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Director: Fernando Emilio Valladares Fuente

Email: fernando.valladares@upr.edu.cu

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Original article

Biomechanical analysis of the free squat in powerlifting in Quito

Análisis biomecánico de la sentadilla libre en el levantamiento de potencia en Quito

Análise biomecânica do agachamento livre no powerlifting em Quito

Fátima Ruiz Castro[1*] , *Diego Velasco Tenesaca*[2] , ***Gabriel Coral Apolo***[2]

[1]University of the Armed Forces-ESPE. Quito, Ecuador.

*Corresponding author: firuiz@espe.edu.ec

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ABSTRACT

The analysis of the sports technique from the biomechanical point of view makes it possible to control the assumptions that make up the specific sports technique for its future improvement, this is essential in decision-making as part of the sports management process, especially in sports little studied as It's powerlifting. In this sense, the research objective was to biomechanically analyze the free squat technique in power lifting by gender. The research was descriptive-correlational. Forty-two lifters with an age range between 17-28 years were studied, classified into two independent groups according to gender. The free squat technique was studied in four analysis variables. No significant differences were found in any of the variables analyzed. The knee angle (p=0.845), the maximum speed peak (p=0.095) and the trajectory of the movement in its X axis (p=0.979) and its Y axis (p=0.845) were included. No differences were found between the age ranges of the genders studied (p=0.237). The analyzed free squat technique, in its comparison by gender, did not show significant differences, an aspect that allowed us to deduce a similar technical level between the genders studied. It was concluded that, if the specific motor execution in the sport

studied is correct, the technical component of sports training in powerlifting is satisfactorily fulfilled and regardless of the gender trained.

Keywords: Genres, powerlifting, free squat.

RESUMEN

El análisis de la técnica deportiva desde el punto de vista biomecánico posibilita controlar los supuestos que conforman la técnica deportiva específica para su futuro perfeccionamiento, esto es esencial en la toma de decisiones como parte del proceso de dirección deportiva, sobre todo en deportes poco estudiados como es el powerlifting. En tal sentido, se determinó como objetivo de la investigación analizar biomecánicamente la técnica de sentadilla libre en el levantamiento de potencia por géneros. La investigación fue de tipo descriptiva-correlacional. Se estudiaron a 42 levantadores con rango etario entre 17-28 años, clasificados en dos grupos independientes según el género. Se estudió la técnica de la sentadilla libre en cuatro variables de análisis. No se evidenciaron diferencias significativas en ninguna de las variables analizadas. Se incluyó el ángulo de la rodilla (p=0.845), el pico de velocidad máxima (p=0.095) y la trayectoria del movimiento en su eje X (p=0.979) y su eje Y (p=0.845). No se evidenciaron diferencias entre los rangos etarios de los géneros estudiados (p=0.237). La técnica de sentadilla libre analizada, en su comparación por géneros, no evidenció diferencias significativas, aspecto que permitió deducir un nivel técnico similar entre los géneros estudiados. Se concluyó que, si es correcta la ejecución motriz específica en el deporte estudiado, el componente técnico del entrenamiento deportivo en powerlifting se cumple satisfactoriamente e independientemente del género entrenado.

Palabras clave: Géneros, powerlifting, sentadilla libre.

SÍNTESE

A análise da técnica esportiva do ponto de vista biomecânico permite controlar as suposições que compõem a técnica esportiva específica para seu futuro aperfeiçoamento, isto é essencial na tomada de decisões como parte do processo de gestão esportiva, especialmente em esportes pouco estudados, como o powerlifting. Neste sentido, o objetivo da pesquisa era analisar biomecanicamente a técnica de agachamento livre no powerlifting por gênero. A pesquisa foi descritivo-correlacional. Foram estudados 42 elevadores com idades entre 17-28 anos, classificados em dois grupos independentes de acordo com o gênero. A técnica do agachamento livre foi estudada em quatro variáveis de análise. Não foram encontradas diferenças significativas em nenhuma das variáveis analisadas. Foram incluídos o ângulo do joelho (p=0,845), a velocidade máxima de pico (p=0,095) e a trajetória do movimento em seu eixo X (p=0,979) e eixo Y (p=0,845). Não foram evidentes diferenças entre as faixas etárias dos gêneros estudados (p=0,237). A técnica de agachamento livre analisada, em sua comparação por gênero, não mostrou diferenças significativas, um aspecto que nos permitiu deduzir um nível técnico semelhante entre os gêneros estudados. Concluiu-se que, se a execução motora específica no esporte estudado estiver correta, o

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componente técnico do treinamento esportivo em powerlifting é cumprido satisfatoriamente e independentemente do gênero treinado.

Palavras-chave: Gêneros, powerlifting, agachamento livre.

INTRODUCTION

Power lifting began to be practiced at the end of the fifties of the last century in the mythical bodybuilding gyms that were beginning to become so fashionable in the United States. Powerlifting, weight-power, or simply power (in English powerlifting) is a strength sport that is made up of three events: the squat, the bench press and the deadlift (Austin & Mann, 2021 and Dennis, 2021). Compared to weightlifting, which includes movements from the bottom up, those of powerlifting have a shorter trajectory; however, the two sports disciplines require a lot of muscular strength. In the main characteristics consulted, it is observed that in weightlifting strength-speed and technique are used more (Everett, 2020), while in powerlifting maximum strength predominates more (Travis *et al.,* 2020; Ferland *et al.,* 2020) in part because powerlifting movements are performed with a shorter trajectory.

In recent years, supposed problems of the spine, knees, and other joints directly related to the technical movement of powerlifting related to the squat have been argued (Bengtsson *et al.,* 2018), but they are aspects that are normally related to the process. direction of sports training, such as the inefficient motor execution of a specific technique such as the one mentioned, a common aspect in various related sports, such as weightlifting and other sports (Falk *et al.,* 2021; Mena Pila & Morales, 2018).

From a technical point of view, the squat performed in which you lower yourself completely reduces the chances of injuries to the spine and knees (Lavorato, 2009) and it has been shown that in people who train with good squat technique, they prevent some types of injury related to the overload and overuse of the knee joint and the lower back area (Escamilla, 2014). However, there are authors who justify its dangers, generally when performing a poor technical movement (Lavorato, 2009).

In the case of the knees, the explanation is applied physics or motor mechanics, stopping the squats at 90° exerts a pressure against the bar, greater than that of the weight itself, in order to overcome the inertia of the descent and reverse the movement (Boyle, 2018). Because the half squat can be performed with a heavier weight than the deep squat, it puts tremendous stress on the ligaments. It is known that at approximately 90°, the cruciate ligaments and the patellar tendon are in maximum tension as they, together with the quadriceps muscles, are in charge of stopping the weight of the bar in the half squat.

In contrast, the braking of the deep squat is carried out by the natural anatomical stop: the support of the glutes and hamstrings on calves and heels. The effort exerted by the knee joint near the 90° angle is the greatest in the entire range, so one can imagine what would happen if one tried to brake there with an excessively heavy load.

In sports where the lifting or conduction of external weight is essential, biomechanical analyzes provide an extensive source of data that are widely explored from the mechanical and physiological point of view, (Játiva *et al.,* 2021; Godoy & Ruiz, 2022 and Navarrete *et al.,* 2022), within these data, kinetic and kinematic parameters are included that are useful for understanding human locomotion, measuring and connecting it with the specific performance in each sports modality (Mon-D. *et al., 2019 and* Mon-López *et al.,* 2019).

The biomechanical analysis of any technical gesture related to sport provides us with data that gives us a better vision of the movement, both mechanical and physiological (León *et al.,* 2016), which shows a better understanding of the kinematic and kinetic parameters of human movement.

The free squat is an exercise used as part of a training routine for some sports or as physical conditioning. When done well, this exercise is very complete, since it works the muscles of both the upper and lower body; however, a poor execution of this exercise would cause muscle and joint injuries as stated in Lavorato (2009).

The squat is a widely used exercise for physical conditioning, since it activates several muscles at the same time; however, a bad position could lead to back and knee injuries, which are especially common in unconditioned subjects. In this study, squat data are analyzed in unconditioned subjects, organized into two groups, one comprised of women and one of men, to assess potential knee joint implications for future prospective action.

Given the above, the preliminary purpose of the research was to analyze biomechanically the free squat technique in power lifting by gender, as it is the theoretical and methodological basis for the prospective design of other researches, such as those related to the possible positive and negative implications in the joint movement of the knee and for the improvement of the technical performance of the sport under study.

MATERIALS AND METHODS

The present research was considered of a descriptive-correlational type, an intentional non-probabilistic sampling was used, when selecting 42 lifters (they are classified numerically for data protection), with an age range included in the areas of greatest biological maturity (juvenile categories and senior; 17-28 years old). The subjects studied were classified into two independent groups according to gender, group 1 (20 subjects, male) and group 2 (22 subjects, female), belonging to the gyms" Power Fitness" and "Planeta Fitness" in the city of Quito, Ecuador. To avoid distortion of the results, a comparison of the age ranges between genders was made, with a view to establishing age balance in both independent groups.

The squat technique was studied (two attempts per person), all under a controlled scenario, choosing the best attempt from a biomechanical perspective. For the present research, a letter of informed consent was required.

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The following variables were analyzed in the movement:

1. Knee and hip angles (º): anatomical points of reference were considered (knee: lateral malleolus, femoral condyle and greater trochanter; hip: femoral condyle, greater trochanter and acromion).

2. Peak maximum speed (m/s): a measurement was obtained that goes from the Femoral condyle to the greater trochanter.

3. Trajectory: an imaginary vertical line was drawn, where the center of the bar was taken as a reference. And the respective monitoring of the bar was carried out based on the effects of the force of gravity on its two axes.

For data collection, a camera that captures 60 frames per second was used, as well as a tripod to provide stability and avoid uncontrolled disturbances, which manages to capture true and accurate data of the technical movement. For the analysis of the data, the Kinovea program in its version 0.9.3 was used and for the tabulation of the data the SPSS V25 program, the Mann-Whitney U test was applied (p= 0.05) since there was no distribution normality of the data and counting significant differences between the two independent samples with the average ranges obtained at a confidence level of 95 %.

RESULTS AND DISCUSSION

Table 1 evidenced the results obtained from the male gender, where the last rows showed the average, minimum and maximum values, as well as the standard deviation of the four variables under analysis, plus age (Table 1).

Table 1. *- Results obtained, male gender*

	AGE	ANGLE	SPEED	CENTER GRAVITY	
No.				X	Y
1	18	88	1.09	0.48	0.75
2	23	70.6	0.58	0.5	0.71
3	19	84	2.01	0.47	0.78
4	18	55.6	0.54	0.3	0.64
5	18	48	1.8	0.39	0.6
6	18	44	1.61	0.52	0.59
7	17	71	1.37	0.43	0.7
8	18	56	1.88	0.5	0.64
9	18	68	1.71	0.43	0.69

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10	18	68	1.48	0.51	0.87
11	18	75	1.44	0.4	0.68
12	18	73	1.51	0.52	0.73
13	19	64.1	0.92	0.27	0.55
14	24	66.5	1.46	0.33	0.57
15	18	60.1	1.34	0.33	0.65
16	18	69.3	1.88	0.27	0.67
17	22	63.4	0.83	0.25	0.59
18	22	72.3	0.61	0.31	0.72
19	21	66.3	0.49	0.33	0.64
20	28	59.9	0.56	0.32	0.67
AVERAGE	**19.65**	**66.16**	**1.26**	**0.39**	**0.67**
MAXIMUM	**28**	**88**	**2.01**	**0.52**	**0.87**
MINIMUM	**17**	**44**	**0.49**	**0.25**	**0.55**
STANDARD DEVIATION		**10.62**	**0.51**	**0.09**	**0.08**

The mean or average values, in each variable obtained from the male gender (Table 1) were positioned, in the case of age, at 19.65 years (≈20), with a maximum value of 28 years and a minimum value of 17 years (juvenile and senior category); while the average, in the angle variable, was established at 66.16º, with a maximum value of 88º and a minimum value of 44º.

Regarding the speed variable, the average was established at 1.26m/s, with a maximum value of 2.01m/s and a minimum value of 0.49m/s. On the other hand, the mean values established in the center of gravity as part of the movement trajectory were located for the X axis at 0.39º and for the Y axis at 0.67º, with their respective maximum and minimum values.

In the case of Table 2, the values obtained for the female gender were recorded, and as in Table 1, the mean, minimum and maximum values are described, as well as the standard deviation of the data in their comparison (Table 2).

Table 2. *- Results obtained, female gender*

	AGE	**ANGLE**	**SPEED**	**CENTER GRAVITY**	
No.				X	Y
1	18	41	23	0.39	0.68
2	18	85	0.67	0.44	0.86
3	18	61	1.27	0.44	0.71
4	18	77	1.35	0.48	0.75
5	17	61	1.06	0.52	0.65
6	18	88	1.24	0.38	0.69
7	18	69	1.41	0.56	0.76
8	18	64	0.89	0.73	0.87
9	18	43	0.68	0.28	0.58
10	18	60	1.65	0.23	0.63

111	22	62	0.78	0.31	0.66
12	25	70.03	0.49	0.24	0.67
13	25	60.1	0.81	0.33	0.63
14	23	54.9	0.48	0.31	0.56
15	23	117.9	0.5	0.42	0.66
16	23	69.5	0.89	0.35	0.63
17	24	60.1	1.33	0.44	0.62
18	23	78	1.24	0.35	0.66
19	22	46.3	0.95	0.42	0.79
20	25	75.4	1.09	0.39	0.69
21	22	66	0.65	0.35	0.62

AVERAGE	**20.76**	**67.11**	**1.03**	**0.40**	**0.68**
MAXIMUM	**25**	**117.9**	**23**	**0.73**	**0.87**
MINIMUM	**17**	**41**	**0.48**	**0.23**	**0.56**
STANDARD DEVIATION		**16.95**	**0.44**	**0.11**	**0.08**

The mean reached in the age variable was established at 20.76 years (≈21), with a maximum value of 25 years and a minimum of 17 years and, as in the male gender, the age range was found between the juvenile to senior category, range where the greatest possible biological maturity was reached and therefore the maximum possibilities of sports performance, as specified in Weineck (2019), who included the fundamental component of sports technique, since in eminently technical sports one arrives later to the peak of performance, as defined by Bercovici (2021).

On the other hand, the average reached in the angle variable was established at 67.11º, with a maximum value of 117.9º and a minimum value of 41º, while in the speed variable, the average was established at 1.03m/s, with a maximum value of 2.3m/s and a minimum value of 0.48m/s. In the case of the average values established in the center of gravity for the X axis, it was located at 0.40º and for the Y axis at 0.68º.

To establish the comparison between genders, in terms of the results recorded in the previous tables, the Mann-Whitney U Test (Table 3) for two independent samples establishes the existence or not of statistical differences (Table 4).

Table 3. *- Mann-Whitney U test*

	AGE	**ANGLE**	**SPEED**	**CENTER GRAVITY**	
No.				X	Y
1	18	41	23	0.39	0.68
2	18	85	0.67	0.44	0.86
3	18	61	1.27	0.44	0.71
4	18	77	1.35	0.48	0.75
5	17	61	1.06	0.52	0.65
6	18	88	1.24	0.38	0.69
7	18	69	1.41	0.56	0.76

8	18	64	0.89	0.73	0.87
9	18	43	0.68	0.28	0.58
10	18	60	1.65	0.23	0.63
111	22	62	0.78	0.31	0.66
12	25	70.03	0.49	0.24	0.67
13	25	60.1	0.81	0.33	0.63
14	23	54.9	0.48	0.31	0.56
15	23	117.9	0.5	0.42	0.66
16	23	69.5	0.89	0.35	0.63
17	24	60.1	1.33	0.44	0.62
18	23	78	1.24	0.35	0.66
19	22	46.3	0.95	0.42	0.79
20	25	75.4	1.09	0.39	0.69
21	22	66	0.65	0.35	0.62

AVERAGE	**20.76**	**67.11**	**1.03**	**0.40**	**0.68**
MAXIMUM	**25**	**117.9**	**23**	**0.73**	**0.87**
MINIMUM	**17**	**41**	**0.48**	**0.23**	**0.56**
STANDARD DEVIATION		**16.95**	**0.44**	**0.11**	**0.08**

Table 4. - *Test statistics*[a,b]

	Age	**Angle**	**Speed**	**Center Gravity. X**	**Center Gravity. Y**
Kruskal–Wallis H	1,396	.038	2,788	.001	.038
gl	1	1	1	1	1
asymptotic sig	.237	.845	.095	.979	.845

a. Kruskal-Walli's test
b. Grouping variable: Groups

Table 3 evidenced the results with the Mann-Whitney U Test, when comparing the results registered in both genders. The age variable showed the non-existence of significant differences (p=0.237), sample of a similar age range in both genders and a controlled indicator that made it possible to not distort the results, due to the existing differences in biological maturity that usually present different age ranges, with emphasis on initial training categories.

Biological maturity can present distortions in different components of sports preparation, as would be the case of the technique, where, according to Játiva *et al.,* (2021) when comparing biomechanical differences in the snatch technique in weightlifting, between elite and novice athletes, significant differences were determined in the angle of the second knee draw (p=0.011) and in the maximum velocity peak in the first draw (p=0.046). In other investigations, such as the one presented in Navarrete *et al.* (2022), significant differences are determined in the snatch technique when comparing various biomechanical variables in categories of initiation and development.

When comparing the angles of the analyzed movement, the Mann-Whitney U Test did not specify significant differences, the (p=0.845) indicated that the movement in both genders did not have notable differences in terms of sports technique, although the average range was lower in the female gender (20.64), perhaps due to the greater capacity for joint flexibility that this gender normally possesses (Rodríguez, 2010), although this variable must be analyzed in the future through empirical tests.

On the other hand, the speed indicator did not present significant differences by gender (p=0.095), although of all the variables or indicators analyzed it was the one that presented the greatest differences, as established with the average ranges reached. The male gender was the one with the highest numerical data (24.20) and therefore, the one with the highest speed of motor execution; factor that could be influenced by the greater muscle mass that this gender has and a greater capacity for strength, which directly influenced joint speed (Véliz & Cid, 2020).

In the case of the values obtained with the center of gravity, the Mann-Whitney U test did not show significant differences either, neither for the X axis (p=0.979), nor for the Y axis (p=0.845), so that It was deduced that in the analyzed variables there are no notable differences in the free squat technique.

Taking into account the results of this study, as well as the integrality factors of sports performance (Calero-Morales, 2011), it was determined that the average flexion of the knee joint for men and women meets the criteria of minimization, because they exceed the fundamental degree that lies up to 40 degrees; therefore, it was possible to verify that apparently no person suffers from any pathology in the knee joint and that both genders presented a similar performance in the technical component that led to deduce the existence of an adequate acquisition of the sports technique.

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CONCLUSIONS

The analyzed free squat technique, in its comparison by gender, did not show significant differences, an aspect that allowed to deduce a similar technical level between the genders studied. It was concluded that, if the specific motor execution in the sport studied is correct, the technical component of sports training in powerlifting is satisfactorily fulfilled, regardless of the gender trained.

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