n = 10, 4.5%) and Japan (n = 10, 4.5%) (Table 5). The classification of athletes by country of origin did not produce predictive results among those athletes achieving first place in the ranking. Only KAZ (6 athletes) versus IND (4 athletes) showed differences in classification through the Kruskal-Wallis independent sample test (p = .049) (Table 6).

Table 5. Athlete's classifications among the 33 countries.

Country	Athletes	Percentage	Cumulative percentage	Country	Athletes	Percentage	Cumulative percentage
ARM	4	1.8	1.8	JPN	10	4.5	60.5
AZE	1	0.5	2.3	KAZ	6	2.7	63.2
BEL	1	0.5	2.7	LTU	4	1.8	65.0
BGR	16	7.3	10.0	LVA	2	0.9	65.9
BLR	5	2.3	12.3	MDA	1	0.5	66.4
BRA	28	12.7	25.0	MLI	3	1.4	67.7
CAN	5	2.3	27.3	NOR	6	2.7	70.5
DEU	14	6.4	33.6	POL	2	0.9	71.4
EGY	5	2.3	35.9	ROU	8	3.6	75.0
ESP	6	2.7	38.6	RUS	18	8.2	83.2
FRA	9	4.1	42.7	SVK	3	1.4	84.5
GBR	1	0.5	43.2	SWE	7	3.2	87.7
GEO	10	4.5	47.7	TUR	2	0.9	88.6
HUN	4	1.8	49.5	UKR	11	5.0	93.6
IND	4	1.8	51.4	USA	9	4.1	97.7
ISR	1	0.5	51.8	ZAF	5	2.3	100.0
ITA	9	4.1	55.9	**Total**	**220**	**100.0**	

Table 6. Athletes final classification by country of origin.

Country	1st	2nd	3rd	4th	5th	Below	Total
ARM	1(25.0%)				1(25.0%)	2(50.0%)	4
AZE						1(100.0%)	1
BEL						1(100.0%)	1
BGR	3(18.8%)	3(18.8%)	1(6.3%)	1(6.3%)		8(50.0%)	16
BLR	1(20.0%)					4(80.0%)	5
BRA		1(3.6%)	1(3.6%)			26(92.9%)	28
CAN						5(100.0%)	5
DEU		1(7.1%)	1(7.1%)	3(21.4%)	1(7.1%)	8(57.1%)	14
EGY				1(20.0%)		4(80.0%)	5
ESP						6(100.0%)	6
FRA					1(11.1%)	8(88.9%)	9
GBR						1(100.0%)	1
GEO	3(30.0%)	2(20.0%)		1(10.0%)		4(40.0%)	10
HUN						4(100.0%)	4

Country	1st	2nd	3rd	4th	5th	Below	Total
IND*						4(100.0%)	4
ISR						1(100.0%)	1
ITA			1(11.1%)			8(88.9%)	9
JPN						10(100.0%)	10
KAZ*	1(16.7%)		4(66.7%)			1(16.7%)	6
LTU					2(50.0%)	2(50.0%)	4
LVA				1(50.0%)		1(50.0%)	2
MDA	1(100.0%)						1
MLI						3(100.0%)	3
NOR				1(16.7%)		5(83.3%)	6
POL						2(100.0%)	2
ROU			1(12.5%)	1(12.5%)		6(75.0%)	8
RUS	1(5.6%)	5(27.8%)	3(16.7%)		3(16.7%)	6(33.3%)	18
SVK		1(33.3%)				2(66.7%)	3
SWE						7(100.0%)	7
TUR			1(50.0%)			1(50.0%)	2
UKR	2(18.2%)		2(18.2%)		1(9.1%)	6(54.5%)	11
USA						9(100.0%)	9
ZAF		1(20.0%)	1(20.0%)			3(60.0%)	5
Total	13(5.9%)	14(6.4%)	16(7.3%)	9(4.1%)	9(4.1%)	159(72.3%)	220

*Note. Placing: individual classification; Below: classification from 6th to 30th place; * Kruskal-Wallis test.*

DISCUSSION

This study reveals a unique scenario of the body composition of world arm wrestlers in a competitive environment. The interrelationships found in the components FM% and FFM% head the main factors of influence. The FM% showed variability in proportion to the number of athletes, scattered by country. Notably, the FFM% showed uniformity in terms of podium ranking (Silva, 2019). However, several factors may also impact the optimal performance in elite arm wrestlers in respect of health issues, and nutritional behaviour.

The study reported that body composition exerted a strong influence in weight-sensitive sports (Bajkowski and Cynarski, 2024; Sengeis et al., 2019). The FM% in the 75th percentile group (Figure 2) and above may have overestimated the weight class groups, amounting to a difference of as much as 11.1% (i.e., 90 kg; 100 kg) according to the body mass ("*Rules WAF,*" 2024). Indeed, the FM% can place a burden on physical performance (Giovanelli et al., 2023; Silva, 2019). This situation strongly suggests that many athletes could compete in lower weight classes.

From nutrition status, athletes may also be exposed to risk factors due to low FM%, such as relative energy deficiency in sport (RED-S). This syndrome usually affects weight-sensitive or gravitational sports, owing to either intentional or unintentional low energy availability (LEA) or as a consequence of overtraining (Dipla et al., 2020). The former can start through the failure to observe the dietary needs required to adhere to an athlete's program (Amawi et al., 2024). On the other hand, overtraining can reduce the metabolism ratio relative to the FFM, and cause regression to LEA(Logue et al., 2020). It also leads to a deficiency in testosterone production, low bone turnover, and higher cortisol levels (Angelidi et al., 2024). Consequently, this syndrome increases the risk factors for injury, including damage to musculoskeletal tissue, and reduces bone mineral density, regardless of gender (Dipla et al., 2020; Silva, 2019).

The FFM% outcomes suggest consistency with athletes´ classifications. Strength training programs help to improve the BM ratio, increasing strength mainly in experienced male athletes, but not always with changes in FM% (Bartolomei et al., 2014). Several athletes demonstrated optimum fitness in the 75th FFM% (<94.0% and >91.1%) up to third place (Figure 4). Among other reasons, many arm wrestlers did not appreciate how to increase FFM (muscle mass) and reduce body mass in order to compete against opponents with lower body mass (Andreato et al., 2012; Drid et al., 2015).

Arm wrestlers practice weight cutting up to 24 hours before competition (Barley and Harms, 2021; Brandt et al., 2018; Castor-Praga et al., 2021; Sengeis et al., 2019). However, the sport's international rules strongly discourage this practice, classifying athletes in the same weight class that applied during the season ("Rules WAF*," 2024)*. Athletes who pursue this behaviour can achieve their goals in a period of weight loss, inserted between periods of strength training, with a weekly weight loss target of 0.7% of body weight, whereas athletes who simply seek to maintain their muscle mass might adjust their weekly weight-loss rate to 0.5-1.0% of their body weight (Ruiz-Castellano et al., 2021). Knowledge of body composition helps control the macronutrient distribution of the diet, and vice versa, to achieve healthy limits of performance (Martín-Rodríguez et al., 2024).

Sources of energy metabolism in arm wrestling embody the strength capability of the upper limbs (Akpınar et al., 2013), including several other skills: explosive power, and between maximum power and strength endurance (Voronkov et al., 2014). Despite the fact that athletes may compete over several days, activities that generate micro-trauma in different or opposing limbs or muscle groups can assist with protein resynthesis through the mediation of satellite and proliferation cells (Abaïdia et al., 2017). In this regard, high-intensity activities could help the neuromuscular recovery process on the day after the competition (Abaïdia et al., 2017). Accordingly, this recovery effect may be associated with the system of competition in which all divisions always start with only the left arm on the first day and the right arm the day after ("*Rules WAF*," 2024).

Classification up to thirtieth place in the ranking (Figure 6) followed a system of competition known as double knockout. Traditionally, the ideal is to reach the Knockout Classification of the quarter-finals (Mcgarry and Schutz, 1997). This system allows for a tie in the final, where athletes can compete in as many as eight matches for final classification. The weight classes can run for more than an hour, stopping in the late morning and restarting for the semifinals after about 3 hours. It is possible for the athletes to compete in different divisions on alternate days, depending on age, para-sport, and in stand-up for competition in the senior division (Silva, 2019). From a practical standpoint, lower FM content increases power and strength, essential to recover the athletes' performance (Martín-Rodríguez et al., 2024). Nevertheless, we also found finalists that were evaluated as over the weight, overstepping the boundaries between the classes.

Limitations and strength

This study has several limitations due to its cross-sectional design. It was not possible to monitor athletes during training, so it assumed that competing athletes were in the same weight class in which they classified during the season. It did not provide a physical test for strength, very useful for comparing body composition and performance. It still remains to compare adult male categories with all other age groups, also distributed by para-athlete's classifications, as well as all of these groups in the female division.

The strong point of this work is the sample size of athletes evaluated, performing in a competitive environment, compared with others similar studies.

CONCLUSIONS

The final classification of the athletes revealed a wide diversity of countries making the podium. In the analysis of body composition, the FM% suggests that several athletes could compete in lower weight classes, which may account for the absence of differences between FFM% with performance in competition. Thus, world-level arm wrestlers revealed nutritional issues concerning values for body composition components in a competition environment.

AUTHOR CONTRIBUTIONS

Conceptualization, M.A.P. and F.L.L.; methodology, M.A.P., F.L.L., T.F.L., and G.G.J.; software, M.A.P.; formal analysis, M.A.P. and F.L.L.; investigation, M.A.P., F.L.L., M.S., V.T., and G.G.J.; resources, M.A.P., and G.G.J.; data curation, M.A.P., F.L.L., M.S., V.T.; writing-original draft preparation, M.A.P., F.L.L., and T.F.L.; writing-review and editing, M.A.P., and F.L.L.; visualization, M.A.P., T.F.L., and F.L.L.; project administration, M.A.P., and G.G.J.

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DISCLOSURE STATEMENT

No potential conflict of interest was reported by the authors.

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