



ABSOLUTE AND RELATIVE PEAK POWER DURING PNEUMATIC SQUAT EXERCISE USING DIFFERENT PERCENTAGES OF LOAD IN ELITE SOCCER PLAYERS

original paper

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ABSTRACT

Purpose. The study compared muscle peak power during pneumatic squat exercise with different percentages of load, corresponding to 80%, 100%, and 120% of body mass (BM), in male professional soccer players.

Methods. The study involved 40 male elite soccer players (25.2 ± 3.6 years; 179.6 ± 6.1 cm; 78.3 ± 5.2 kg; body fat $12.3 \pm 3.3\%$) from a club of the Brazilian first division soccer league participating in national competitions organized by the Brazilian Soccer Confederation. Peak power was assessed by using a pneumatic squat machine (squat power test). The athletes applied different training loads during the squat power test (3 trials with 80% of BM followed by a 5-minute rest to perform attempts with 100% and 120%, respectively).

Results. The two-way ANOVA yielded main effects for group ($F_{3,26} = 3.08$, $p < 0.04$) and for timing of measurement $F_{2,52} = 526.1$, $p < 0.0001$), indicating a significant difference in the absolute peak power of goalkeepers when compared with defenders and midfielders at the loads corresponding to 80%, 100%, and 120% of BM. Intra-group comparison demonstrated a significant increase ($p < 0.0001$) in the absolute and relative peak power with loads corresponding to 120% of BM when compared with 80% and 100% of BM in all groups (defenders, goalkeepers, midfielders, and forwards).

Conclusions. The results confirm that loads corresponding to 120% of BM during pneumatic squat exercise contribute to greater absolute and relative peak power.

Key words: soccer players, peak power, squat exercise, performance

Introduction

Soccer is a sport of great popularity in the world, with 275 million participants of both sexes in a wide range of ages [1, 2]. A soccer match is characterized by jumping, confronting, running, passing, kicking the ball, with athletes required to perform quick, precise movements, rapid changes of direction, actions demanding deceleration and acceleration. Force development and muscle power are thus necessary to maintain optimal performance [3, 4].

It is evidenced that performance during explosive actions depends on muscle power, which may be determined by a number of neuromuscular variables, such as a combination of morphological and neural factors including muscle cross-sectional area and architecture, musculotendinous stiffness, motor unit re-

cruitment, rate coding, motor unit synchronization, and neuromuscular inhibition [4–6]. Such combinations of factors are associated with enhanced external mechanical power, general sports skill performance, decreased injury rates, and training load monitoring [7].

An optimal training load during practice contributes to morphological, metabolic, and functional physiological adaptations that are advantageous when seeking successful competitive results [3, 8, 9]. This optimal training load is adjusted at various times during the training cycle to increase or maintain muscle power of athletes during the phase of training for playing soccer at a high level (i.e. baseline or competition phase). In addition, training load prescribing and monitoring are crucial for providing information on the efficacy of training doses and for supporting injury prevention strategies [6, 8, 9]. Thus, well-trained players gain an

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edge in their performances as a result of periodized training procedures. But, what is the optimal training load for muscle power development in soccer players? Evidence of the training load monitoring in the build-up to a competitive athlete illustrates the importance of resistance training to the gain of muscle power used within soccer [10–13]. Nevertheless, the lack of studies which would characterize the optimal training load for muscle power development in soccer players still seems conflicting in the scientific literature. Some authors observed that a training load of 40–60% of 1-repetition maximum (1RM) during back squat exercise seemed to be effective to improve maximal power output in elite soccer players [10, 11]. On the other hand, it was noted that strength training with a high intensity zone (90% of 1RM) was superior to a moderate intensity zone (70% of 1RM) program because it increased strength without a change in muscle cross-sectional area and improved repeated sprint ability [12]. However, a current study showed that 2 sessions per week of back squat training with loads of 70–90% of 1RM to the regular soccer training program of soccer players turned out sufficient to improve markers of soccer-related athletic performance such as sprint times, agility, jump, leg peak power, and the ability to make repeated changes of direction [13]. But the number of studies involving squat and pneumatic resistance in soccer players is limited.

Physical training with pneumatic resistance becomes effective by the relationship between force, acceleration, and mass in accordance with Newton's second law. Pneumatic equipment utilizes air pressure as a means of resistance, thereby reducing the mass component of the load to near zero. Thus, pneumatic resistance training may avoid the limitations of free weight by contributing to a load/resistance that is not subject to inertia [4, 6]. But little is known about the use of % of body mass (BM) as an optimal training load during squat with pneumatic resistance equipment.

In this context, some authors have highlighted that the prescriptions of loads based on % of BM can be efficient to increase muscle power in professional athletes [9]. Scientific literature shows that loads of 40–80% of BM during a jump squat exercise performed on a Smith machine may be efficient to increase muscle power in different sports [9]. Specifically, in elite soccer players, it was observed that no additional intensity zone and/or 40% of BM promoted improvements in speed during sprints of 5, 10, and 20 m and mean propulsive velocities during jump squat exercise [14]. However, few studies have examined the link between % of BM, peak muscle power, and pneumatic

squat exercise in elite soccer. Accordingly, the aim of this study was to compare the peak power muscle during pneumatic squat exercise with different percentages of load corresponding to % of BM among male professional soccer players. It was hypothesized that loads > 100% of BM during pneumatic squat exercise would contribute to greater peak muscle power.

Material and methods

Subjects

The study included 40 male elite soccer players (25.2 ± 3.6 years; 179.6 ± 6.1 cm; 78.3 ± 5.2 kg; body fat $12.3 \pm 3.3\%$) from a club of the Brazilian first division soccer league participating in national competitions organized by the Brazilian Soccer Confederation. The players' training frequency was 6.3 ± 1.2 days/week, with training programs that consisted of plyometric training, ball possession, skipping, velocity, and resistance training. Exclusion criteria were as follows: (1) smoking history during the previous 3 months; (2) presence of a cardiovascular or metabolic disease; (3) systemic hypertension ($\geq 140/90$ mm Hg or use of antihypertensive medication); (4) use of anabolic steroids, drugs, or medication with the potential to impact physical performance (self-reported); (5) recent musculoskeletal injury; (6) symptoms of pain in any region of the body. All data collection was carried out at the beginning of training sessions during preseason.

Body composition was measured with bioelectrical impedance analysis (InBody720, Biospace, Seoul, Korea). The body composition analyser has in-built hand and foot electrodes. The subjects were dressed in underwear and barefooted, in the upright position, with their feet on the electrodes of the platform and their arms abducted with hands gripping the electrodes on the handles. All analyses were performed after 8 hours of fasting. All biometric measurements were carried out in an air-conditioned room (21°C). No clinical problems occurred during the study.

Squat power test

Peak power was tested by using the Keiser Air 300 Squat Machine (Keiser, Fresno, USA), which is a pneumatic strength and power measurement machine. All athletes were tested in accordance with the specific position: defender \times midfielder \times forward \times goalkeeper. The participants were already familiarized with the testing equipment because pneumatic resistance was

part of the strength training program throughout the season. Prior to the squat power test, a 10-minute warm-up was performed that included 5 minutes of cycling at 50 W on a cycle ergometer, followed by 10 squats at 40% of the athletes' BM.

After the warm-up, the subjects were allowed 5 minutes of passive rest, followed by 3 maximal velocity trials during the squat power test, with a 1-minute rest between the trials. The athletes initiated the squat power test from a standing position, lowering to reach the starting position of 90° of knee flexion, which was measured with a digital goniometer (Global Medical Devices; Maharashtra, India), with the load distributed across their shoulders. After maintaining the squat position for 3 seconds, the participants initiated the upper phase as quickly as possible back to the standing position without removing the heels from the floor.

The athletes were instructed to apply different training loads during the squat power test. All subjects started with 80% of BM; afterwards, the load was increased to 100% and 120% of BM. The rest between the sets with different training loads lasted for 5 minutes (i.e. 3 trials with 80% of BM followed by a 5-minute rest to carry out the attempts with 100% and 120%, respectively). The greatest peak power obtained in the 3 trials was used for the individual's comparison assessment.

Statistical analysis

Statistical analysis was initially performed with the Shapiro-Wilk normality tests and the homoscedasticity test (Bartlett criterion). Means and standard deviations were used to represent the centrality and spread of data. Comparisons between groups (defender \times midfielder \times forward \times goalkeeper) and different training loads were performed by two-way ANOVA with Bonferroni post-hoc tests. In turn, intra-group comparison for each different training load was independently performed with one-way repeated-measures ANOVA followed by Tukey's post-hoc tests. The effect size was calculated to determine the significance of the difference by means of the f^2 for ANOVA. The level of significance for all statistical comparisons was set at $p < 0.05$ by using GraphPad® software (Prism 6.0, San Diego, USA).

Ethical approval

The research related to human use has complied with all the relevant national regulations and institutional policies, has followed the tenets of the Declaration of Helsinki and the ethical standards in sport

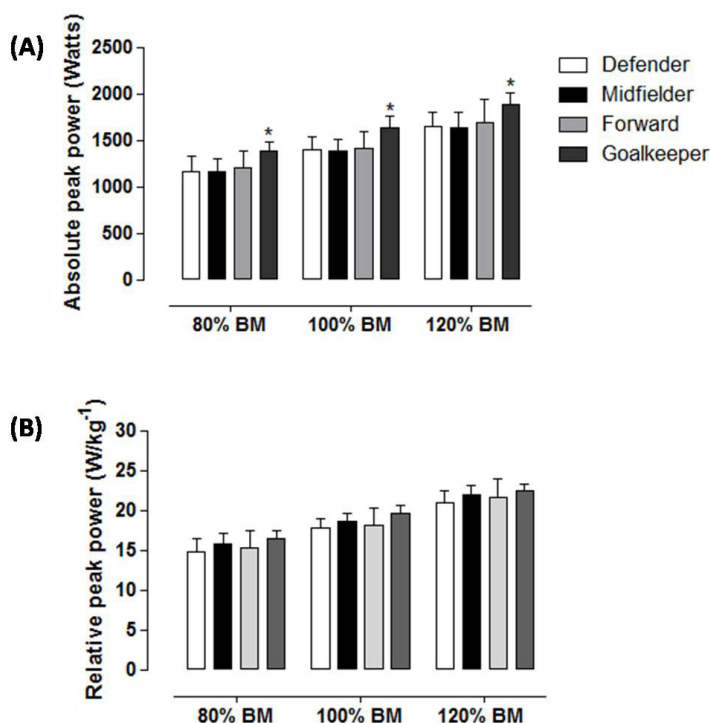
and exercise science research (CAE: 76189817.0.0000.5235), and has been approved by the local institutional Ethics Committee for Human Experiments.

Informed consent

Informed consent has been obtained from all individuals included in this study.

Results

All analysed data presented normal distribution. The two-way ANOVA yielded main effects for group ($F_{3,26} = 3.08$, $p < 0.04$) and for timing of measurement ($F_{2,52} = 526.1$, $p < 0.0001$); the Bonferroni post-hoc ($p < 0.05$) showed significant differences in the absolute peak power of goalkeepers when compared with defenders and midfielders at the loads corresponding to 80%, 100%, and 120% of the athletes' BM (Figure 1A). On the other hand, the two-way ANOVA revealed no significant differences in the relative peak power ($F_{6,52} = 0.27$, $p < 0.094$) between the groups (Figure 1B).



BM – body mass

* $p < 0.05$ for goalkeeper \times defender and midfielder groups

Figure 1. Mean \pm standard deviation values for comparisons between groups (defender \times midfielder \times forward \times goalkeeper) and different training loads (80% \times 100% \times 120% of body mass) in professional soccer players

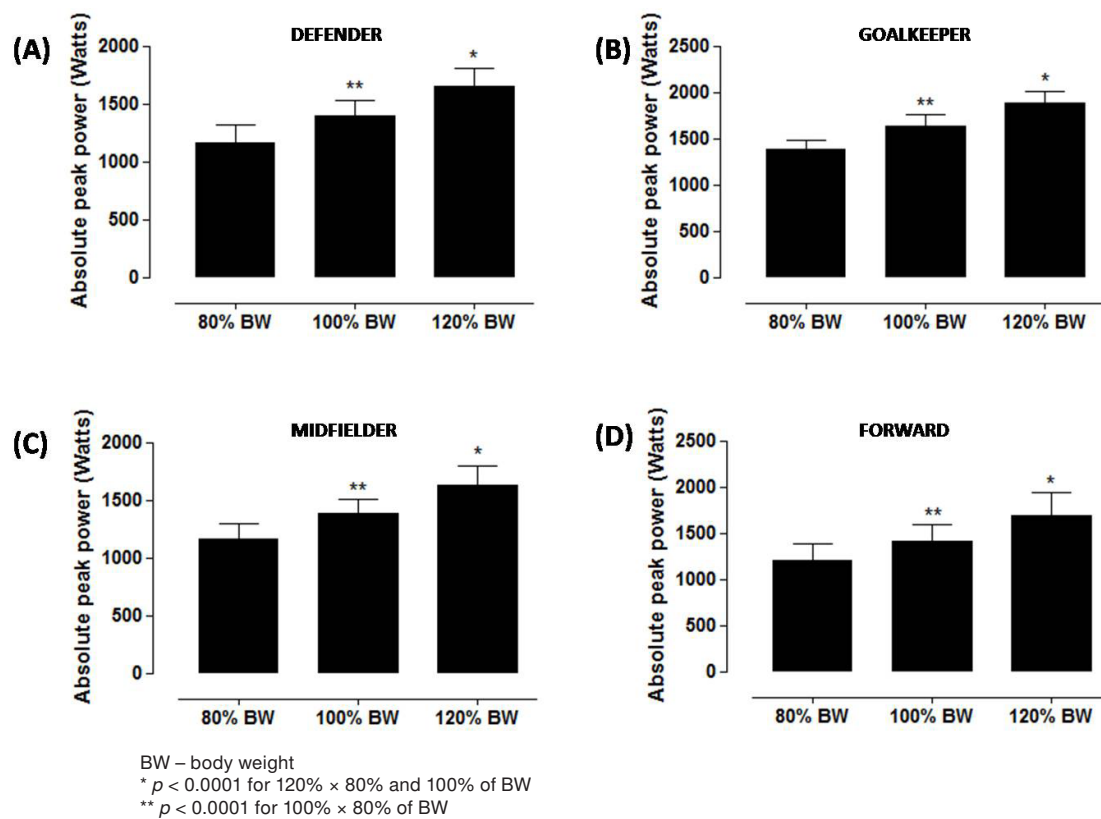


Figure 2. Mean \pm standard deviation values for intra-group comparisons of the absolute peak power with different training loads (80% \times 100% \times 120% of body mass) in professional soccer players

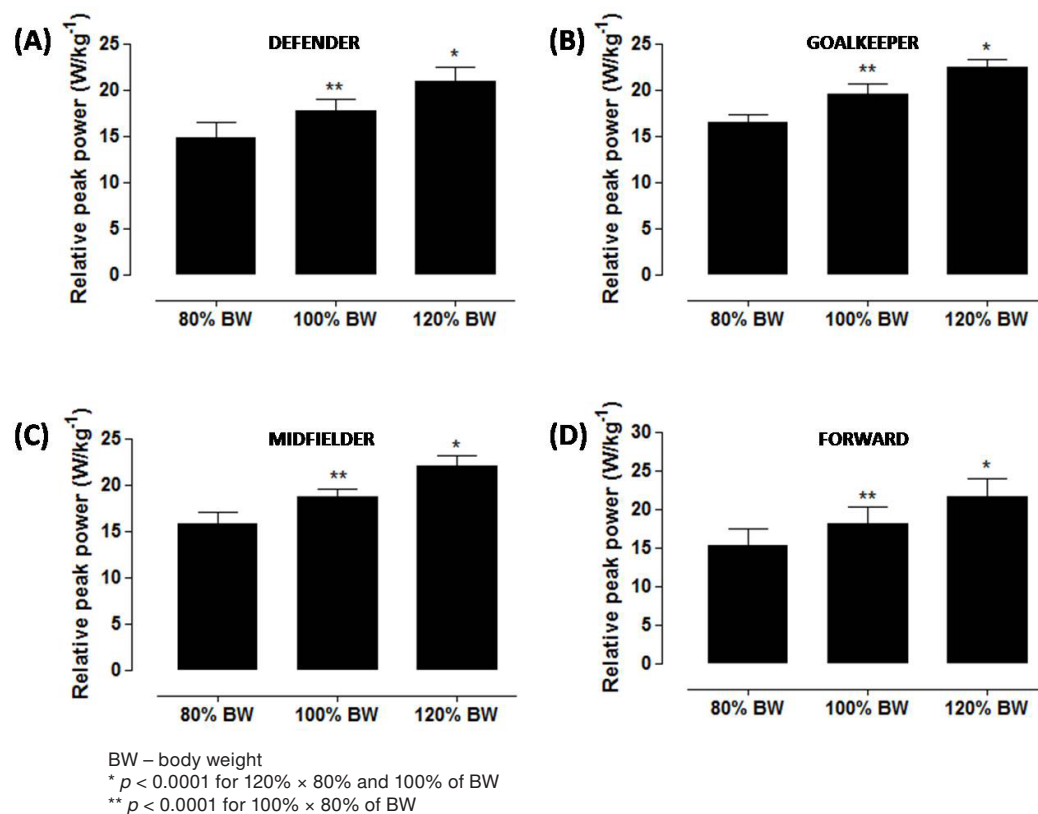


Figure 3. Mean \pm standard deviation values for intra-group comparisons of the relative peak power with different training loads (80% \times 100% \times 120% of body mass) in professional soccer players

Absolute and relative peak power intra-group comparisons are presented in Figures 2 and 3. One-way ANOVA demonstrated a significant increase in the absolute and relative peak power at the loads corresponding to 120% of BM when compared with 80% and 100% of BM in defender (absolute: $F_{2,18} = 16.86$, $p < 0.0001$, $\eta^2 = 0.30$; relative: $F_{2,18} = 8.74$, $p < 0.0001$, $\eta^2 = 0.18$), goalkeeper (absolute: $F_{2,8} = 47.78$, $p < 0.0001$, $\eta^2 = 0.20$; relative: $F_{2,8} = 38.76$, $p < 0.0001$, $\eta^2 = 0.10$), midfielder (absolute: $F_{2,14} = 20.13$, $p < 0.0001$, $\eta^2 = 0.29$; relative: $F_{2,14} = 9.10$, $p < 0.0001$, $\eta^2 = 0.12$), and forward athletes (absolute: $F_{2,12} = 26.07$, $p < 0.0001$, $\eta^2 = 0.44$; relative: $F_{2,14} = 27.67$, $p < 0.0001$, $\eta^2 = 0.36$) (Figures 2 and 3). In addition, a significant increase in the absolute ($p < 0.0001$; Figure 2) and relative ($p < 0.0001$; Figure 3) peak power was evident at the loads corresponding to 100% when compared with 80% of BM in all groups of athletes.

Discussion

This study compared the peak muscle power during pneumatic squat exercise with different percentages of load, corresponding to % of BM in male professional soccer players. Our findings support the original hypothesis that loads $> 100\%$ of BM during pneumatic squat exercise contribute to greater absolute and relative peak muscle power. Indeed, the notable results evidenced in the present study show that loads corresponding to 120% of BM resulted in an increase of absolute and relative peak muscle power in all groups of professional soccer players. But, absolute peak muscle power of goalkeepers was greater when compared with the defender and midfielder groups. No studies were found that would evaluate the peak muscle power during pneumatic squat exercise with different percentages of load corresponding to % of BM among male professional soccer players.

Pneumatic resistance is not related to the inertia and momentum of the load, thus limiting the effect of velocity variations, becoming constant throughout the movement and leading to greater mean power [15, 16]. Indeed, this exhibits less variation in the muscular force required to complete a resistance training program and, consequently, reduces the risk of muscle injury [17]. Evaluation of peak power using pneumatic equipment has recently been applied as a reliable muscle power assessment method because this equipment can accurately measure the force and velocity components of muscle power output [15, 16]. Peak power is an instantaneous measure of the optimal force-velocity combination at a specific point during the

movement. Several studies evaluated peak power muscle with % of 1RM [10, 12, 13]; however, no research utilized loads corresponding to % of BM.

A study mentioned that during squat exercise, for increasing peak power, a weightlifter must train with a load of 80–100% of 1RM, whereas a sprinter or jumper can increase performance with a training load of 10–50% of 1RM [18]. But, the greatest peak power values were associated with loads of 40% and 50% of 1RM during standard parallel squat [19]. In particular, professional soccer players revealed improvement in the power output during preseason with an optimal resistance training load of 45% of 1RM (30–60% of 1RM) [11]. Conversely, soccer players who trained twice a week during 10 weeks performing half-squat with a fixed external load of 65% of 1RM showed an increase in absolute ($\pm 11\%$) and relative ($\pm 11.2\%$) peak power [20]. Contrary to our results, another study reported that a load corresponding to 112.5% of BM (60.3% of 1RM) contributed to maximum peak power (1148.6 ± 301 W) in professional soccer players; however, half-squat tests were performed on a Smith machine [21]. Our results verified that a load corresponding to 120% of BM reached 1694 ± 192 W of maximal peak power during squat with pneumatic resistance equipment, while another study [21] showed that a load of 125% of BM attained values of 1033.5 W with a Smith machine. The difference of $\pm 39\%$ in the maximal peak power between squat exercises with the pneumatic resistance equipment vs. Smith machine may be related to improvements in peak power and power endurance owing to the requirement of pneumatic resistance equipment in eccentric muscle actions of the exercise and an increase of the hip and thigh power production during the concentric phase [15, 16]. A greater eccentric muscle action in leg muscle contributes to a better transition of the extensor muscles to explosive power [22, 23]. The performance improvement may occur by lower limb resistance training and a control of the training load [24]. Thus, coaches must understand the need of appropriate training load monitoring to increase relative and absolute peak power output.

Limitations

The limitations of the study include (1) the absence of measures of physiological parameters of physical exertion, which would be interesting; this, yet, does not limit the answer to the study question; and (2) lack of assessments of the angulations in knee flexion during pneumatic squat exercise. Additionally, it is suggested that future studies evaluate the physiological

effect, angulations of different knee flexions, and perception of effort.

Conclusions

The results of this investigation confirm that loads > 100% of BM during pneumatic squat exercise contribute to greater absolute and relative peak muscle power. In particular, professional soccer players showed improvements in the peak power with loads corresponding to 120 % of BM. It is recommended to use this optimal training load as it might be counterproductive to the muscle power gains.

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Disclosure statement

The author does not have any financial interest and did not receive any financial benefit from this research.

Conflict of interest

The author states no conflict of interest.

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