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Powerlifting Balance Of SBD Disciplines (Squat, Bench Press And Deadlift) Ratio To Total Score

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ABSTRACT

This research studied the powerlifting balance of squat, bench press and deadlift (SBD) disciplines ratio to the total score. The data set was from Powerlifting Championships recognized by the International Powerlifting Federation, compiled by the Open Powerlifting project. The records were 65,867 men's and 35,679 women's samples from classic powerlifting and 19,295 men's and 7,426 women's samples from equipped powerlifting, all with ages from 24 to 39 years from 2012 to November 2022. For each record, the SBD ratios were calculated by the mean of the formula (SBD discipline / Total score) by one hundred. Dispersion plots of Good Lift Points (GLP) score versus the SBD ratios and Bar plots of mean and variance of SBD ratios were done, highlighted by quantiles of GLP score. The Mean and Standard Deviation from Elite Powerlifters (90-100th quantiles) of each weight class were used to calculate the SBD ratio ranges. An algorithm with twenty-six permutations, where the addition and subtraction from 0.5 to 3 standard deviation to the mean marked the ranges' Upper and Lower borders. The best permutation by each weight class was selected when the athletes' group inside the optimal ratio ranges (ORR) showed the highest Impact Factor (GLP mean by frequency) and the shortest ORR. To evaluate the effectiveness of the ORR for each weight class in sexes and events were analyzed lower levels of Powerlifters, inside 0-50th and 50th-90th quantiles of GLP score. For these sets, was applied One Way ANOVA to evaluate the meaning differences between IN and OUT groups from ORR, using post-hoc test of Tukey's HSD or Games-Howell. From sixty-four evaluations, forty-eight were higher in GLP mean score for the IN group, meaning differences regarding the OUT group. At the same time, fifteen were only the highest but not statistically different, and only one was rejected for both. Regardless of the quantile level, for Classic Powerlifting, four Women's (57, 63, 69 and +84) and five Men's (66, 74, 93, 105 and +120) classes presented ORR supported; while for Equipped Powerlifting were four Men's (74, 83, 93 and 105) and six Women's (57, 63, 69, 76, 84 and +84) classes. These findings support the theory of Powerlifting balance in SBD disciplines, which influences performance.

Keywords: powerlifting, balance, ratio, squat, bench press, deadlift.

INTRODUCTION

Although it started in the 1950s, nowadays, powerlifting is an arising strength sport on the world level, where many international federations and associations feature the participation of both sexes (International Powerlifting Federation, 2022a). Three disciplines gather this sport: squat, bench press and deadlift (known as SBD), and in the competitive events, each athlete has three maximum lift attempts, where the sum of the best lifts for each discipline scoring in total (Velázquez-Ormeño, 2009). The championships can be organized into two main events: Equipped and Classic Powerlifting. First, the

athletes wear supportive shirts, suits and accessories manufactured with synthetic materials that store elastic potential energy, increasing stiffness and decreasing the load on muscles, thereby helping the lift. Instead, in classic events, the athletes can only costume protective accessories without supportive assistance and no rebound effect (International Powerlifting Federation, 2022b).

In powerlifting, the relationships between Squat (SQ), Bench Press (BP), Deadlift (DL) and Total are influencing the performance. During a championship, the consecutive order of execution for the disciplines is first SQ, second BP and last DL (International Powerlifting Federation, 2022b). It is known among powerlifting coaches and athletes that BP's result would depend on the strength and energic cost during the SQ, and consecutively, the outcome of DL depends on SQ and BP's effort. Moreover, a study by Hernández-Ugalde (2022b) determined that the annual progress of SBD disciplines and total, regardless of the event, sex and age division, have an order of likelihood to the results: 1-Improvement of all disciplines and total, 2-Improvement of two disciplines and total, 3-No improvements, 4-Improvement of one discipline but not total, 5-Improvement of one discipline and total, and 6-Improvement of two disciplines but not total. Other external and internal factors could also affect the results in championships or annual progress.

Instead, there are marked differences between equipped and classic events. Some authors have reported that Equipped Powerlifters can lift higher maximal loads than those classics (Ball & Weidman, 2017; Wilk et al., 2020). Likewise, equipped world records in squat and bench press for both sexes are significantly better than the Classic division. Still, deadlift world records do not present statistically significant differences between them (Wilk et al., 2020). However, the success of annual progress in the three disciplines is higher in classic powerlifters because the use of suits, shirts and accessories in equipped events is complex, and many factors can occur more failures than in classic events (Hernández-Ugalde, 2022b).

The strength difference between sex is another factor considered for the performance in powerlifting. Something well-known in this sport is that the relative strength of men is more significant than women in SBD disciplines (Latella et al., 2018; Ball & Weidman, 2017). In addition, for powerlifting and weightlifting sports, the ratio between the total load lifted versus body mass is higher for men than for women (Marković & Sekulić, 2006). By contrast, Hernández-Ugalde (2022b) found higher success of annual progress in women than men, even though the latter are stronger.

Some researchers have reported that age is the main factor influencing powerlifting performance. From youth up to the third decade, exponential growth has been reported, and peak performance is between 27 and 31 years old (Hernández-Ugalde, 2022a). In addition, Latella et al. (2018) studied the strength-to-bodyweight ratio for the: squat, bench press and deadlift and determined a peak of performance in Junior (19-23 years old) and Open (24-39 years old) divisions. Moreover, Solberg et al. (2019) informed for equipped powerlifters have a peak age (35 ± 7 years) progressing in weight lifted of ~12% on average during the five years before the peak. Thus, many studies have concluded that exists a linear decline for both sexes after 40 years of age in performance in powerlifting (Anton et al., 2004; Latella et al., 2018; Hernández-Ugalde, 2022a). Lastly, the successful annual progress of SBD disciplines and total decline altogether as the age division is older (Hernández-Ugalde, 2022b).

Other studies in powerlifting have determined relationships among physical characteristics and body composition concerning performance and strength in SBD and total. Latella et al. (2018) found that lighter classes can lift a more significant percentage of body weight than heavier competitors. Moreover, studying Men's junior powerlifters and college football players, Ferland et al. (2020 a) determined a positive correlation among these variables: absolute and relative hip circumference versus SQ and BP, and Torso Large/Height ratio versus DL, and Waist circumference /Hip circumference ratio versus % of the SQ on the total, but negatively influenced the DL. Another research, where participating men's and women's junior powerlifters obtained a positive correlation among resistance training, lean body tissue, arms mass, leg mass, bone mineral content and bone mineral density regarding absolute (kg) and relative (Wilks) maximal strength measures (Ferland et al. 2020b). In addition, studying forty men's powerlifters, Palma-Lafourcade et al. (2019) found that the performance of SQ, BP and DL were positively correlated with many anthropometric variables relating to lean mass, fat mass, body bone mineral mass, body protein and body mass index.

Despite the multiple factors influencing powerlifting performance above, some relationships still need to be investigated. This study aims to determine

and evaluate the powerlifting balance of each SBD discipline ratio to Total score, for Men and Women, in Equipped and Classic powerlifting events. The hypothesis initially is that this balance can be obtained from the optimal ratio ranges of Elite Powerlifters results and that these ranges could also determine higher performance on the athletes.

METHODOLOGY

Procedure

This study analyzed data from World, Regional and National Championships recognized by the International Powerlifting Federation (IPF). The IPF's records were chosen because of the standard rules and antidoping control (International Powerlifting Federation, 2022b). The set data was compiled by the Open Powerlifting project until 10/11/2022 (https://openpowerlifting.gitlab.io/opl-csv/bulk-csv.html), using only results from 2012 to November 2022 period. Four powerlifting data groups were studied according to sex and types of events: Men's and Women's Classic, and Men's and Women's Equipped. The data set was cleansed using R software Version 4.0.3 (R Core Team, 2020) by issues such as misspelled names, sharing names of different athletes, different birth year given for the same athlete, and records published without age. Only records of athletes participating with ages between 24 and 39 years old were used for this study. For each data set, the outliers were eliminated from the lower tail for the Good Lift Points (GLP) variable, which were lower than the GLP's Mean minus 3.5 Standard Deviations (Table 1). The GLP score was established by IPF as a relative measure to compare the strength performance among powerlifters with different weights (International Powerlifting Federation, 2022b).

Table 1. Number of records studied for each set of data.

Sex and Event	Number of records
Men's Classic Powerlifting	65.867
Women's Classic Powerlifting	35.679
Men's Equipped Powerlifting	19.295
Women's Equipped Powerlifting	7.426

Each group mentioned above in Table 1 was individually applied to the subsequent analyses.

Statistical analysis

All analyses were done using the R software Version 4.0.3 (R Core Team, 2020), and the library's most relevant packages were mentioned below. First, for each record was calculated the ratio of the following way in each discipline (Squat, Bench Press, Deadlift):

$$Ratio = \frac{Discipline}{Total}\ 100$$

In addition, twelve dispersion plots were performed based on GLP versus the discipline ratio mentioned above, which were classified every ten quantiles from 0 to 100th quantile ranges (Figure 2). The mean and variance of discipline/total ratios were measured for every ten quantiles from 0 to 100th quantile ranges and plotted in twelve bar plots (Figure 3).

The optimal range for each discipline of powerlifting was obtained from the mean and standard deviation of 90-100th quantiles level, called in this paper Elite powerlifters group. This placeholder of ratio ranges was done using the following algorithm (Figure 1) for each weight class:

1. It used the discipline/total ratio's mean and standard deviation of Elite powerlifters.
2. It generated many ranges of possible Ratio Ranges for each discipline using the formula:

$$MIN = \bar{x} - (\sigma\ f) \quad ; \quad MAX = \bar{x} + (\sigma\ f)$$

The MIN is the lower value, and MAX is the upper within the range, x̄ is the mean of discipline/total ratio by weight class, σ is the standard deviation, and f is the factor of multiplication. Twenty-six permutations of ranges were done, using *f* values from 0.5 to 3 increasing each 0.1 value, where each permutation of squat, bench press and deadlift (SBD) ratio ranges used the same f values.
3. Each permutation mentioned above was used to codify in each record from Elite Powerlifters (90-100th quantiles) using three letters, "M" when this is inside of the range from MIN to MAX, "L" when this is lower than the MIN, and "H" when this is higher than the MAX. Then for example, when a record presents the Squat/Total Ratio inside of the range is codified as "M", Bench Press/ Total Ratio is higher than the range is codified as "H" and Deadlift/Total Ratio is lower than the range is codified as "L"; the final code would be "MHL". All the records were grouped under this codification, calling SBD position variable.

4. After, in each permutation, for each group of SBD position variable was calculated the Impact Factor using the following formula:

$$I = x\ p$$

, where x is the GLP's mean for each group of SBD position variable, and p is the frequency of this group in the data set in the same permutation.
5. When the permutation obtained the highest value of Impact Factor (I) of "MMM" group of SBD position variable and also had the lowest factor of multiplication (f), its ratio ranges of squat, bench press, and deadlift were selected for the statistical analysis (see table 2).
6. To test the robust and accurate of the optimal ratio ranges by discipline, the data was aggregated in two groups for each weight class: 0-50th and 50th-90th quantiles of GLP score. Inside these groups were classified as "IN" when the records of ratio ranges for SBD are inside all optimal ratio ranges suggested and "OUT" when those were out from the ratio ranges of all the SBD disciplines, two disciplines, or least a discipline.
7. In addition, an upsampling procedure (groupdata2 package 2.0.0) was done over the samples from IN and OUT groups due to the imbalance in size between them.
8. Then, Levene's Test (lawstat package 3.2) was applied to determine if the variances were homogenous or heterogeneous.
9. Last, One Way ANOVA was applied to evaluate if meaning differences exist ($p < 0.01$) between "IN" and "OUT" groups by each weight class, using post-hoc test of Tukey's HSD (stats package 3.6.2.) for homogeneous variances or Games-Howell (rstatix package 0.7.1.) for heterogeneous variances.

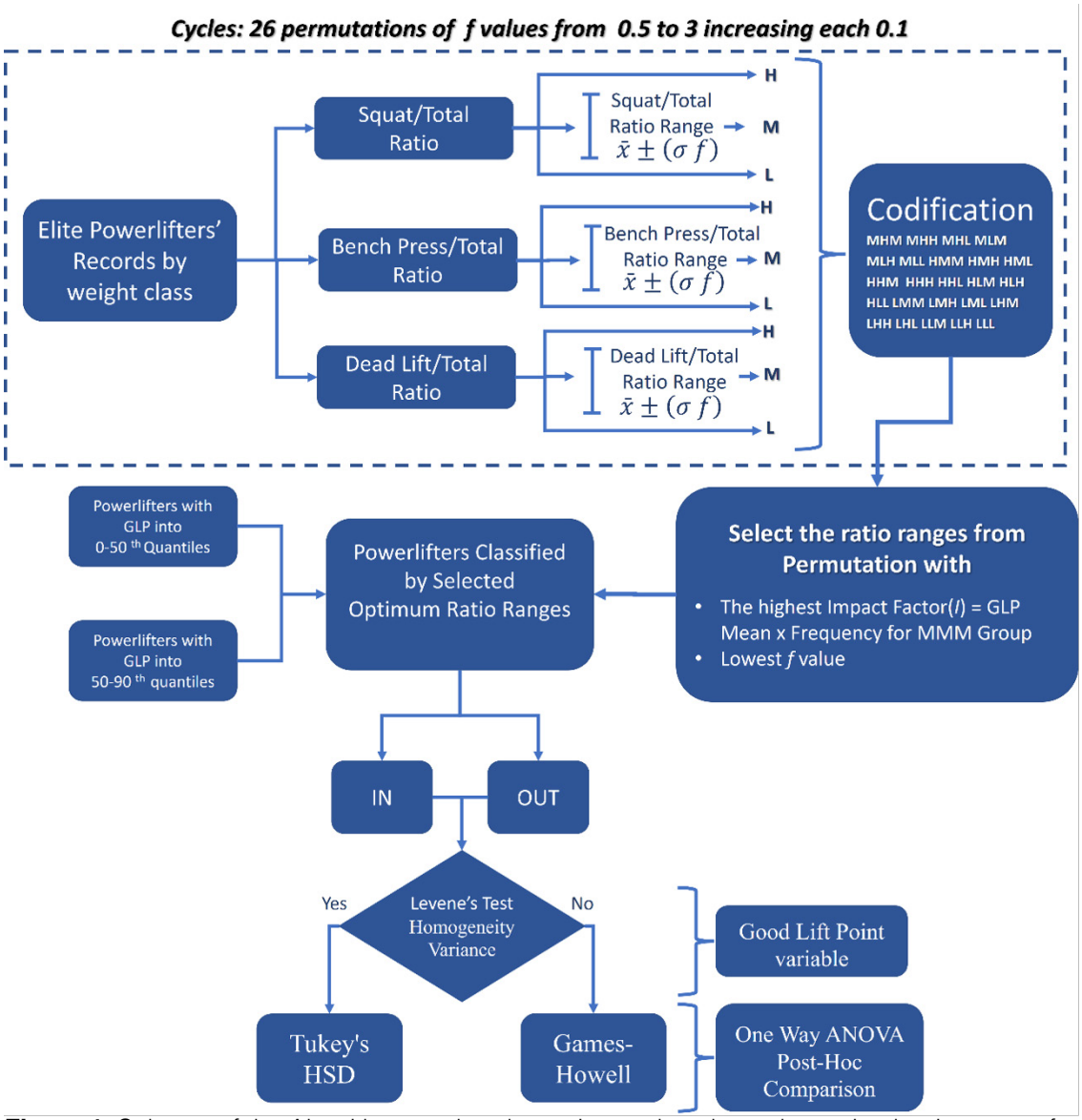

Figure 1. Scheme of the Algorithm used to determine and evaluate the optimal ratio ranges for SBD.

RESULTS

Figure 2 presents twelve dispersion plots of GLP versus each SBD Discipline ratio to total for Men's and Women's Classic and Equipped Powerlifting, distinguished in quantiles on GLP variable; each 10th quantile level is a different color from 0 to 100th. A central tendency of the most points was observed but decreasing the quantile level and increasing the spreading of points. In addition, Figure 3 presents twelve bar plots for comparing each 10th quantile level by mean and variance measures for each discipline (Squat, Bench Press, Deadlift) ratio to total classified by Men's and Women's Classic and Equipped Powerlifting. It noted that while increasing the quantile level and decreasing the variance measure.

Table 2 shows the calculation of the optimal ratio ranges of SBD disciplines based on Mean and Standard Deviation obtained from Elite Powerlifters. This procedure was done for each weight class of Men's and Women's Classic and Equipped Powerlifting. It was observed that increasing class weight and decreasing the multiplication factor f (which determine the wide range) and the Impact factor (I).

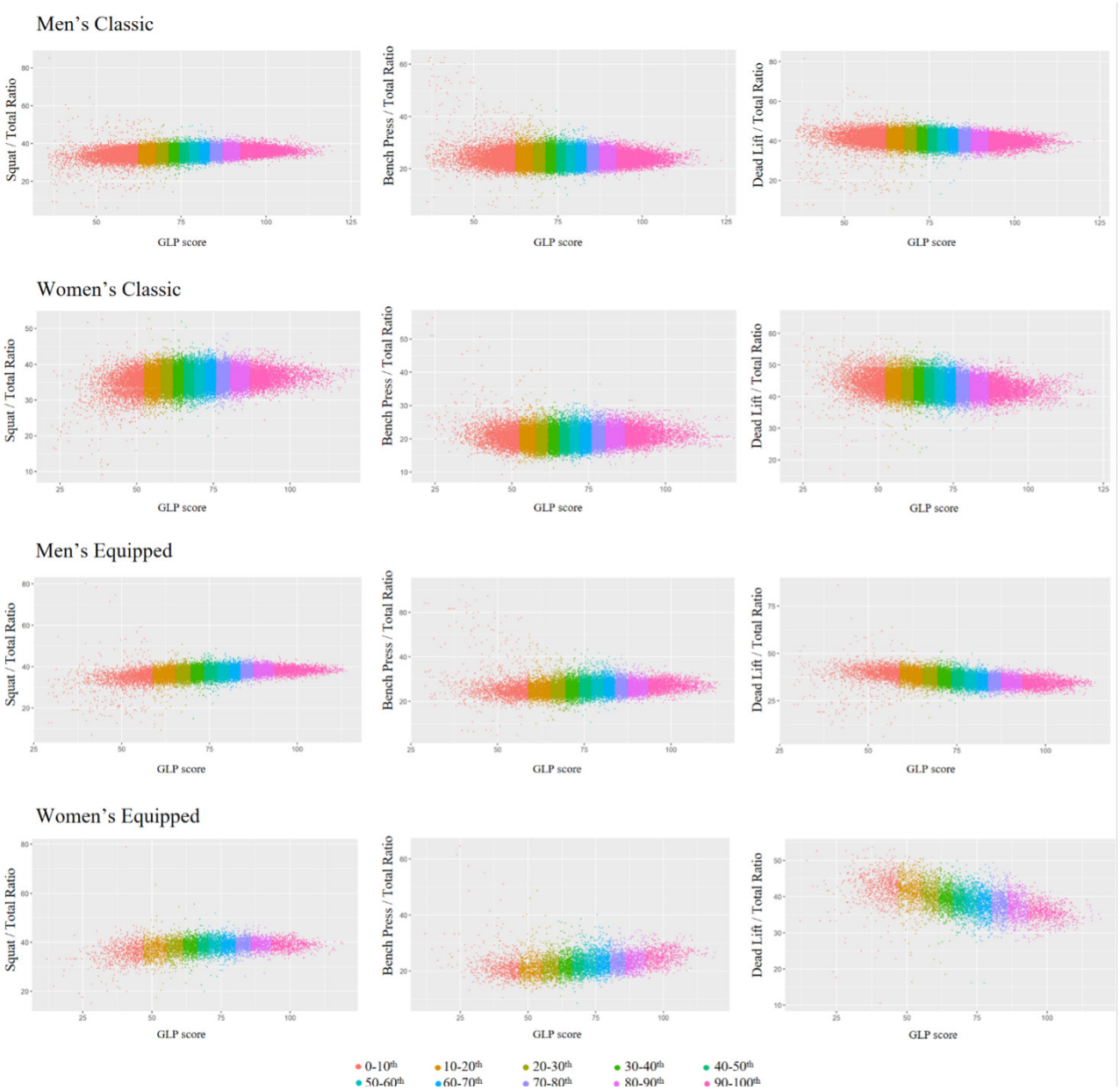

Figure 2. Dispersion plots of GLP versus Disciplines (Squat, Bench Press, Deadlift)/Total Ratio classified by Men's and Women's Classic and Equipped Powerlifting and colored by quantile level.

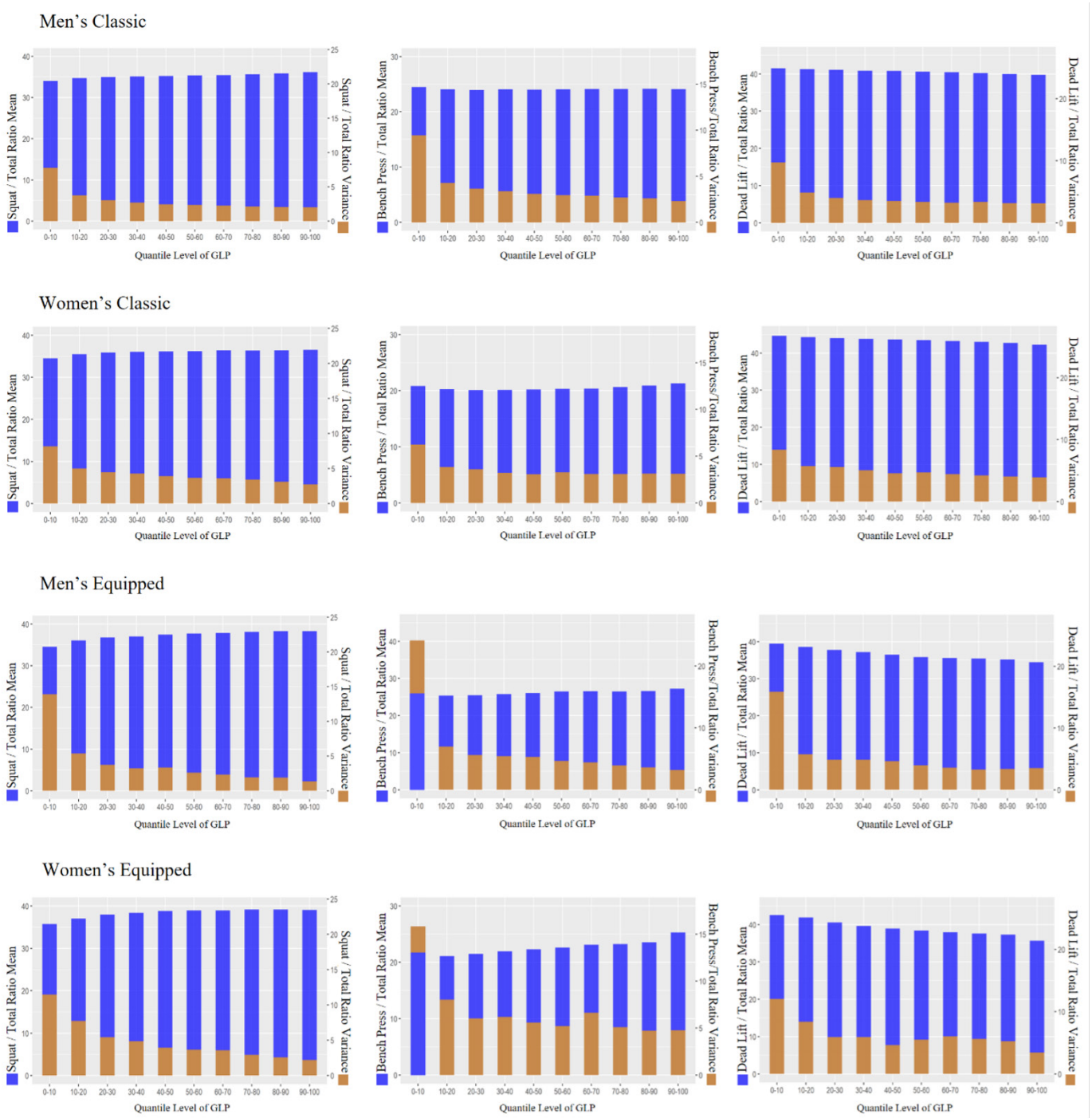

Figure 3. Comparison of quantile levels by mean and variance discipline (Squat, Bench Press, Deadlift)/Total ratio classified by Men's and Women's Classic and Equipped Powerlifting.

Table 2. Optimal Ratio Ranges based on Mean and Standard Deviation from Elite Powerlifters classified by sex and event.

Men's Classic

Weight Classes	Factor (*f*)	Squat		Optimal Ratio Ranges			Bench Press		Optimal Ratio Ranges			Deadlift		Optimal Ratio Ranges			GLP Means MMM	% Records	Impact (*I*)
		Mean	SD	MIN	MAX	WIDE	Mean	SD	MIN	MAX	WIDE	Mean	SD	MIN	MAX	WIDE			
59	1.8	36.29	2.55	31.71	40.87	9.16	24.57	1.77	21.40	27.75	6.35	39.13	2.98	33.76	44.51	10.75	77.64	27.64%	21.46
66	1.6	35.53	1.76	32.72	38.34	5.62	24.11	1.84	21.17	27.05	5.88	40.36	1.94	37.25	43.47	6.22	78.98	28.66%	22.64
74	1.6	35.67	1.56	33.17	38.17	5	23.69	1.99	20.51	26.87	6.36	40.64	2.15	37.20	44.07	6.87	79.91	30.52%	24.39
83	1.4	35.75	1.64	33.45	38.05	4.6	23.80	2.03	20.95	26.64	5.69	40.45	2.16	37.43	43.47	6.04	80.44	26.92%	21.66
93	1.3	35.96	1.69	33.77	38.15	4.38	23.97	1.94	21.45	26.48	5.03	40.07	1.96	37.52	42.62	5.1	81.07	27.83%	22.56
105	1.2	36.17	1.70	34.14	38.21	4.07	24.19	1.84	21.99	26.40	4.41	39.64	2.11	37.11	42.16	5.05	81.52	27.96%	22.79
120	1	36.83	1.83	35.00	38.66	3.66	24.51	1.92	22.59	26.42	3.83	38.67	2.08	36.58	40.75	4.17	82.31	26.14%	21.51
+120	0.7	37.99	2.22	36.44	39.54	3.1	24.73	2.01	23.32	26.14	2.82	37.28	2.39	35.60	38.95	3.35	80.78	17.98%	14.52

Women's Classic

Weight Classes	Factor (*f*)	Squat		Optimal Ratio Ranges			Bench Press		Optimal Ratio Ranges			Deadlift		Optimal Ratio Ranges			GLP Means MMM	% Records	Impact (*I*)
		Mean	SD	MIN	MAX	WIDE	Mean	SD	MIN	MAX	WIDE	Mean	SD	MIN	MAX	WIDE			
47	1.6	35.46	2.04	32.19	38.73	6.54	20.96	2.27	17.32	24.6	7.28	43.58	2.39	39.76	47.4	7.64	76.5	32.97%	25.22
52	1.5	35.67	1.97	32.72	38.62	5.9	21.21	2.33	17.72	24.7	6.98	43.12	2.48	39.41	46.84	7.43	74.49	33.43%	24.9
57	1.4	36.01	1.92	33.32	38.7	5.38	21.49	2.31	18.26	24.73	6.47	42.5	2.45	39.07	45.93	6.86	74.25	33.75%	25.06
63	1.3	36.38	1.96	33.83	38.93	5.1	21.49	2.31	18.49	24.49	6	42.13	2.37	39.05	45.21	6.16	73.33	32.18%	23.59
69	1.3	36.46	1.81	34.11	38.81	4.7	21.31	2.19	18.46	24.16	5.7	42.23	2.26	39.29	45.17	5.88	70.91	31.94%	22.65
76	1.2	36.7	1.81	34.52	38.87	4.35	21.13	2.1	18.61	23.65	5.04	42.17	2.29	39.42	44.92	5.5	72.47	30.52%	22.12
84	1	37.17	2.08	35.09	39.26	4.17	20.77	2.21	18.56	22.98	4.42	42.06	2.35	39.71	44.4	4.69	71.75	24.79%	17.79
+84	0.9	38.79	2.36	36.66	40.91	4.25	21.43	2.48	19.2	23.65	4.45	39.79	2.75	37.31	42.26	4.95	70.82	23.60%	16.71

Table 2 continued

Men's Equipped

Weight Classes	Factor (*f*)	Squat		Optimal Ratio Ranges			Bench Press		Optimal Ratio Ranges			Deadlift		Optimal Ratio Ranges			GLP Means MMM	% Records	Impact (*I*)
		Mean	SD	MIN	MAX	WIDE	Mean	SD	MIN	MAX	WIDE	Mean	SD	MIN	MAX	WIDE			
59	2.5	39.01	1.24	35.91	42.11	6.2	25.47	1.42	21.93	29.01	7.08	35.52	1.93	30.7	40.34	9.64	87.89	29.86%	26.24
66	2.6	37.93	1.91	32.95	42.91	9.96	25.88	1.89	20.96	30.8	9.84	36.19	1.89	31.28	41.1	9.82	86.72	27.68%	24.01
74	2.6	37.87	1.36	34.34	41.41	7.07	26.1	2.31	20.11	32.1	11.99	36.02	2.34	29.93	42.12	12.19	84.03	28.07%	23.59
83	2.4	38.23	1.56	34.48	41.97	7.49	26.84	2.2	21.55	32.13	10.58	34.93	2.1	29.89	39.97	10.08	84.95	27.76%	23.58
93	2.1	38.21	1.52	35.01	41.41	6.4	27.11	1.91	23.1	31.11	8.01	34.68	1.87	30.74	38.62	7.88	83.94	26.29%	22.07
105	1.8	38.16	1.43	35.58	40.74	5.16	27.79	2.37	23.52	32.07	8.55	34.05	2.33	29.85	38.25	8.4	84.95	25.14%	21.36
120	1.5	38.61	1.4	36.51	40.72	4.21	28.1	2.1	24.95	31.24	6.29	33.29	2.28	29.87	36.72	6.85	85.54	23.07%	19.73
+120	1.1	38.91	1.29	37.48	40.33	2.85	29.23	1.82	27.23	31.23	4	31.86	1.81	29.88	33.85	3.97	85.08	18.18%	15.47

Women's Equipped

Weight Classes	Factor (*f*)	Squat		Optimal Ratio Ranges			Bench Press		Optimal Ratio Ranges			Deadlift		Optimal Ratio Ranges			GLP Means MMM	% Records	Impact (*I*)
		Mean	SD	MIN	MAX	WIDE	Mean	SD	MIN	MAX	WIDE	Mean	SD	MIN	MAX	WIDE			
47	1.7	39.13	2.19	35.4	42.85	7.45	24.25	3.22	18.77	29.72	10.95	36.63	1.92	33.37	39.89	6.52	80.27	25.95%	20.83
52	1.6	39.22	1.81	36.32	42.12	5.8	24.43	2.59	20.29	28.57	8.28	36.35	2	33.16	39.54	6.38	83.98	21.02%	17.65
57	1.5	38.86	2.08	35.73	41.99	6.26	24.9	2.51	21.13	28.67	7.54	36.24	1.95	33.31	39.17	5.86	82.36	20.88%	17.2
63	1.5	38.45	1.86	35.66	41.24	5.58	25.42	2.82	21.19	29.66	8.47	36.13	2.14	32.92	39.33	6.41	80.05	22.18%	17.76
69	1.3	38.49	1.51	36.54	40.45	3.91	26.23	2.43	23.07	29.38	6.31	35.28	2.53	31.99	38.57	6.58	82.94	17.39%	14.42
76	1	39.19	1.6	37.58	40.79	3.21	25.42	2.51	22.9	27.93	5.03	35.4	2.82	32.58	38.22	5.64	84.99	18.56%	15.77
84	0.8	39.86	2.08	38.19	41.53	3.34	25.9	2.98	23.51	28.28	4.77	34.24	2.08	32.58	35.91	3.33	88.11	13.68%	12.05
84	0.9	39.7	1.44	38.39	41	2.61	26.45	3.5	23.29	29.6	6.31	33.86	2.68	31.45	36.27	4.82	83.1	12.52%	10.4

Table 3. One Way ANOVA Post Hoc comparison of GLP variable between IN and OUT groups from optimal ratio ranges, classified by weight classes.

Men's Classic

Level	0 to 50th Quantiles					50th to 90th Quantiles				
Weight Classes	N per Group [1]	GLP Mean by Group		Post-hoc Test	dj. P-value	N per Group [1]	GLP Mean by Group		Post-hoc Test	dj. P-value
		IN	OUT				IN	OUT		
59	391	66.07	62.67	Tukey HSD	0.000*	231	84.64	83.98	Tukey HSD	0.107
66	998	68.46	65.11	Games-Howell	0.000*	744	83.47	82.89	Tukey HSD	0.004*
74	2231	69.18	66.75	Games-Howell	0.000*	2100	83.77	83.07	Tukey HSD	0.000*
83	3425	69.07	67.10	Games-Howell	0.000*	3466	83.79	83.55	Tukey HSD	0.017
93	4357	69.52	67.46	Games-Howell	0.000*	3549	84.04	83.60	Tukey HSD	0.000*
105	3722	69.57	67.82	Games-Howell	0.000*	2667	84.19	83.68	Tukey HSD	0.000*
120	2504	70.07	67.16	Games-Howell	0.000*	1888	84.11	83.87	Tukey HSD	0.075
+120	1916	69.20	66.34	Games-Howell	0.000*	1312	84.94	84.05	Tukey HSD	0.000*

Women's Classic

Level	0 to 50th Quantiles					50th to 90th Quantiles				
Weight Classes	N per Group [1]	GLP Mean by Group		Post-hoc Test	dj. P-value	N per Group [1]	GLP Mean by Group		Post-hoc Test	dj. P-value
		IN	OUT				IN	OUT		
47	224	58.15	57.65	Tukey HSD	0.481	311	77.72	76.80	Tukey HSD	0.028
52	554	60.18	59.21	Tukey HSD	0.018	743	77.14	76.62	Tukey HSD	0.049
57	1295	60.06	58.43	Games-Howell	0.000*	1216	77.04	75.92	Tukey HSD	0.000*
63	2067	59.81	58.57	Games-Howell	0.000*	1618	77.04	76.30	Tukey HSD	0.000*
69	1454	59.42	57.36	Games-Howell	0.000*	835	76.49	75.78	Tukey HSD	0.003*
76	2057	59.71	58.38	Games-Howell	0.000*	1386	76.29	76.05	Tukey HSD	0.191
84	1656	59.58	57.60	Games-Howell	0.000*	926	76.63	76.16	Games-Howell	0.045
+84	2279	59.46	56.58	Games-Howell	0.000*	1094	76.36	75.75	Tukey HSD	0.003*

*Note: [1] Sample size after Upsampling treatment. * The differences between groups were significant ($p < 0.01$).*

Men's Equipped

Level	0 to 50th Quantiles					50th to 90th Quantiles				
Weight Classes	N per Group [1]	GLP Mean by Group		Post-hoc Test	dj. P-value	N per Group [1]	GLP Mean by Group		Post-hoc Test	dj. P-value
		IN	OUT				IN	OUT		
59	134	65.56	60.88	Games-Howell	0.001	167	86.57	85.40	Tukey HSD	0.013
66	257	67.97	57.76	Games-Howell	0.000*	339	84.53	84.58	Games-Howell	0.884
74	696	66.84	60.34	Games-Howell	0.000*	732	84.13	82.65	Games-Howell	0.000*
83	948	67.54	62.28	Games-Howell	0.000*	1078	84.48	82.85	Games-Howell	0.000*
93	1212	68.67	63.14	Games-Howell	0.000*	1293	84.38	83.02	Tukey HSD	0.000*
105	1180	69.32	64.30	Games-Howell	0.000*	1312	84.39	83.37	Games-Howell	0.000*
120	920	70.42	65.45	Games-Howell	0.000*	601	84.11	83.67	Games-Howell	0.075
+120	759	69.58	66.23	Games-Howell	0.000*	510	83.74	83.48	Tukey HSD	0.322

Women's Equipped

Level	0 to 50th Quantiles					50th to 90th Quantiles				
Weight Classes	N per Group [1]	GLP Mean by Group		Post-hoc Test	dj. P-value	N per Group [1]	GLP Mean by Group		Post-hoc Test	dj. P-value
		IN	OUT				IN	OUT		
47	170	57.09	55.05	Tukey HSD	0.089	116	81.77	78.99	Tukey HSD	0.002*
52	374	60.65	54.90	Games-Howell	0.000*	235	82.42	81.33	Tukey HSD	0.075
57	571	61.12	55.06	Games-Howell	0.000*	277	81.39	79.90	Tukey HSD	0.006*
63	632	61.78	55.16	Games-Howell	0.000*	287	81.77	79.04	Games-Howell	0.000*
69	351	61.11	54.79	Games-Howell	0.000*	180	81.84	80.12	Games-Howell	0.009*
76	488	65.42	57.11	Games-Howell	0.000*	331	81.28	78.60	Tukey HSD	0.000*
84	251	65.94	56.61	Games-Howell	0.000*	249	85.39	80.42	Tukey HSD	0.000*
+84	297	63.80	54.75	Games-Howell	0.000*	233	82.53	80.41	Tukey HSD	0.000*

*Note: [1] Sample size after Upsampling treatment. * The differences between groups were significant ($p < 0.01$).*

Table 3 brings the results for each weight class of Men's and Women's Classic and Equipped Powerlifting of One Way ANOVA applied to two-level groups, 0-50th and 50th-90th quantiles of GLP score. This table also shows the Post Hoc comparison of the GLP variable between IN and OUT groups following the optimal ratio ranges suggested in Table 2; 48 of 64 One-way ANOVA tests granted meaning differences between IN and OUT groups. In the 0-50th quantile level, Men's Classic shows all weight classes with meaning differences; Women's Classic presents only two classes without telling differences; Men's and Women's Equipped only results from one class without meaning differences. In the 50-90th quantile level, for Men's Classic, five weight classes not showed meaning differences; and Women's Classic were four classes without meaning differences; in Men's Equipped, four classes were not meaning differences; and last, Women's Equipped was only one without meaning differences.

In general, regardless of the quantile level, for Classic Powerlifting, four (57, 63, 69 and +84) and five (66, 74, 93, 105, and +120) weight classes present optimal ratio ranges supported, respectively Women and Men; while for Equipped Powerlifting, four of Men (74, 83, 93 and 105) and six of Women (57, 63, 69, 76, 84 and +84) weight classes (see Tables 2 and 3). Of those mentioned, for Men's Classic Powerlifting, the optimal ratio ranges rounded: for Squat, the widest 32.72 to 38.34% (66 weight class) and the shortest 36.44 to 39.54% (+120 weight class); in Bench Press, the widest 20.51 to 26.87% (74 weight class) and the shortest 23.32 to 26.14% (+120 weight class); and Deadlift, the widest 37.2 to 44.07% (74 weight class) and the shortest 35.6 to 38.95% (+120 weight class). While that Women's Classic Powerlifting, the optimal ratio ranges were: for Squat, the widest 33.32 to 38.7% (57 weight class) and the shortest 36.66 to 40.91% (+84 weight class); in Bench Press, the widest 18.26 to 24.73% (57 weight class) and the shortest 19.2 to 23.65% (+84 weight class); and Deadlift, the widest 39.07 to 45.93% (57 weight class) and the shortest 37.31 to 42.26% (+84 weight class). Moreover, in Men's Equipped Powerlifting, the optimal ratio ranges showed values: for Squat, the widest 34.48 to 41.97% (83 weight class) and the shortest 35.58 to 40.74% (105 weight class); in Bench Press, the widest 20.11 to 32.1% (74 weight class) and the shortest 23.1 to 31.11% (93 weight class); and Deadlift, the widest 29.93 to 42.12% (74 weight class) and the shortest 30.74 to 38.62% (93 weight class). Finally, in Women's Equipped Powerlifting, the optimal ratio ranges rounded: for Squat, the widest 35.73 to 41.99% (57 weight class) and the shortest 38.39 to 41% (+84 weight class); in Bench Press, the widest 21.19 to 29.66% (63 weight class) and the shortest 23.51 to 28.28% (+84 weight class); and Deadlift, the widest 31.99 to 38.57% (69 weight class) and the shortest 32.58 to 35.91% (84 weight class).

DISCUSSION

The results of this study are relevant to most Powerlifters in the Open Division. Although this division is open to any age of the athletes, most participants are between 24 and 39 years old. This age range was chosen in this research because some previous studies had determined that the peak performance of powerlifting is in this stage of life (Latella et al., 2018; Solberg et al., 2019; Hernández-Ugalde, 2022 a). In addition, knowing that the age factor robustly affected the performance and annual progress of the athletes (Hernández-Ugalde, 2022 a, Hernández-Ugalde, 2022 b), for these reasons, it was considered only to analyze the Open Division. If it were analyzed all together, the age factor could produce mistakes and noise in the results. For the future, it is also relevant to examine the other divisions by separated.

The dispersion of points in Elite powerlifters for GLP versus SBD discipline/total ratio and its variance observed were the main clues to discern the optimal ratio ranges. Figure 2 shows that SBD disciplines/total ratio points of Elite powerlifters are more concentrated than lower quantile levels, occurring in every SBD discipline for all sex and events categories. Other evidence was observed in Figure 3 while increasing the quantile level and decreasing the variance measure brought fewer data variability to this group. The hypothesis was that the Elite Powerlifters keep an intrinsic balance of the SBD disciplines ratio to total. This balance would be an essential factor that influences high performance, for which the lowest variance noted of this group was adjusted with this claim.

The mean and standard deviation from Elite Powerlifter helped calculate the optimal ratio ranges for the SBD discipline. The dispersion of elite powerlifters points had a central tendency to concentrate near a mean (see figure 2), so it was convenient to use this group as a placeholder to start calculating ratio ranges. Likewise, considering that the standard deviation is a measure that offers information about the mean dispersion of a variable, the idea raised that the minimum and maximum ratio

ranges could be calculated from the addition and subtraction from 0.5 to 3 times (multiplication factor, called f value here) the standard deviation to the mean.

Each class weight presents different and particular optimal ratio ranges for the SBD discipline. At the beginning of the analysis, all the weight classes were processed together (data not shown) following the algorithm described in Figure 1. However, the findings of ratio ranges were too broad, which was not convincing. After each weight class was analyzed separately, it resolved the issue where each weight class has different ratio ranges for SBD disciplines, with an acceptable wide. It was highlighted that, in most cases, the heavier weight classes have shorter wide ratio ranges. Therefore, heavier powerlifters must have a tighter balance over the ratio ranges of SBD disciplines. Another observed clue was that lightweight's powerlifters obtained a higher mean Deadlift/Total ratio than heavier class for all sexes and events categories (see table 2). Furthermore, Ball & Weidman (2017) determined other types of ratios as Squat/Bench Press and Deadlift/Bench Press, but not using the total score. They obtained similar mean ratios for all weight classes of each sex and event (equipped or classic) but using all ages divisions together.

The selection of the best permutation with the optimal ratio range was based on the highest Impact factor (I) and the lowest multiplication factor (f), for "MMM" group of the SBD position variable. The code "MMM" means that all records of athletes for this group are inside the suggested optimal ratio ranges. Hence, when the "MMM" score is the highest I value, most athletes in this group would have the best mean performance against the others. In addition, the selection condition based on the lowest f value reaches ratio ranges not so wide, due to this factor determining the wide ranges. Initially, it was used the GLP means instead of I value, and it was noted that there were many permutations with shorter ratio ranges where the MMM group was second or third in GLP mean score, so other codes were higher placed first, but with extremely low frequency observed in the Elite Powerlifting group. Therefore, the Impact factor (I) = GLP mean by frequency helped to resolve this issue, and the ratio ranges are not so wide (see Table 2).

Most of the optimal ratio ranges obtained from Elite Powerlifting also worked to other lower performance levels. The results in Table 3 show, in most cases, that the IN group, where all records are inside the optimal ratio ranges for the SBD disciplines, a higher GLP means than the OUT group is outside of them (Table 3). Likewise, the statistical analysis support, in most cases, that IN and OUT groups had differences between them. From sixty-four evaluations of the optimal ratio ranges over weight classes by sexes and events, 48 were higher in GLP mean score for the IN group, meaning differences regarding the OUT group. At the same time, 15 were only the highest but not statistically different, and only one was rejected for both measures. Last, about those sixteen categories of quantile level and weight class without optimal ratio ranges supported, further studies could evaluate some modifications to the algorithm to find the correct ranges, while a recommended practice for powerlifting coaches and athletes would be to reach the ratio means values from Elite Powerlifters for those weight classes.

This study is a pioneer in the analysis of the balance for SBD ratio to Total in Powerlifting. There is a lack of research on this topic, and then there is not a pool of studies that could be used to compare and discuss results. Only Ball and Weidman (2017) reported some ratios as SBD disciplines/Weight Body, Squat/Bench Press, and Deadlift/Bench Press, and compared among the groups of Men's and Women's Classic and Equipped Powerlifters. Furthermore, from the empirical knowledge, athletes and coaches of powerlifting have suggested in many forums and blogs about 3:4:5 bench press/squat/deadlift ratios (Powerlifting Watch, 2006; Archibald, 2017), but without scientific test. Lastly, these findings highlight the SBD balance ratio to total, affecting performance. If, in the future, there should be any changes in the weight classes; it would be necessary to wait some years to get a significant amount of data to recalculate again the optimal ratio ranges under the algorithm suggested by this study.

CONCLUSION

A Powerlifting balance of SBD disciplines ratio to total score can be relevant to reach high performance. The findings of this study support that the high GLP score observed in Elite Powerlifting of Open Division is not only due to a significant technical and physical training routine done over years, but it also is affected by an intrinsic balance of SBD ratio to the total score. Likewise, this Powerlifting balance also influences other athletes with lower levels. The athletes within the optimal ratio ranges could reach higher performances for any level. Furthermore, the weight classes have different optimal ratio ranges

among them, such as the weight increase by classes as the optimal ratio ranges decrease in wide, in most cases.

Furthermore, the method built in this study determined and tested the Powerlifting balance, being an innovator and efficient procedure. From sixty-four evaluations of the optimal ratio ranges classified by weight classes, sexes, and events, 48 were statically supported. Lastly, as a relevant guide to athletes and coaches of powerlifting, it is recommended to be inside the optimal ratio ranges statistically supported to reach high performances; even more practical is to seek the ratio means values from Elite Powerlifters for each SBD discipline.

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