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(RESEARCH ARTICLE)

Effect of training load on lower limb power and jumping ability of professional soccer players

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Abstract

Research objective: The main research objective is to analyze the effects of training load on the lower limb power and jumping ability used in the maximum strength phase I during the preparatory period after the fall round league games among professional soccer players.

Materials and Methods: The research material was a selected group of soccer players (n = 56) of the first Polish league, representing a similar sports level with a minimum of 4 years of training experience in the league and in the age range of 22 to 28 years. The study is focused on comparing two strength training programs which have been based on varying the intensity of training (% 1 RM). The first group performed training with an external load of 50-60% of 1RM (SG1), while the second group performed training with a load of 70-80% of 1RM (SG2). The training plan ran over 4 weeks (2 sessions per week; 4-number of series; 5-number of repetitions; 3-minute interval time between series; 2-minute interval time between exercise), with pre- and post-tests which included: anthropometry, 1RM, peak power output with 50% (unilateral), 60% (bilateral) (SG1) and 70% (unilateral), 80% 1RM (bilateral) (SG2) in the leg press, squat, and CMJ. The use of pneumatic devices the Keiser Leg Press A420 and Keiser Air Squat A300 (Keiser, Fresno, CA, USA) was used to measure the generated power of the lower limb muscles (leg press, squat). The dynamometric device Force Decks Dual Force Plate System (Brisbane, Queensland, Australia) was used to measure the jumping ability (CMJ).

Results: Analyzing the changes in power generated during leg presses and during squats, it should be concluded that the results in both groups improved. However, the changes in the SG1 group, using an external load of 50-60% 1RM, were significantly greater. Interestingly, in the SG2 group, using an external load of 70-80% 1RM, the level of power generated by the right lower limb during the unilateral squat decreased after training. Similarly, to the jumping ability, greater changes were recorded in the SG1 group after completing the training program.

The SG1 group with training using an external load of 50-60% 1RM achieved significantly better results than the SG2 group with training using an external load of 70-80% 1RM for 7 variables: bilateral leg press, unilateral leg press (right lower limb), unilateral leg press (left lower limb), bilateral squat, unilateral squat (right lower limb), power [W/kg] and the speed [m/s] of the jump. It was also possible to observe a certain increasing trend in the results in the unilateral squat (left lower limb) and countermovement jump height (*CMJ*), while not statistically significant.

Conclusions: The method of using moderate and heavy loads can be used in the maximum strength phase I during the preparatory period after the fall round league games as an effective solution to improve the results in terms of power and jumping ability generated by soccer players.

The main findings of the present study were as follows: training with an external load of 50-60% 1RM during the preparatory period after the fall round league games is more effective in improving muscle power and jumping ability (power [W/kg] and the speed [m/s] of the jump) soccer players than training with an external load of 70-80% 1RM.

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Keywords: The training load; Strength training; Bilateral leg press; Unilateral leg press; Bilateral squat; Unilateral squat; CMJ; Professional Soccer Players

1. Introduction

Motor preparation is an essential aspect that has a fundamental impact on the use of technical-tactical skills and the effective performance of a soccer player during a match [1]. In modern soccer, each player must be at a certain motor level in order to conduct a balanced sports battle, as well as to play a comprehensive role on the field.

In football, the basic task is shaping the appropriate level of muscle power obtained by the player. Muscle power of the lower limbs is needed in virtually every element of the game of football (e.g. acceleration, braking, driving the ball, passing and receiving the ball rolling, in the air or from the air (with the sole/inner part of the foot/outer part of the foot/simple instep /external instep/thigh, shots, receiving the ball with the foot (e.g. sliding), feints and dribbling).

During a soccer match, the ability to move dynamically in space - with a clearly marked flight phase - also plays an extremely important role. In soccer, jumping abilities appear in many elements of the movement actions of soccer players, including in head duels, head strikes in jumps on goal, and in goalkeeper parades. Resolving a head duel in one's favor allows to gain an advantage over the opponent and control the game. Creating an advantage over the opponent in the first contact with the ball boosts the team, strengthens mentally and forces the opposing team to receive the ball.

It is important to consider that jumpiness (proportional to the work done) and power (equal to the ratio of work to time done) are different quantities. Time is the key parameter that differentiates them. In the case of jumpiness, the longer (in terms of the capacity of the human locomotor system), the greater the height of the jump. In the case of power, the shorter, the greater the power value. Jumpiness that is not exercised and not systematically developed with a focus on achieving maximum results in jumping increases almost parallel and proportionally with the development of strength and speed.

The effective planning and organization of training are crucial to the effective delivery of the training stimulus for both individual players and the team [2]. Training load (TL) is a widely used concept in training prescription and monitoring and is also recognized as an important tool for reduce the risk of athlete injury, illness, as well as to avoid undertraining or overtraining. Training load monitoring is fundamental for training planning and periodization to have the optimal physical condition to compete [3,4]. Exercise intensity is one of the most important variables in resistance training (RT) for increasing muscular strength [5].

Considering the constantly increasing level of sports competition and a significant increase in the starting load, new methods and tools are being sought to optimize the process of sports training. Sports success in modern soccer depends on many factors. In addition to technical-tactical and psychological preparation, the motor potential of the player (the ability to quickly obtain and maintain high muscle power) and the team can undoubtedly determine the final outcome of the match. In view of this, applying training loads that guarantee the development of motor abilities is one of the most important tasks facing coaches.

Therefore, this research concerns the aspect of motor preparation of professional soccer players. The subject of the study was the analysis of the impact of various external loads used during the preparatory period on the power of lower limbs and jumping ability of soccer players of the first Polish league.

2. Material and methods

In the sampling process, the general population was defined first. In the analyzed research, it consisted of soccer players of the first Polish league. Taking into account the issues concerning, in particular, obtaining the consents of the authorities of all the clubs involved in the given games to participate in the research, it was concluded that conducting a representative random survey was not feasible. The sampling was therefore non-random selection - it was purposive. The study included players, representing a similar sporting level with a minimum of 4 years of training experience in a given league. The age of the study participants ranged from 22 to 28 years. The study group consisted of 60 participants, included in two clubs, but due to injury 4 players had to drop out of the study. Ultimately, the group was set at 56 soccer players of the central level (I League).

The study was conducted in the macro-cycle of the preparatory phase in the period after the fall round league games in the maximal strength phase I (nomenclature according to Bompa and Haff, 2010; Bompa, Buzzichelli, 2022) [6,7]. The researches were conducted in the Workshop of Strength and Muscle Power at the AWF Katowice and at the Multi-purposed Hall of AWF Katowice. The subjects were divided into two equal groups: GB1 (*n*=28) and GB2 (*n*=28). The division into groups was realized by simple randomization without return. Both groups performed strength training 2 times in a seven-day microcycle (Table 1). The preparatory macro-cycle with the 3:1 load distribution used lasted four weeks.

The players had valid medical examinations and full ability to play in games organized by the Polish Football Association. The test was approved by the Bioethics Committee of the AWF in Katowice (No. 3/2013 of June 26, 2013) and was performed under the grants (N RSA2 025 52, N RSA3 039 53).

The training plan for both groups was periodized in the same way in terms of: number of series (4), number of repetitions (5), interval time between series (3 min), interval time between exercise (2 min). On the other hand, it differed in terms of the %1 RM range (maximal load for a single repetition). The first study group performed training with an external load of 50-60% 1RM, while the second study group performed training with a load of 70-80% 1RM.

Tabel 1 The microcycle construction

Week microcycle structure							
Time	**Monday**	**Tuesday**	**Wednesday**	**Thursday**	**Friday**	**Saturday**	**Sunday**
9:00	Strenght training	Aerobic training 70% Maximal Aerobic Speed (MAS)	Strenght training	Training Session Soccer plyometrics, rondos	Passing activation drills + Set pieces training	Friendly game	REST
17:00	Training Session Possession games and position play	Training Session Repeat sprint drill and medium-sided games	Training Session Small-sided games	Training Session Formation Based Soccer Training; control and passing tasks, tactical drills	REST	REST	REST

The strength training consisted of performing 5 exercises in the following order: *Back Squat (High Bar), Bench Press, Barbell Lunge*, *Pull ups* with pronated grip (2 series) and with supinated grip (2 series), forward support on forearms using TRX tape (in suspension) *Plank* (1 min). Exercises such as pull ups on the bar with pronated and supinated grip Pull ups and forward support on the forearms using TRX tape (in suspension) *Planks* were performed without external load.

One week prior to the main measurement session, body height was measured (using a Charder HM-200P PORTSTAD portable stadiometer) and the athlete's weight and body composition were analyzed using an *InBody 370* analyzer. Measurements were taken under standard conditions, during fasted morning hours (8:00-09:00 - SG1, 9:00-10:00 - SG2), with a 72-hour training absenteeism and not consuming alcohol or fluids containing caffeine and carbohydrates. The following variables were recorded: body weight (*BM*), body mass index (*BMI*), fat mass (*FM*), fat-free mass (*FFM*), muscle mass (*MM*), body water content (*TBW*)

2.1. Measurement of muscular power of the lower limbs

Prior to the main measurement sessions, a measurement of maximal strength was carried out to determine the RM1 value for each exercise: leg press (bilateral and unilateral) using the *Keiser Leg Press A420* device, bilateral and unilateral squat using the *Keiser Air Squat* device with the *A300* diagnostic module. Before the maximal strength test, there was a 20-minute general warm-up: riding on an *M3 Total Body Trainer* ergometer (10 min), jogging in place with knee lifts, forward and backward leg swings, jump squats, unilateral kneel, unilateral kneel with lateral deepening, supported kneel, frog position.

To determine the maximal level of muscular strength, the athletes performed a test of 10 single repetitions in the form of bilateral and unilateral leg press, and 5 repetitions each in the form of bilateral and unilateral squat.

Using the Keiser Leg Press A420 device the testing 10 repetition maximal power protocol (the first two repetitions – warm up) involved completing an incremental leg press test from a seated position (90° of knee flexion) with feet flat on each footplate beginning at low resistance and continuing until failure, pushed defined as the final load that could be moved to full knee extension with both legs whilst maintaining proper seating position [8]. The athletes were asked to complete each repetition through extending both legs together with maximum velocity and instruction to "push as fast and as evenly as possible" [9]. The 10RM test starts with a countdown on the user's display when the value reaches "0". The external load increases by 23 kg in each subsequent repetition. The device automatically increases the resistance on average by 10% of the RM value and starts counting down the time until the next repetition. The rest time between the first repetitions is relatively short and increases as the resistance increases.

Using the Keiser Air Squat A300 device the participants initiated the squat power test from a standing position, lowering to reach the starting position of 90° of knee flexion, with the load distributed across their shoulders. After maintaining the squat position for 2 seconds, the participants initiated the upper phase as quickly as possible back to the standing position without removing the heels from the floor. All participants started with 80% of Body Mass; afterwards, the load was increased to 100% and 120% of Body Mass. The rest between the sets with different training loads lasted for 5 minutes (3 trials with 80% of BM followed by a 5-minute rest to carry out the attempts with 100% and 120%, respectively) [10].

After 48 hours, maximal strength was measured to determine the value of 1 RM for two exercises: the *Bench Press* and the *Barbell Lunge* using *ELEIKO* devices. Before the test of maximal strength, there was a general warm-up: riding on the *M3 Total Body Trainer* ergometer (10 min) and dynamic stretching (3-5 minutes). In order to familiarize themselves with the technique of barbell bench press, the subjects were also asked to perform 1 series of 15 repetitions using a 6 kg barbell. This trial series was a continuation of the general warm-up and prepared the subjects for the measurement of maximal strength (special warm-up). To minimize fluctuations in power output results, subjects were instructed to raise and lower the barbell at a constant rhythm. The repetition duration, expressed by four numbers 2/0/2/0, corresponded to a 2-second eccentric phase, no stop in the isometric phase, a 2-second concentric phase and no stop in the transitional phase. The lying barbell press was performed with a wide grip of the barbell (81cm). After a 5-minute rest break, barbell presses were performed with increasing weight according to the protocol of Saeterbakken et al. (2011): 20 repetitions with about 30% 1RM (1/3 body weight), 12 repetitions with about 50% 1RM (1/2 body weight), 6 repetitions with about 70% 1RM (1/1.4 body weight), 1 repetition with about 85% 1RM (1/1.2 body weight). The rest break between series was 5 minutes [11].

Then, after the 5-minute rest break, the subjects performed trials with acceptable loads. If the athletes performed more than 1 repetition with the expected load, the load was increased by 2.5-5 kg until the test subject could not perform the repetition at the correct pace and with correct movement technique. The last weight that was lifted successfully (the largest size) was determined as the maximal load for a single repetition (1RM).

The measurement of maximal force to determine the 1 RM value for the *Barbell Lunge* exercise began after 10 minutes of performing 10 repetitions using light weights around 30% of the 1RM. After a 3-minute rest break, the subjects performed 5 repetitions with 50% 1RM. After a 5-minute rest break, 2 repetitions with about 70% 1RM, and then the load was increased by 10% 1RM after each successful attempt. If the weight was not lifted successfully the load was reduced by 5% 1RM, until the maximal load was determined.

The second stage was conducted after the adaptation week. It consisted of measuring speed, as well as maximal power (1 RM) for two strength exercises: the leg press (bilateral and unilateral) using the *Keiser Leg Press A420* device, and the squat bilateral and unilateral using the *Keiser Air Squat* device with the *A300* diagnostic module. Measurements were taken for SG1 between 8:00 a.m. and 12:00 p.m., and for SG2 between 1:00 p.m. and 5:00 p.m. Before the actual measurements were taken, a 20-minute general warm-up was performed.

2.2. Measurement of jumping ability capabilities

The jumping ability was measured using countermovement jump (*CMJ*). During the test, the height (cm), power (W) and speed (m/s) of the jump were examined. A dynamometer platform was used. Before jumping, the players were thoroughly briefed on the actions they were to perform and motivated to perform the exercise correctly. Attention was also paid to simultaneous explosion from two legs and cushioning during landing. Each subject performed a vertical jump from a standing position with shoulder sweep (countermovement jump - *CMJ*) twice, with a two-minute rest break after the jump, preceded by a quick leg flexion. From an upright position, the exerciser performed a vertical jump on the command "ready".

2.3. Statistics

In the study, variables of a quantitative nature (quotient scale) were evaluated [12]. The analysis of such data has its own peculiarities, involving the use of adequate statistical tools for comparisons. In order to characterize the structure of the studied variables, basic descriptive statistics were calculated in the form of measures of position and variability [13], and the normality of the distributions of the analyzed variables was verified using the Lilliefors test. Homogeneity of variances was verified using Levene's test. Analysis of variance with repeated measures was used to verify the significance of differences [14]. In the course of the analyses, the assumption of sphericity was verified, using the Mauchley test when the assumption was not met the Greenhous-Geisser correction was applied. When significant differences were found in the analysis of variance, Tuckey's post-hoc multiple comparison tests for equal numbers were used to verify between which groups there were significant differences. The strength of the effect for the interaction was calculated using the coefficient η2. The strength of the effect was classified as weak when η2 belonged to the interval 0.01-0.059; average 0.06-0.137 and large >0.137 [15]. All analyses were performed using the Statistica 13.1 package. A significance level of 0.05 was assumed for all analyses [16].

3. Results

Table 2 Characteristics of anthropometric parameters of the study group

Parameter							
Number of participants				56			
Age [years]		AV ± SD		25.0 ± 2.5			
Body mass [kg]		AV ± SD		75.5 ± 5.45		76.9 ± 2.37	
Height [cm]		AV ± SD		180.6 ± 6.76			
BMI		Median		23.2			
Body composition		Before		After			
FM [kg]	11.4 ± 2.3	FM [%]	15.1	FM [kg]	10.8 ± 1.8	FM [%]	14.3
FFM [kg]	64.1 ± 3.15	FFM [%]	84.9	FFM [kg]	64.7 ± 4.14	FFM [%]	86.3
TBW [l]	48.4 ± 2.75	TBW [%]	64.2	TBW [l]	48. 5± 3.63	TBW [%]	64.2
MM [kg]	38.5 ± 9.4	MM [%]	51.1	MM [kg]	39.8 ± 7.7	MM [%]	52.7

FM Fat Mass - [kg]; FM (%) – Fat Mass [%]; FFM Fat Free Mass, kg; FFM (%) –Fat free mass; TBW Total Body Water, kg; TBW (%) – Total Body Water [%]; MM Muscle Mass, kg; MM (%) – Muscle Mass.

Table 2 shows the characteristics of the study group (the average age of the players was: 25.0 ± 2.5 years; mean body height was: 180.6 ± 6.76 cm). Analysis of the results of measurements of anthropometric parameters showed an increase in average body weight (75.5 ± 5.45 kg vs. 76.9 ± 2.37 kg), average muscle mass (38.5 ± 9.4 kg vs. 39.8 ± 7.7 kg), a decrease in average body fat percentage (15.1 vs. 14.3), while not statistically significant.

Table 3 shows the descriptive parameters and normality of the distribution of the studied variables, during the diagnostic measurement in the SG1 and SG2 groups before and after the training intervention, concerning the bilateral and unilateral leg presses.

Analysis of the results in Table 3 gave reasons to conclude for all variables that there were no grounds to reject the null hypothesis of normality of the distribution of the analyzed variables p NR>0.05. So, analysis of variance with repeated measurements can be used for further analysis. The results of the analysis of variance for the variable Bilateral leg press [60% 1RM] [W/kg] gave rise to the finding of significant differences F=12.24; p=0.0011 and high strength of effect η2=0.23. Tests of multiple comparisons showed that significant differences occurred between the results before and after in the SG1 group p=0.0002 (statistically significant increase in power after training) and between the results in the SG1 and SG2 groups p=0.0002 after training.

Based on the analysis of variance for the variable [50% 1RM] [W/kg] Unilateral leg press RLL, significant differences were found F=34.61; p<0.0001 and large effect strength η2=0.45. Tests of multiple comparisons showed that significant differences occurred between the before and after results in the SG1 group p=0.0002 (statistically significant increase in power after the training) and between the results in the SG1 and SG2 groups p=0.0001 after the training. The SG1 group had a statistically significant higher power output after training than the SG2 group.

Table 3 Descriptive parameters and normality of the distribution of the studied variables, during the diagnostic measurement in groups SG1 and SG2 before and after the training intervention – leg press

Variable	**SG1**				**SG2**			
	M	**SD**	**V**	**p NR**	**M**	**SD**	**V**	**p NR**
Bilateral leg press [60% 1RM] [W/kg] - before	27.39	3.86	14.09%	0.33	26.95	3.859	14.32%	0.47
Unilateral leg press RLL [50% 1RM] [W/kg] - before	15.98	1.93	12.07%	0.38	15.54	1.929	12.41%	0.33
Unilateral leg press LLL [50% 1RM] [W/kg] - before	15.27	1.94	12.73%	0.44	14.83	1.943	13.11%	0.28
Bilateral leg press [60% 1RM] [W/kg] - after	34.20	5.24	15.33%	0.088	27.56	4.895	17.76%	0.094
Unilateral leg press RLL [50% 1RM] [W/kg] - after	22.33	2.72	12.16%	0.26	16.48	2.534	15.38%	0.29
Unilateral leg press LLL [50% 1RM] [W/kg] - after	21.90	2.60	11.85%	0.15	16.08	2.423	15.07%	0.14

M- arithmetic mean, SD - standard deviation, V - coefficient of variation, p NR - test probability for Lilliefors normality of distribution test, RLL - right lower limb; LLL - left lower limb.

The results of the analysis of variance for the variable Unilateral leg press LLL [50% 1RM] [W/kg] found significant differences F=41.41; p<0.0001 and a large strength of effect η2=0.49. Based on the results of the multiple comparisons tests, it can be observed that significant differences occurred between the results before and after in the SG1 group p=0.0002 (statistically significant increase in power after the conducted training) and between the results in the SG1 and SG2 groups p=0.0002 after the conducted training. The GB1 group showed a statistically significant higher power after the training than the SG2 group.

Similar analyses were performed for the squat.

Table 4 Descriptive parameters and normality of distribution of studied variables, during diagnostic measurement in groups SG1 and SG2 before and after training intervention - squat

Variable	**SG1**				**SG2**			
	M	SD	V	p NR	M	SD	V	p NR
Bilateral squat [60% 1RM] [W/kg] - before	15.58	2.31	14.81%	0.36	15.37	2.308	15.02%	0.21
Unilateral squat RLL [50% 1RM] [W/kg] - before	8.74	1.17	13.41%	0.11	8.54	1.172	13.72%	0.23
Unilateral squat LLL [50% 1RM] [W/kg] - before	8.01	1.98	24.77%	0.082	7.81	1.983	25.41%	0.098
Bilateral squat [60% 1RM] [W/kg] - after	22.84	2.67	11.67%	0.29	16.96	2.488	14.67%	0.25
Unilateral squat RLL [50% 1RM] [W/kg] - after	9.23	0.74	7.98%	0.15	8.18	0.688	8.41%	0.099
Unilateral squat LLL [50% 1RM] [W/kg] - after	9.09	0.71	7.84%	0.18	8.04	0.665	8.27%	0.088

M- arithmetic mean, SD - standard deviation, V - coefficient of variation, p NR - test probability for Lilliefors normality of distribution test. RLL - right lower limb; LLL - left lower limb.

Based on the results in Table 4, it can be concluded that for all variables there is no basis for rejecting the null hypothesis of normality of the distribution of the analyzed variables p NR>0.05. And therefore, analysis of variance with repeated measurements can be used for further analysis. The results of the analysis of variance for the variable Bilateral squat [60% 1RM] [W/kg] revealed significant differences F=87.05; p<0.0001 and a large strength of effect η2=0.67. Tests of multiple comparisons showed that significant differences occurred between the results before and after in the SG1 group p=0.0002 (statistically significant increase in power after the training) and between the results in the SG1 and

SG2 groups p=0.0002 after the training. The SG1 group had a statistically significant higher power output after training than the SG2 group.

The results of the analysis of variance for the variable Unilateral squat RLL [50% 1RM] [W/kg] gave rise to significant differences F=4.34; p=0.04 and the average strength of the effect $\eta 2=0.094$. Based on the results of the multiple comparison tests, it can be observed that significant differences occurred only between the results in the SG1 and SG2 groups p=0.003 after the training. The SG1 group had a statistically significant higher power output after training than the SG2 group.

The results of the analysis of variance for the variable Unilateral squat LLL [50% 1RM] [W/kg] yielded no significant differences F=1.74; p=0.19 and a weak strength of effect $\eta 2=0.039$. An increase in performance after the training was too small for the differences to be statistically significant.

Similarly, analyses were carried out for the jumping ability of the tested athletes at the distances analyzed.

Table 5 Descriptive parameters and normality of distribution of studied variables, during diagnostic measurement in groups SG1 and SG2 before and after training intervention – countermovement jump

Variable	**SG1**				**SG2**			
	M	SD	V	p NR	M	SD	V	p NR
countermovement jump– height [cm] - before	47.47	4.81	10.13%	0.10	46.01	3.657	7.95%	0.094
countermovement jump – power [W/kg] - before	32.76	3.59	10.97%	0.13	28.80	2.877	9.99%	0.13
countermovement jump- speed [m/s] - before	2.99	0.081	2.72%	0.15	2.95	0.243	8.24%	0.10
countermovement jump– height [cm] - after	48.31	3.84	7.96%	0.098	46.68	4.893	10.48%	0.14
countermovement jump– power [W/kg] - after	36.65	3.43	9.37%	0.11	29.86	2.162	7.24%	0.15
countermovement jump- speed [m/s] - after	3.22	0.22	6.84%	0.12	3.03	0.17	5.58%	0.097

Based on the results in Table 5, it can be concluded that for all variables there is no basis for rejecting the null hypothesis of normality of the distribution of the analyzed variables p NR>0.05. Therefore, repeated measures analysis of variance can be used for further analyses. The results of the analysis of variance for the variable Countermovement jump - height [cm] yielded no significant differences F = 0.11; p=0.74 and a weak strength of effect $\eta 2=0.003$.

The results of the analysis of variance for the variable Countermovement jump - power [W/kg] gave rise to significant differences F = 44.20; p<0.0001 and a large strength of effect $\eta 2=0.51$. From the results of multiple comparison tests, it was noted that significant differences occurred between the results before and after in the SG1 group p = 0.0002 (statistically significant increase in relative power after the training) and between the results in the SG1 and SG2 groups p = 0.0002 after the training. After training, statistically significantly higher relative power was found in the SG1 group than in the SG2 group.

The results of the analysis of variance for the variable Countermovement jump - speed [m/s] gave rise to significant differences F = 4.45; p=0.041 and medium strength of effect size $\eta 2=0.096$. Based on the results of multiple comparison tests, it can be observed that significant differences occurred between the results before and after in the SG1 group p = 0.0003 (statistically significant increase in speed after training) and between the results in groups SG1 and SG2 p = 0.007 after training. After training, a statistically significantly higher speed was found in the SG1 group than in the SG2 group.

4. Discussion

Training with a load that optimizes the development of muscular power is fundamental for professional athletes. Additionally, training of broadly understood muscular strength is one of the key elements in the formation of individual motor variables in soccer, as high levels of muscular strength and power help improve football skills.

Knowledge of optimal training loads generated by the maximal power output is a critical factor in the design of resistance training programs [17]. Previous research exploring optimal load for professional athletes is conflicting. According to the American College of Sports Medicine (2009) the use of external loads in strength training in the range from 50 to 85% of 1RM increases muscle hypertrophy and endurance, increases muscle strength and power and helps maintain their achieved level [18]. The consensus on lower body movements remains unclear with optimal loads ranging from 30-80% 1RM [19,20,21]. In the literature, the highest values of muscle power build-up rates for lower body exercises such as leg press and various forms of squats are extensive, ranging predominantly from 50-80% 1RM [22,23,24,25,26]. The breadth of the results depends in particular on the type of exercise, experience of the athletes, gender and training experience [27,28].

In the present research, analyzing the levels of muscular power and jumping ability during training with an external load of 50-60% 1RM versus training with an external load of 70-80% 1RM, significantly better results were noted during training with an external load of 50-60% 1RM. In the course of the study, it was determined that soccer players generate significantly greater lower limb power and achieve significant improvements in jumping ability results with a load of 50-60% 1RM.

The obtained values of the analyses prove that when performing training with an external load of 50-60% of 1RM, it was possible to observe a significant improvement in the results after a 4-week training intervention for 6 variables: bilateral leg press, unilateral leg press (right lower limb), unilateral leg press (left lower limb), bilateral squat, power [W/kg] and the speed [m/s] of the jump. It was also possible to observe a certain increasing trend in the results in the unilateral squat (right lower limb, left lower limb) and in countermovement jump height (*CMJ*), although not statistically significant.

The results of the study indicate that when performing training with an external load of 70-80% of 1RM, one could observe a certain increasing trend in the results after the 4-week training intervention for all variables (except the variable Unilateral squat RLL), but not statistically significant.

The results of the study conducted in this research showed that the SG1 group with external load training at 50-60% 1RM achieved significantly better results than the SG2 group with external load training at 70-80% 1RM for 7 variables: bilateral leg press, unilateral leg press (right lower limb), unilateral leg press (left lower limb), bilateral squat, unilateral squat (right lower limb), power [W/kg] and the speed [m/s] of the jump. It was also possible to observe a certain increasing trend in the results in the unilateral squat (left lower limb) and in countermovement jump height (*CMJ*) while not statistically significant.

Soriano et al. (2015) conducted the meta-analysis about the optimal load for maximal power production during lower-body resistance exercises. A thorough analysis of the results showed that moderate loads (from >30 to <70 % of 1RM) appear to provide the optimal load for power production in the squat exercise [29]. Gantois et al. (2023) analyzed velocity- and power-load relationships of the free-weight back-squat and hexagonal bar deadlift exercises. Research has shown that the load which maximizes power output (Pmax) was 64.6±2.9% and 59.6±1.1% 1RM for the BSQ and HBD exercises, respectively [19]. The results of research conducted by Strand and et al. (2019) show that multi-joint exercises produced optimal load values at 50-60% 1 RM for leg press [30]. Stone et al. (2003) conducted research on power and maximum strength relationships during performance of dynamic and static weighted jumps. From a practical aspect, to improve jumping power output, results suggest that improving maximum strength should be a primary component of training programs and that strength training should shift from lighter (10% 1RM) to heavier (40% 1RM) loads [31]. The results of these studies, however, show significant improvements in power [W/kg] and the speed [m/s] of the jump with a load of 50-60% 1RM and in countermovement jump height (*CMJ*) while not statistically significant. It seems that in order to improve the jump height parameter, the training program must be based on lighter loads.

5. Conclusion

The method of using moderate and heavy loads can be used in the maximum strength phase I during the preparatory period after the fall round league games as an effective solution to improve the results in terms of power and jumping ability generated by soccer players. However, analyzing the levels of muscular power and jumping ability during training with an external load of 50-60% 1RM versus training with an external load of 70-80% 1RM, significantly better results were noted during training with an external load of 50-60% 1RM.

In the course of the study, it was determined that soccer players generate significantly greater lower limb power and achieve significant improvements in jumping ability results (power [W/kg] and the speed [m/s] of the jump) with a load of 50-60% 1RM.

The results of this study provide additional support that the use of moderate loads (50-60% 1RM) soccer players generate significantly greater lower limb power and achieve significant improvements in jumping ability results, than heavy loads (70-80% 1RM).

Compliance with ethical standards

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Disclosure of conflict of interest

The author declares there are no conflicts of interest in connection with this paper, and the material described is not under publication or consideration for publication elsewhere.

Statement of informed consent

Informed consent was obtained from all individual participants included in the study.

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Author's short biography

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