Luz, *24*, e1501, 2025, Edición 102. III Época. ISSN 1814-151X

https://luz.uho.edu.cu

Gender Differences in Load-Velocity Profile of the Squat and Deadlift in Soccer Players

Diferencias de género en el perfil carga-velocidad de sentadilla y peso muerto en futbolistas

Diferenças de gênero no perfil carga-velocidade do agachamento e levantamento terra em jogadores de futebol

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Abstract

This study aimed to explore the differences in the load-velocity profile between deadlift and squat exercises in men and women. The load-velocity profiles (from 30% to 100% of the one-repetition maximum [1RM] in 5% increments) of 42 soccer players (25 men and 17 women) were tested during deadlift and squat. Relationship between mean propulsive velocity and %1RM were analyzed. ANOVA test was applied to compare each dependent variable (i.e., mean velocity values attained at each %1RM and mean test velocity), with sex (men and women). Close relationships between bar velocity and relative load were observed for both sexes for squat (R^2 = 0.76-0.95) and deadlift (R^2 = 0.86-0.88). Moreover, men showed statistically higher mean propulsive velocity than women (p < 0.001–0.05) in squat and deadlift. These results confirm that men present higher

Resumen

Este estudio tuvo como objetivo explorar las diferencias en el perfil carga-velocidad entre los ejercicios de peso muerto y sentadilla en hombres y mujeres. Se evaluaron los perfiles de carga-velocidad (del 30% al 100% de la repetición máxima [1RM] en incrementos del 5%) de 42 jugadores de fútbol (25 hombres y 17 mujeres) durante el peso muerto y la sentadilla. Se analizó la relación entre la velocidad de propulsión media y el %1RM. Se aplicó la prueba ANOVA para comparar cada variable dependiente (es decir, valores medios de velocidad alcanzados en cada %1RM y velocidad media de la prueba), con el sexo (hombres y mujeres). Se observaron relaciones estrechas entre la velocidad de la barra y la carga relativa para ambos sexos en sentadilla (R2 = 0,76-0,95) y peso muerto (R2 = 0,86-0,88). Además, los hombres mostraron una velocidad de propulsión media

Recibido:5 de abril de 2024/Aceptado: 13 de agosto de 2024/Publicado: 1 de enero de 2025
Artículo original

velocities at moderate to high relative loads (i.e., %1RM) compared to women during lower-body exercises.

Keywords: velocity-based training; sex differences; 1RM; rate of force development

estadísticamente mayor que las mujeres ($p < 0{,}001$-$0{,}05$) en sentadilla y peso muerto. Estos resultados confirman que los hombres presentan velocidades más altas con cargas relativas de moderadas a altas (es decir, %1RM) en comparación con las mujeres durante los ejercicios de la parte inferior del cuerpo.

Palabras clave*:* Entrenamiento basado en la velocidad; Diferencias de sexo; 1RM, Tasa de desarrollo de la fuerza

RESUMO

Este estudo teve como objetivo explorar as diferenças no perfil carga-velocidade entre os exercícios de levantamento terra e agachamento em homens e mulheres. Foram avaliados os perfis de carga-velocidade (de 30% a 100% da repetição máxima [1RM] em incrementos de 5%) de 42 jogadores de futebol (25 homens e 15 mulheres) durante o levantamento terra e o agachamento. A relação entre a velocidade média de propulsão e o %1RM foi analisada. O teste ANOVA foi aplicado para comparar cada variável dependente (isto é, valores médios de velocidade alcançados em cada %1RM e velocidade média do teste) com o sexo (homens e mulheres). Foram observadas relações estreitas entre a velocidade da barra e a carga relativa para ambos os sexos no agachamento ($R^2 = 0{,}76$-$0{,}95$) e no levantamento terra ($R^2 = 0{,}86$-$0{,}88$). Além disso, os homens apresentaram uma velocidade média de propulsão estatisticamente maior do que as mulheres ($p < 0{,}001$-$0{,}05$) no agachamento e no levantamento terra. Esses resultados confirmam que os homens apresentam velocidades mais altas com cargas relativas moderadas a altas (isto é, %1RM) em comparação com as mulheres durante os exercícios da parte inferior do corpo.

Palavras-chave: treinamento baseado em velocidade; diferenças de sexo; 1RM; taxa de desenvolvimento de força

Introduction

Lower limb muscle power is important for improving performance and decreasing the injury rate in soccer players (Silva et al., 2015). In this line, strength and power training using different methods (e.g. traditional strength training, eccentric or flywheel training) is commonly employed to increase lower limb muscle power (Silva et al., 2015). In fact, training programs based on multiple components (e.g., a combination of strength, balance, plyometrics) seems to be the most effective strategy for reducing noncontact injuries in soccer sport (Silva et al., 2015). Hence, maximize strength and power is fundamental as soccer players have to produce high levels of muscle power during competition (Roso-Moliner et al., 2024). Moreover, the most important actions in soccer, such score a goal, usually occur after high-intensity movements (Martínez-Hernández et al., 2023).

Multiple methods have been developed to monitor strength training (Uribarri et al., 2024), taking into account the multifactorial nature of sports performance (Mon-López et al, 2019). Traditionally, one-repetition maximum (1RM) test is the most common and simplest method used to assessing strength, and based on this, performance benchmarks are established. (Morales et al., 2024) The traditional 1RM test consists of lifting the heaviest load with proper technique for a single repetition in a given exercise. However, this direct assessment of 1RM has some limitations because is physically, technically, and psychologically stressful. Then, using the traditional way to assess strength could have a potential risk of injury and produce high levels of fatigue to players. In addition, 1RM may fluctuate daily or change systematically due to rest, nutrition, training or detraining (Garcia-Ramos, 2024).

Velocity-based training (VBT) has been proposed as an alternative method to evaluate strength indirectly VBT uses the measurement of the bar´s velocity in a determinate exercise. VBT can be implemented across all facets of a resistance training, supporting the prescription of load, sets, number of repetitions. One of the most interesting applications of VBT is the possibility of estimating 1RM strength from the velocity recorded against submaximal loads. General load-velocity (L-V) relationships, introduced by González-Badillo and Sánchez-Medina (González-Badillo, et al., 2010), have previously been proposed to estimate the 1RM. However, some studies have shown that generalized L-V relationships is limited because there are sex differences in %1RM-velocity relationships (Garcia-Ramos, 2024; Nieto-Acevedo et al., 2023c). Furthermore, a recently systematic review with metanalyses, conclude that men exhibit greater velocities at the same relative loads (%1RM) than women, particularly with light and moderate loads (Nieto-Acevedo et al., 2023a).

Regarding the type exercises used, deadlift and the squat are part of the strength soccer programs which are included in resistance training to enhance lower body strength and power (Pareja-Blanco, et al., 2017). Pareja Blanco et al. (2017) indicate that squat and deadlift can result in similar improvement in lower body maximal strength and jump performance and can be successfully included in strength training programs. However, most of the previous velocity data studies has been collected on a resistance trained population, but not specific soccer athletes. Thus, data are needed to not only further elucidate if sex may influence in velocity to individualize VBT, but also to investigate these factors in team sport athletes.

Hence, taking into account that squat and deadlift exercises could be fundamental to improve performance in soccer to reduce risk injury to have a high economic and team performance impact in soccer (Eliakim et al, 2020). Then, the aim of this study is to determine if there are differences in mean propulsive velocity (MPV) from 30 to 100%1RM in the squat and deadlift exercises between male and female soccer players. Consequently, it was hypothesized that men would have higher velocities in each %1RM than women in both exercises.

Method

Participants

Although the power analysis conducted in previous studies revealed that sample sizes of only 3–9 participants were needed to detect the differences in mechanical variables (force, velocity and power) (Garcia-Ramos, 2024) to ensure an optimal sample size we recruited 42 soccer players, 25 men (age = 21.19 ± 3.23 years; body mass = 72.31 ± 8.59 kg; height = 157.07 ± 56.29 cm) and 17 women (age = 23.58 ± 3.86 years; body mass = 61.95 ± 9.55 kg; height = 165.32 ± 7.64 cm). All participants trained 12h of physical activity per week. They used to train resistance using back squat and deadlift exercise (training frequency of at least 2–3 times per week).

In addition, the inclusion criteria were having at least one year of resistance training experience in squat and deadlift; and not having any health or musculoskeletal injuries that could compromise the testing.

After being informed of the purpose and testing procedures, subjects signed a written informed consent form prior to participation. The present investigation was approved by the Research Ethics Committee of the Universidad Politécnica de Madrid (FDRED00000-DML-DATOS-20230609) and was conducted in accordance with the Declaration of Helsinki (23).

Experimental Design

Participants carried out a preliminary session in which they were familiarized with the testing equipment and the exercise protocol. This session was also used for body composition assessment, personal data, and health history questionnaire administration. Participants came to the laboratory on two more occasions separated by 48–72 h (Pareja-Blanco et al., 2020). Each exercise was tested on each occasion. Individual load–velocity profiles were determined by means of an incremental loading test that followed standard procedures for squat (SQ) (Pareja-Blanco et al., 2020) and deadlift (DL) (Morán-Navarro et al., 2021) exercises. The test sessions were conducted at the same place and time of day (±1 h; Match Day -4) for each subject and under the same environmental conditions. Participants were requested to avoid strenuous exercises and beverages containing caffeine/alcohol for 24 h prior to testing on both sessions.

Testing Procedures

The following considerations were taken into account for the deadlift technique. The subject had to lift the bar while avoiding countermovement of the hips, ending with arms and legs completely extended. A self-selected width with a mixed grip (one arm pronated and one arm supinated) was used. It was performed starting from the floor and at the same height for all participants (approximately the average distance between the knee and the ankle), with a stance approximately shoulder-width apart and with both feet positioned flat on the floor in parallel or slightly externally rotated, while keeping a neutral spine, chest up and head in line with the spine. The subjects were then instructed to pull the bar in a vertical direction at the maximum intended velocity until their body was fully erect and were instructed to maintain the final static position for ~1s (Morán-Navarro et al., 2021).

Squatting was with the bar rested on the upper trapezius and the movement started in the bottom of the squat position, which ensured that all participants had their thighs as parallel to the floor as possible. From this position, the participants were instructed to complete the concentric phase of the lift as fast as possible until full extension was attained at the hip and knee joint. The heels were not allowed to lift off from the floor. Between each repetition, the participants had to hold the bottom position for at least 3s to ensure that the eccentric phase would not interfere with their concentric performance. According to past research, imposing a pause between the eccentric and concentric phases of the back squat (i.e. stop-back squat) increases the reliability of strength assessments when using a smith machine (Pallarés et al., 2014).

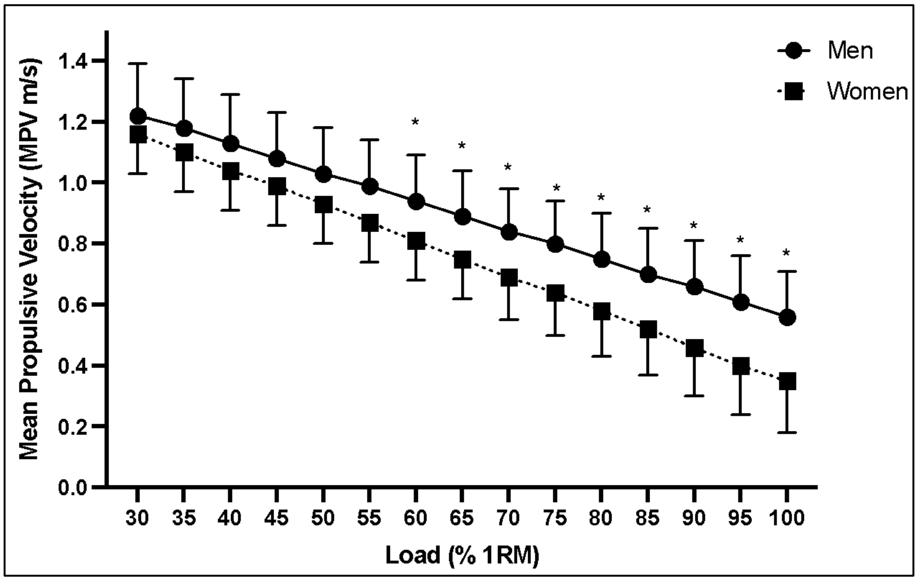
The warm-up protocol consisted of 3 min of stationary cycling at a self-selected easy pace and 5 min of joint mobilization exercises, followed by 6 repetitions with fixed loads of 30 and 20kg for men and women, respectively, for both exercises. Individual load–velocity relationships and 1RM strength were determined using a progressive loading test. MPV was tested due to strong correlations observed between mean propulsive velocity (MPV) and load (%1RM) in previous studies (González-Badillo et al., 2010). The initial load was using a 20kg barbell (Eleiko, Halmstad, Sweden) and gradually increased using MPV as a parameter for adding load. The next protocol was the following: initially, in increments of 20 kg until an MPV of 0.8 $m \cdot s^{-1}$ was reached, 3 repetitions were performed. Two repetitions were performed when the MPV was between 0.8 and 0.6 $m \cdot s^{-1}$ (10kg increments), and only one repetition from the present until the end of the test. Increments of 5kg were used when the MPV ranged from 0.6 to 0.5 m·s−1, and 2.5kg increments were used when the MPV was less than 0.5 m·s−1 to 1RM. The heaviest load that each subject could properly lift while completing a full range of motion and without any external help was the 1RM. Inter-set rests were fixed at 3 min to reduce possible neural or mechanical fatigue (Pareja-Blanco et al., 2020). Only the best repetition (fastest and executed correctly) at each load was considered for subsequent analysis. All repetitions were recorded with a linear velocity transducer (ADR encoder, Toledo, Spain), which has been previously validated (Moreno-Villanueva et al., 2022). Strong verbal encouragement (e.g., "let's go," "keep going") was provided during all tests to motivate participants to give maximal effort.

Statistical Analysis

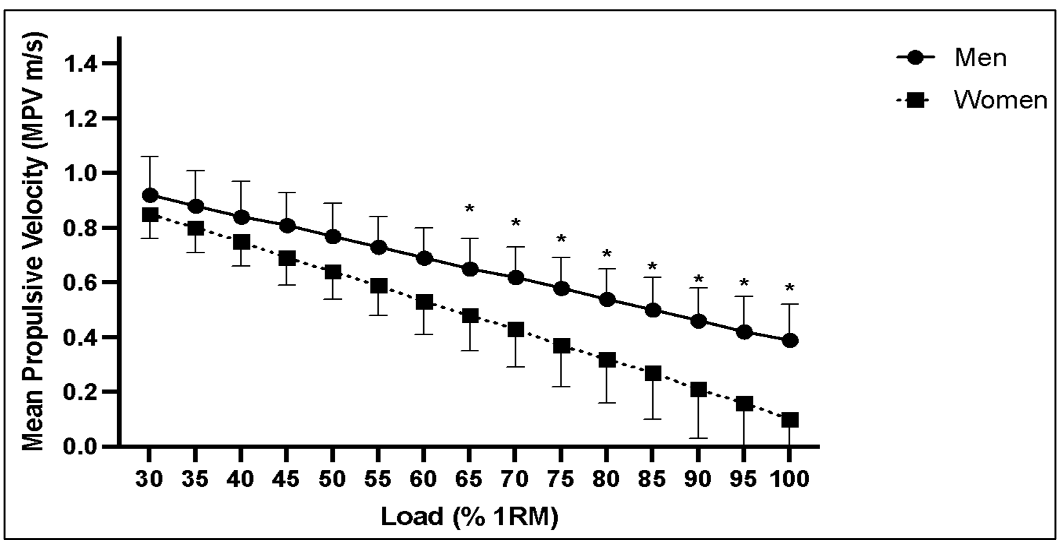
Data are presented as means (*M*) and standard deviation (*SD*) and Pearson's correlation coefficient (*r*). The normal distribution of the data was confirmed by Shapiro–Wilk, and the homogeneity of variances was confirmed by Levene's test ($p > 0.05$). Linear regression and Pearson's correlation coefficient were used to check the relationship between measured and predicted MPV values. ANOVA was applied to compare each dependent variable (i.e., mean velocity values attained at each %1RM and mean test velocity), with sex (men and women). When significant differences were observed, a Bonferroni´s post hoc comparison was performed. Significance level was set at $p < 0.05$. Analyses were carried out using a custom spreadsheet (Microsoft Excel version 16.69.1) and JASP software version 0.16.4 (Nieuwe Achtergracht, Amsterdan).

Results

The linear regression model relationship between relative load (%1RM) and MPV is represented in Figure 1. A very strong association between these two variables could be observed for the squat (R^2 = 0.76) in men and (R^2 = 0.95) in women and the deadlift (R^2 = 0.86) in men and (R^2 = 0.88) in women. The MPV associated with each %1RM was obtained from these polynomial fits, from 30% 1RM onwards, in 5% increments (Table 1).



(a)



(b)

Figure 1. Relationship between relative load (%1RM) and mean propulsive velocity (MPV) for women (squares and dotted line) and men (circles and continuous line) in squat (a) and deadlift (b)**.** Significant differences between the sexes * $p < 0.05$.

The ANOVA test applied to the mean velocity attained at each test %1RM revealed that men achieved statistically higher values than women (*p*-range: < 0.001–0.05). These differences between sexes were observed in moderate to high loads, 65–100 %1RM in the DL exercise, and 50–100 %1RM in the SQ (Table 1).

Table 1. Estimated mean propulsive velocity values for each %1RM in the squat and deadlift exercises for men (n = 25) and women (n = 17) derived from the individual load–velocity relationships.

Load (%1RM)	**Deadlift**							**Squat**							
	Men			Women				Men			Women			
	M		*SD*	*M*		*SD*		*M*		*SD*	*M*		*SD*	
30	0.92	±	0.14	0.85	±	0.09		1.22	±	0.17	1.16	±	0.13	
35	0.88	±	0.13	0.80	±	0.09		1.18	±	0.16	1.10	±	0.13	
40	0.84	±	0.13	0.75	±	0.09		1.13	±	0.16	1.04	±	0.13	
45	0.81	±	0.12	0.69	±	0.10		1.08	±	0.15	0.99	±	0.13	
50	0.77	±	0.12	0.64	±	0.10		1.03	±	0.15	0.93	±	0.13	*
55	0.73	±	0.11	0.59	±	0.11		0.99	±	0.15	0.87	±	0.13	*
60	0.69	±	0.11	0.53	±	0.12		0.94	±	0.15	0.81	±	0.13	*
65	0.65	±	0.11	0.48	±	0.13	*	0.89	±	0.15	0.75	±	0.13	**
70	0.62	±	0.11	0.43	±	0.14	**	0.84	±	0.14	0.69	±	0.14	**
75	0.58	±	0.11	0.37	±	0.15	**	0.80	±	0.14	0.64	±	0.14	**
80	0.54	±	0.11	0.32	±	0.16	**	0.75	±	0.15	0.58	±	0.15	**
85	0.50	±	0.12	0.27	±	0.17	**	0.70	±	0.15	0.52	±	0.15	**
90	0.46	±	0.12	0.21	±	0.18	**	0.66	±	0.15	0.46	±	0.16	***
95	0.42	±	0.13	0.16	±	0.19	**	0.61	±	0.15	0.40	±	0.16	***
100	0.39	±	0.13	0.10	±	0.20	**	0.56	±	0.15	0.35	±	0.17	***

*Values are Mean (M) and Standard Deviation (SD). All velocity values correspond to mean propulsive velocity. %1RM: relative load expressed as percentage of one-repetition maximum. Significant differences between the sexes * p < .05, ** p < .01, *** p < .001*

Discussion

The aim of the present study was to examine gender differences of soccer players in MPV across a spectrum of loads (30- 100% 1RM) in squat and deadlift exercises. The main finding of this study was that men showed higher MPV in deadlift (> 65% 1RM) and squat (> 50% 1RM) than women ($p < 0.05$). Additionally, both exercises and both genders presented strong association between MPV and load. These results are aligned with previous researches, showing that the R^2 for the load–velocity relationship obtained is typically ≥ 0.85 (31–33). Although we obtained lower R^2 ($R^2 = 0.76$) values for squat exercise in men.

Similar to our results, previous studies have reported that men had higher velocities than women in squat (Pareja-Blanco et al., 2020), bench press (Pareja-Blanco et al., 2020), military press, deadlift and row (Nieto-Acevedo et al., 2023b) exercises. Most of the previously mentioned studies found favorable differences for men (Nieto-Acevedo et al., 2023c) at low to moderate loads; although, these differences tend to disappear as they approach 1RM. On the other hand, in our study men reported higher velocity values at 1RM. However, Nieto-Acevedo et al. (Nieto-Acevedo et al., 2023c) found that men lifted faster than women at low loads (30-55% 1RM) in deadlift, whereas in the present study men showed significant higher MPV values from 65 to 100% 1RM in deadlift exercise. Although we only found differences in squat in favor of men from 50 to 100% 1RM, our results would be in line with Pareja Blanco et. al (2020) who observed lower velocities for women for all relative loads except for 100% 1RM.

These differences with previous research could be explain by the different type of sample included in the studies. Most of studies have analyzed recreational participants while we included soccer players. Consequently, our sample is more homogeneous because they play the same sports with similar hour of practice per week. In this line, Fitas et al. (2023) showed greater differences because they found that the magnitude of sex differences in velocity for submaximal relative loads was dependent on the individual strength levels, founding larger effect for comparisons between relatively strong (moderate to extremely large effect sizes: 0.7–2.6) than relatively weak participants (moderate effect sizes: 0.8–1.3).

Regarding the relationships between velocity and %1RM we found strong correlations both in men (SQ: $R^2 = 0.76$; DL: $R^2 = 0.86$) and women (SQ: $R^2 = 0.95$; DL: $R^2 = 0.88$). Similarly, (24,37–39) obtained a relationship in women squat exercise ($R^2 = 0.92$-0.96). However, our men load-velocity relationships in squat exercises seems to be lower than previous studies ($R^2 = 0.76$ vs. $R^2 = 0.93$). Moreover, according to Nieto-Acevedo et al. (2023c) ($R^2 = 0.938 - 0.947$), our results showed a strong correlation between velocity and %1RM in both sex in deadlift ($R^2 = 0.86 - 0.88$).

These differences in %1RM-velocity relationship with other studies could be explained by the sample used (e.g. sport-specific athletes vs. recreational subjects) (García Ramos, 2024), use different equipment (Smith machine or free weight) (Pallarés et al., 2014) testing with different velocity monitoring device (ADR encoder, Toledo, Spain vs. T-Force Ergotech, Murcia, Spain) (Weakly et al., 2021), and variantexercise utilized the stretch-shortening cycle compared to the concentric-only execution (Pallarés et al., 2014). García Ramos, 2024 recommend not use generalized L-V relationships because has some limitations, which include the variant-specific, sex-specific, age-specific, device-specific, equipment-specific, subject-specific, and training-specific nature of %1RM-velocity relationships.

In addition, regardless sex differences, the result from Nuzzo (2024) reveal that sex differences in muscle fiber types exist and men exhibit greater cross-sectional areas for all muscle fiber types, greater distribution percentages for Type II. Sex differences in muscle fiber types might help to explain greater muscle strength and power among men than women.

This study could add important information to the previous literature regarding soccer and gender VBT, however it is important to consider some limitations. Although it is a controversial topic and some authors suggest that the estimation of the 1RM from the load-velocity relationship seems not to vary over the 3 different phases of the MC (i.e., menstrual, follicular, and luteal phases). García-Pinillos et al. 2022, we did not measure the menstrual cycle in female participants. Lastly, it would be interesting that future studies will analyze other sports or other strength athletes such a powerlifter, CrossFit athletes because some studies have shown that their 1RM velocities are lower than other athletes. Maybe this sample could provide additional information on whether the present findings are maintained even among highly strength trained men and women.

Conclusions

The study suggests that women have lower velocities than men at moderate to high load (>50% 1RM) squat and (> 60 %1RM) deadlift. It seems that sex show a considerable impact on the load–velocity relationship. In consequence, it would be recommended use sex-specific equations to estimate load from velocity measures. As a practical application, strength and conditioning coaches can accurately monitoring intensity of training (%1RM) depending on the sex in squat and deadlift.

Funding: This research was funded by the Centro de Estudios del Entrenamiento Deportivo en Alto Rendimiento Deportivo (CEEDAR). Dirección Provincial de Deportes "Pinar del Río", República de Cuba, under Grant "Factores que determinan el rendimiento deportivo en Alta Competición", approved by resolution No: 10012023-DPD-m-Pinar del Río.

Institutional Review Board Statement: This study was conducted in accordance with the Declaration of Helsinki and approved by the Universidad Politécnica de Madrid. Vicerrectorado de Investigación, Innovación y Doctorado (FDRED00000-DML-DATOS-20230609)

Informed Consent Statement: Not applicable.

Data Availability Statement: The datasets used and analyzed during the current study are available from the corresponding author upon reasonable request.

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Conflicts of Interest

The authors declare no conflict of interest.

Author Contributions: Conceptualization, methodology, formal analysis, writing—original draft preparation R.N.A and D.M-L; writing—review and editing, D.M.-L.; supervision, D.M-L. and A.G. All authors have read and agreed to the published version of the manuscript.

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