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Tomasz Chamera
Gdansk University of Physical Education and Sport, Gdansk, Poland, tomasz.chamera@awf.gda.pl

Magdalena Prończuk
Gdansk University of Physical Education and Sport, Gdansk, Poland, nadsprawna@gmail.com

Piotr Smok
The Jerzy Kukuczka Academy of Physical Education in Katowice, Poland, piotr.smok@zsp6.katowice.eu

Miłosz Drozd
The Jerzy Kukuczka Academy of Physical Education in Katowice, Poland, m.drozd@awf.katowice.pl

Małgorzata Michalczyk
The Jerzy Kukuczka Academy of Physical Education in Katowice, Poland, m.michalczyk@awf.katowice.pl

See next page for additional authors

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Abstract

Introduction: The aim of the study was to compare the effects of a 6-week intervention of combined soccer training with resistance training on strength and power variables in highly trained female soccer players. It was hypothesized that 6 weeks is sufficient for a significant improvement in jumping ability and power to occur due to the intervention. The study involved 34 female soccer players of the top women's league (22 ± 5 years old, body height 167 ± 5 cm, body weight 60 ± 8 kg). The players were divided into two groups of 17 participants. The control group performed 3 soccer and 1 strength training sessions (50–60% 1RM load) weekly. The experimental group performed 3 soccer and 2 resistance training sessions during a weekly micro-cycle (50–85% 1RM load). The results of the experiment indicate a significant improvement in vertical jump height and sitting leg press performance in the experimental group: CMJ ($p < 0.05$; $p = 0.000029$; ES:1.00;11%), CMJA ($p < 0.05$; $p = 0.003$; ES = 1.09;13%) and LP ($p < 0.05$; $p = 0.027681$; ES = 0.48;6%), while in the control group changes in results after completing the training program were statistically insignificant for CMJ ($p > 0.05$, $p = 0.274000$, ES:0.07,1%), CMJA ($p > 0.05$, $p = 0.350958$, ES = 0.27;3%) and LP ($p > 0, 05$; $p = 0.130153$; ES = 0.27;4%). The presented results suggest that a short, six-week resistance training program, specific soccer training and strength training carried out twice a week during the preparatory period may significantly improve the strength and jumping variables of the lower limbs in female soccer players.

Keywords

soccer players, specific soccer training, strength training, six-week resistance training program

Authors

Tomasz Chamera, Magdalena Prończuk, Piotr Smok, Miłosz Drozd, Małgorzata Michalczyk, and Adam Maszczyk

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Article

The effects of resistance training on jumping and selected power variables of the lower limbs in female soccer players

Tomasz CHAMERA[1], Magdalena PROŃCZUK[2]*, Piotr SMOK[3], Miłosz DROZD[4], Małgorzata MICHALCZYK[5], Adam MASZCZYK[6]*

1 Faculty of Physical Culture, Gdansk University of Physical Education and Sport, Gdansk, Poland; ORCID 0000-0002-5381-76344
2 Faculty of Physical Culture, Gdansk University of Physical Education and Sport, Gdansk, Poland; ORCID 0009-0005-1478-3151
3 Institute of Sport Sciences, The Jerzy Kukuczka Academy of Physical Education, Katowice, Poland;
4 Institute of Sport Sciences, The Jerzy Kukuczka Academy of Physical Education, Katowice, Poland; ORCID 0000-0002-4477-2390
5 Institute of Sport Sciences, The Jerzy Kukuczka Academy of Physical Education, Katowice, Poland; ORCID 0000-0003-1590-3002
6 Institute of Sport Sciences, The Jerzy Kukuczka Academy of Physical Education, Katowice, Poland; ORCID 0000-0001-9139-9747

* Correspondence: 1. Magdalena Prończuk, nadsprawna@gmail.com; 2. Prof. Adam Maszczyk, The Jerzy Kukuczka Academy of Physical Education, Mikołowska 72A, 40-065 Katowice, Poland; e-mail: a.maszczyk@awf.katowice.pl; phone no.: 604641015

Abstract: Introduction: The aim of the study was to compare the effects of a 6-week intervention of combined soccer training with resistance training on strength and power variables in highly trained female soccer players. It was hypothesized that 6 weeks is sufficient for a significant improvement in jumping ability and power to occur due to the intervention. The study involved 34 female soccer players of the top women's league (22 ± 5 years old, body height 167 ± 5 cm, body weight 60 ± 8 kg). The players were divided into two groups of 17 participants. The control group performed 3 soccer and 1 strength training sessions (50–60% 1RM load) weekly. The experimental group performed 3 soccer and 2 resistance training sessions during a weekly micro-cycle (50–85% 1RM load). The results of the experiment indicate a significant improvement in vertical jump height and sitting leg press performance in the experimental group: CMJ ($p < 0.05$; $p = 0.000029$; ES:1.00;11%), CMJA ($p < 0.05$; $p = 0.003$; ES = 1.09;13%) and LP ($p < 0.05$; $p = 0.027681$; ES = 0.48;6%), while in the control group changes in results after completing the training program were statistically insignificant for CMJ ($p > 0.05$, $p = 0.274000$, ES:0.07,1%), CMJA ($p > 0.05$, $p = 0.350958$, ES = 0.27;3%) and LP ($p > 0, 05$; $p = 0.130153$; ES = 0.27;4%). The presented results suggest that a short, six-week resistance training program, specific soccer training and strength training carried out twice a week during the preparatory period may significantly improve the strength and jumping variables of the lower limbs in female soccer players.

Keywords: soccer players, specific soccer training, strength training, six-week resistance training program.

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1. Introduction

Soccer abilities, mental and tactical preparation, and a high level of motor abilities (endurance, speed, strength, and coordination) are the most significant aspects of the game's outcome [1, 2]. Analyzing the specificity of movements in soccer players reveals a repeated work profile consisting of short-term intense efforts associated with dynamic

movements (e.g., jumping, sliding, changing the direction of running, and contact with the opponent) [3] as well as low-intensity efforts [3, 4].

To adequately prepare the players for league action, we must conduct the preseason with care and precision. During this time of the season, coaches have more opportunities to introduce new tactical components and enhance technique, teamwork, and motor preparation.

During the competitive period, the athletes' primary objective is to maintain motor abilities acquired during the training period. There is no time to enhance performance characteristics due to the season's nature. Therefore, a great deal of emphasis is placed on motor preparation during the preseason [1].

Women are more susceptible to lower limb injuries, overloads, and musculoskeletal injuries than men (e.g. anterior cruciate ligament (ACL) damage) [5–10]. Therefore, motor preparation of female soccer players is of particular significance. This is primarily attributable to anatomical, hormonal, biomechanical, and neuromuscular variables [7, 9]. Balanced motor development, composed of stability, endurance, mobility, and muscle strength, regulates the efficacy of movement and prevents injuries [5, 11].

When preparing athletes for competition, the primary objective is to build a high degree of muscular strength [12], because stronger athletes perform better in competition [13]. Strength training improves maximum running speed, acceleration, stamina, jumping ability, changes of running direction, and kicking power [4, 14, 15]. These elements are of great importance throughout the game when the player executes cyclical motor actions such as sprinting with and, without the ball, spurts, accelerations, quick changes of direction and jumps, among others [3].

The purpose of this study was to examine strength and power variables of elite female soccer players before and after a 6-week intervention based on soccer training and strength training. We expected that a six-week training program would improve neuromuscular fitness (i.e. lower extremity explosive power). Strength training was based on bilateral exercises that strengthened neuromuscular variables, as well as activities that developed muscle strength through the use of movement patterns, muscular power, and body stability.

2. Materials and Methods

2.1. Participants

The research was conducted in the Strength and Power Laboratory at the Academy of Physical Education in Katowice. The study included 34 female soccer players from the top women's league (mean age 22.5 years old, 167.5 cm in mean body height, and 60.8 kg mean body mass). There were 17 athletes in each of the two groups: the experimental and control one. Eleven players from each group were picked at random for the study.

2.2. Procedure

Before the beginning of the preparatory period and before the competitive period, the jumping ability and power variables of the lower limbs were measured twice; at baseline and after a 6-week training regimen. The research comprised both a leg press and a vertical jump.

2.3. Leg press test [LP]

The test consisted of pressing a weight with the lower extremities while seated. The athletes performed four leg presses at 80% of 1RM with both legs. The best result was registered.

2.4. CMJ

The test was conducted on the AMTI force plate. The purpose of the study was to determine the height of the jump and the power of the lower limbs during the CMJA and CMJ by measuring ground reaction force.

2.5. 6-week training intervention

The surveyed team participated in a 6-week training program for the primary women's soccer league. Each week consisted of three practice sessions, one friendly match, and two strength training sessions. All position-specific players, including goalkeepers, underwent an identical resistance training regimen. During the initial training, the CMJ test was used to evaluate each competitor's maximum strength in separate exercises. Three times per week, training comprised both small and regular high-intensity games played on an artificial field. Twice per week, one of the strength training sessions consisted of resistance training. The second training session comprised preventative and remedial elements. A control match comprised the final training unit of the week.

2.6. Resistance training

A conditioning coach devised a 6-week training program targeted at recovering ap-propriate muscle balance, enhancing central stability, and preventing female-specific ailments. The training focused on a variety of energy systems. The objective of the first four weeks of the program was to establish maximum muscle strength (glycolytic system), while the fifth week was supposed to emphasize rapid glycolysis, and the sixth week was intended to strengthen the phosphagen system.

Twice per week, the experimental group's athletes engaged in a 60-minute, eight-station circuit training session. The first two weeks of training consisted of three bi-lateral exercises for the lower limbs, three stability exercises, and two upper-body exercises. Athletes performed 3 sets of 8–10 repetitions at each station at a tempo of 2–0–1–0 with a 1RM of 70% (week 1), 75% (week 2), 80% (week 3), and 85% (week 4). In weeks 5 and 6, the weight was altered to maintain an overload (50% 1RM, 8 reps in the 5 week and 6 reps in the 6 week, 4–0–1–0 tempo of movement) (Table 1). The rest between sets ranged be-tween 30 and 60 s. The training stations included 3 exercises for the lower limbs (squat with a barbell held at the back, front squat, deadlift, hip raise with a barbell, and rolling a fitness ball while lying on the back), 3 activities for stabilization (vibration platform), and 2 exercises for the upper limbs (pull ups, push-ups, dumbbell triceps extension behind the neck, spiderman push-ups). The control group followed the same training regimen for soccer. However, the difference was strength training, which was performed once per week with a load of 50–60% of 1RM and 6–8 repetitions for each exercise (Table 2).

2.7. Statistical analysis

The research findings were initially created in MS Excel, followed by STATISTICA's analysis. The T-Student test for the dependent samples was used to determine the significance of changes in the female athletes' power strength before and after the training protocol was applied. $P = 0.05$ was chosen as the cutoff point for the t-statistical test's signifi-cance. Effect size (ES) measurements were made in accordance with Cohen's formula and classified as low (>0.2 and 0.5), moderate (0.5 and 0.8), or large (0.8) [16].

3. Results

3.1. Leg Press

The results of the strength test performed on the Kaiser leg press (LP) machine in the experimental group showed statistically significant improvements from baseline (1372.615 ±187.201 W) to post intervention (1453.923 ±148.398 W). Peak power values in the control group, however, did not significantly improve (Table 3 and Table 4).

3.2. CMJ

In the experimental group, the CMJ results without arm swing increased significantly (p = 0.002; ES:1.02), after the 6-week intervention, while in the control group, the differences between baseline and after the 6-week intervention were statistically insignificant (Table 3 and Table 4).

3.3. CMJA

Lower limbs' explosive power during the CMJA with arm swing prior to the preparatory period was lower than after the training intervention in the experimental group (average 34.55 ±4.20 cm, vs. average 39.2 ±4.29 cm). This indicates that the athletes' swing jumps improved on average by 13%, with the differences being statistically significant (p = 0.003; ES:1.09). Changes in the CMJA were not statistically significant in the control group (Table 3 and Table 4).

Table 1. Summary of strength training program for the experimental group

Monday							
Exercises	week 1 (50%1RM)	week 2 (50%1RM)	week 3 (50%1RM)	week 4 (50%1RM)	week 5 (50%1RM)	week 6 (50%1RM)	Series
	Number of repetitions/Duration						
Back squat with a barbell	6	6	6	6	-	-	3
Barbell reverse lunge	-	-	-	-	8(2)	6(2)	3
Front squat on a platform	Tremor	Tremor +15s	Tremor +15s + Asymmetry	Tremor +30s	Tremor	Tremor	3
Barbell hip thrust	-	10	8	6	-	-	3
Supine medicine ball rollout	12	-	-	-	-	-	3
Supine medicine ball rollout with single leg	-	-	-	-	20s(2)	20s(2)	3
Lateral platform step-up	Tremor	Tremor +15s	Tremor +15s + Asymmetry	Tremor +30s	Tremor	Tremor	3
Dumbbell overhead triceps extension	12	12	12	12	10	8	3
Deadlift from an elevated platform	8	8	8	8	10	8	3
Spiderman push-ups	6	8	10	12	8	6	3
Lateral platform step-up	Tremor	Tremor +15s	Tremor +15s + Asymmetry	Tremor +30s	Tremor	Tremor	3
Wednesday							
Exercises	week 1 (50%1RM)	week 2 (50%1RM)	week 3 (50%1RM)	week 4 (50%1RM)	week 5 (50%1RM)	week 6 (50%1RM)	Series
	Number of repetitions/ Duration						
Front squat	6	6	6	6	-	-	3
Barbell reverse lunge	-	-	-	-	8(2)	6(2)	3
Lateral platform step-up with rotation	Tremor	Tremor +15s	Tremor +15s + Asymmetry	Tremor +30s	Tremor	Tremor	3
Decline push-up	12	12	14	16	12	10	3
Lateral platform step-up with rotation	Tremor	Tremor +15s	Tremor +15s + Asymmetry	Tremor +30s	Tremor	Tremor	3

Exercises	Wednesday						Series
	week 1 (50%1RM)	week 2 (50%1RM)	week 3 (50%1RM)	week 4 (50%1RM)	week 5 (50%1RM)	week 6 (50%1RM)	
	Number of repetitions/ Duration						
Wide grip pull-up with resistance band	6	6	8	10	8	6	3
Push-ups	6	6	8	10	8	6	3
Single leg hip thrust	12(2)	12(2)	142)	16(2)	10(2)	8(2)	3
Front platform step-up with powerband pull	Tremor	Tremor	Tremor +15s + Asymmetry	Tremor +30s	Tremor	Tremor	3

Table 2. Summary of strength training program for the control group

Exercises	Wednesday						Series
	week 1 (50%1RM)	week 2 (50%1RM)	week 3 (50%1RM)	week 4 (50%1RM)	week 5 (50%1RM)	week 6 (50%1RM)	
	Number of repetitions/ Duration						
Front squat	6	6	6	6	-	-	3
Barbell reverse lunge	-	-	-	-	6(2)	6(2)	3
Lateral platform step-up with rotation	Tremor	Tremor +15s	Tremor +15s	Tremor +15s	Tremor	Tremor	3
Decline push-up	6	6	8	8	6	6	3
Lateral platform step-up with rotation	Tremor	Tremor	Tremor +15s	Tremor +15s	Tremor	Tremor	3
Wide grip pull-up with resistance band	6	6	8	8	6	6	3
Push-ups	6	6	8	8	6	6	3
Single leg hip thrust	6(2)	6(2)	8(2)	8(2)	6(2)	6(2)	3
Front platform step-up with powerband pull	Tremor	Tremor	Tremor +15s	Tremor +15s	Tremor	Tremor	3

Table 3. The results of the paired t-test for CMJ, CMJA, and LP in the experimental group

Variables	Mean pretest	SD pretest	Mean post test	SD post test	Difference [%]	t	$P < 0.05$	Cohen's D	ES
CMJ	31.246	3.728	34.715	3.204	11	-6.511	0.002	1.02	Big
CMJA	34.554	4.204	39.200	4.288	13	-6.489	0.003	1.09	Big
Leg Press	1372.615	187.201	1453.923	148.398	6	-2.505	0.028	0.48	Small

Table 4. The results of the paired t-test for CMJ, CMJA, and LP in the control group

Variables	Mean pretest	SD pretest	Mean post test	SD post test	Difference [%]	t	$P < 0.05$	Cohen's D	ES
CMJ	30.990	3.850	31.115	4.090	1	-1.157	0.274	0.27	Small
CMJA	34.160	3.538	35.213	4.288	3	-0.978	0.351	0.25	Small
Leg Press	1258.363	169.301	1308.353	198.448	4	-1.649	0.130	0.29	Small

4. Discussion

The study's objective was to assess muscle power-related variables in female soccer players during a 6-week resistance and soccer training program. In line with our original assumption, this program increased peak power and vertical jump performance of female professional soccer players.

In the current investigation, the maximum power variables evaluated on the leg press device in the experimental group improved substantially. The soccer players increased their preseason performance by 6%. CMJ jump height increased 11%, while CMJA by 13%.

Other researchers have also observed improvements in jumping ability and lower limb power after six weeks of additional resistance training. Young soccer players' jumping efficiency increased by 7.7% more following 6 weeks of strength training combined with plyometric activities and soccer training, according to Marques et al. [17]. This was compared to only soccer training alone. Professional soccer players' squat strength increased after a 6-week resistance training program, according to research by Styles et al. [4], which suggests that sprinting and jumping abilities may also improve following such interventions.

In our study, the experimental group participants engaged in compound multi-joint strength training, which improved their jumping ability and explosive power. Similar improvements in CMJ test scores were also recorded by Moisés de Hoyo et al. [18] who, following 10 weeks of strength training directed at maximal concentric and eccentric loads with a combination of exercises – leg curl exercise and half squat with a barbell – observed similar changes (ES: 0.58). The same author [14] confirmed a year later that squats (half-squat exercises) were more effective in enhancing jumping and sprinting abilities than running or plyometric training. According to Hammai et al. [12], teenage soccer players' jump performance (CMJ) increased after an 8-week supplemental strength training program that included the back half-squat (70–90%1RM/3–5sets/3–8rep.) The same author [19] claimed a year later that an 8-week strength training program enhances crucial performance factors (maximum power) in youth athletes compared to conventional soccer training. The improvement of sprint running, jumping, and peak power in 17-year-old soccer players was demonstrated by Chelly et al. [20] with the use of two sessions of squat exercises per week.

In earlier studies, only men (amateurs, top soccer players, and youth players) were studied [9, 14, 18, 19]. In the research of other authors, women who practiced various team sports benefited from the effects of strength training on their power metrics. Young female handball players' explosive muscular performance was shown to improve following a 10-week intensive strength training program by Hammami [21].

Men and women have different physical characteristics, which may be significant for adaptive changes. For instance, Lopes [10] reported that men performed better on measures of physical fitness than women did in terms of lower limb strength, endurance, and strength endurance. Eccentric training can benefit both sexes equally, according to Morawetz [23]. The possibility of a larger loss of strength in women just after eccentric exercise is one conceivable gender difference in practice.

Strength differences rather than biological sex differences may be the cause of variances between men and women, according to Askow [22], who noticed that no discernible differences between the sexes when strength was standardized. Walts [2] demonstrated that strength training has little effect on intermuscular or subcutaneous fat, independent of gender. The type of plyometric activity and gender did not interact significantly, according to Kossow [24]. These investigations allow drawing the conclusion that muscle power increases following resistance exercise independent of gender.

5. Conclusions

Studies have shown that increasing strength does not necessarily enhance maximal power. A further 8 weeks of balance and plyometric training in young basketball players,

according to Bouteraa [4], did not significantly alter jump performance (CMJ). The choice of exercises, the load (% 1RM), the number of repetitions, or the players' already high threshold for generating explosive power could all be contributing factors.

In summary, the research highlights the positive effects of incorporating resistance training, particularly compound multi-joint strength exercises like squats, into the training regimens of female soccer players. These improvements encompass various aspects of performance, including jumping ability, sprinting, and maximum power, which are essential for success in soccer. The findings also emphasize the relevance of such training for both professional and youth soccer players.

It can therefore be concluded that:

- Effectiveness of Resistance Training: The study aimed to assess the impact of a 6-week resistance and soccer training program on female professional soccer players. The results support the assumption that this program was effective in increasing peak power and vertical jump performance. This finding highlights the importance of incorporating resistance training into the training regimen of soccer players.
- Improvements in Leg Power: The study specifically noted substantial improvements in maximum power variables measured on the leg press device. This suggests that the resistance training component of the program had a significant impact on lower limb power, which is crucial for soccer players in activities such as sprinting and jumping.
- Jumping Ability Enhancement: The study showed an 11% increase in Countermovement Jump (CMJ) height and a 13% increase in CMJ with Arm Swing (CMJA) in the experimental group. These improvements in jumping ability indicate that the training program had a positive effect on explosive power, a valuable attribute for soccer players.
- Previous Research Support: The study's findings are consistent with prior research in the field. Other studies, such as those by Marques et al., Styles et al., Moisés de Hoyo et al., Hammai et al., and Chelly et al., have also demonstrated the positive impact of resistance training on various aspects of soccer player performance, including jumping ability, sprinting, and maximum power.
- Compound Multi-Joint Strength Training: The study utilized compound multi-joint strength training, which was found to be effective in improving jumping ability and explosive power. This approach is supported by the research of Moisés de Hoyo et al., who used similar training methods with positive results.
- Superiority of Squats: The study's findings, along with the work of other researchers like Moisés de Hoyo et al. and Hammai et al., suggest that exercises like squats (half-squat exercises) may be particularly effective in enhancing jumping and sprinting abilities in soccer players compared to other forms of training.
- Youth Athlete Improvement: Some studies mentioned in the discussion focused on teenage soccer players, indicating that resistance training can benefit both professional and younger athletes. This finding underscores the potential for improving performance and developing key skills in players of various age groups.
- Frequency and Duration: The duration of the resistance training programs in previous studies varied, with programs lasting from 6 to 10 weeks. The frequency and intensity of training sessions also differed, demonstrating that there may be flexibility in designing effective resistance training programs for soccer players.

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