https://doi.org/10.54141/psbd.1516188

PAMUKKALE JOURNAL OF SPORT SCIENCES
ISSN: 1309-0356
dergipark.org.tr/en/pub/psbd

Pamukkale J Sport Sci, 15(3), 632-648, 2024 Research Article

Effect of Bodyweight Squat Exercise With Blood Flow Restriction on Sprint and Jump Performance in Collegiate Soccer Players

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Keywords
Blood flow restriction,
Body weight exercise,
KAATSU,
Resistance training,
Occlusion training,
Squat

Article History
Received 15 June 2024
Revised 06 November 2024
Accepted 22 November 2024
Available Online 30 December 2024

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ABSTRACT

This study investigated the effect of bodyweight squat (BWS) with blood flow restriction (BFR) exercise on sprint and jump performance in collegiate male soccer players. Twenty-four male collegiate soccer players (age: 19.3±1.0 years; height: 178.8±5.8 cm; body mass: 73.5±10.7 kg) were randomly divided equally into BFR or control groups. The BFR group performed BWS with BFR, while the Control group performed BWS without BFR 3x/week for eight weeks on nonconsecutive days. Both groups performed BWS for 30-15-15-15 repetitions with 30-second rest between sets (with continuous BFR pressure between sets). Limb occlusion pressure (LOP) was measured in a supine position after 10 min of passive rest by the automated device. Progressive overload was achieved by increasing LOP % weekly. The pressure was set at 60% LOP for the first four weeks and then was increased to 70% LOP for weeks 5 and 6 and then to 80% LOP for weeks 7 and 8. Countermovement jump (CMJ) and 30m sprint performance were assessed before and after the exercise program. No statistically significant differences between groups were identified. Both groups significantly increased sprint and CMJ performance ($p<0.05$). BFR and control groups increased jumping performance by 7% (ES: 0.55) and 2% (ES: 0.13), respectively. As for sprint performance, BFR and control groups increased by 5% (ES: 1.53) and 3.5% (ES: 1.14), respectively. In conclusion, the BFR group showed a larger effect size for sprint performance, suggesting that BFR may have a moderate to large effect on performance.

Citation: Kamiş, O., Kurt, M., Blaisdell, R., MacDonald, C. and Nobari, H. (2024). Effect of Bodyweight Squat Exercise with Blood Flow Restriction on Sprint and Jump Performance in Collegiate Soccer Players. *Pamukkale Journal of Sport Sciences*, *15*(3), 632-648. https://doi.org/10.54141/psbd.1516188

INTRODUCTION

Athletes continuously seek a competitive advantage to improve performance in many challenging sporting environments. Enhancing muscular power, speed, and injury recovery is the highest priority. Professional organizations such as the National Strength and Conditioning Association (NSCA) and the American College of Sports Medicine (ACSM) recommend resistance exercise at 65% or more of one repetition maximum (1RM) to promote muscle strength and hypertrophy (Haff & Triplett, 2016; Ratamess et al., 2009). Blood flow restriction (BFR) training can be a good alternative training method for athletes, patients, or elderly individuals who cannot work with heavy loads or exert the desired level of effort (Wortman et al., 2021). Low loads reduce mechanical stress on joints and bones (Loenneke et al., 2012), which is especially useful for groups unable to lift heavy loads, as in the case of clinical rehabilitation. Furthermore, BFR training can be performed safely with 20–30% of 1RM when compared to conventional high-load resistance training (HL-RT; Burgomaster et al., 2003; Patterson et al., 2019).

Blood flow restriction (BFR) training is a type of exercise where a pneumatic tourniquet device is used to create a partial arterial occlusion in the most proximal muscles (Rolnick et al., 2021). The reduction in oxygen supply to the muscles activates high threshold motor units responsible for muscle growth, leading to improvements in muscle building (Spranger et al., 2015). The use of BFR during resistance training at low loads (20-40% 1RM) has been shown to improve muscular strength and hypertrophy both in recreationally trained males and professional soccer male players (Kamiş et al., 2024; Korkmaz et al., 2022). Research revealed that this type of exercise produced comparable muscle growth with conventional resistance training even though individuals in BFR training only employed 20–40% of their 1RM (Fabero-Garrido et al., 2022). Numerous research demonstrates that BFR can be an effective means of stimulating hypertrophy in both the upper and lower limbs across a variety of populations, when compared to traditional resistance training (Bjørnsen et al., 2019; Bowman et al., 2020; Centner et al., 2019; Hughes et al., 2019; Wang et al., 2023).

Furthermore, studies demonstrate that using autoregulated pressure applications during BFR exercise can improve performance while reducing discomfort, effort, and delayed onset muscle soreness. Moreover, autoregulated pressure applications reduce the risk of adverse events in both the 30-15-15-15 reps scheme and failure protocols (Ewoud et al., 2023). Autoregulated cuffs in BFR devices are designed to accommodate changes in thigh circumference due to muscular contraction. These cuffs adjust pressure during exercise, preventing excessive intramuscular pressures and hypoxia, which can lead to less delayed onset muscle soreness (DOMS) compared to non-autoregulated devices (Dancy et al., 2023; Rolnick et al., 2023). Research suggests that autoregulated BFR devices have a lower adverse event rate than non-autoregulated ones, making them well-tolerated and safe for training protocols (Dancy et al., 2023). Therefore, using an autoregulated BFR device can enhance performance with less discomfort and exertion.

Resistance training with high loads (70% 1RM) is superior to low loads (20-30% 1RM) for maximizing strength (Schoenfeld et al., 2015). However, it has also been revealed that BFR combined with low-load resistance training (LL-RT) can lead to strength improvements similar to that of HL-RT (Grønfeldt et al., 2020; Loenneke et al., 2012). Although using significantly lighter loads, applying BFR during training may produce muscular growth and strength responses similar to those seen following conventional HL-RT (Yasuda et al., 2011). Team sport athletes may be able to enhance muscular growth without significantly higher training demands by incorporating low-load BFR exercise, which has been identified to increase muscle size and strength (Scott, 2014; Scott et al., 2016). For instance, a study on young soccer players found that BFR training improved knee extension strength and quadriceps muscle size (Korkmaz et al., 2022). Improving players' specific and essential athletic characteristics unique to their sport is the main objective of strength training in any sport. Research has shown that low to moderate-intensity resistance exercises with BFR may produce adaptations comparable to high-intensity resistance training and considerably similar muscle size and strength gain (Madarame et al., 2008; Moore et al., 2004; Takarada et al., 2000; 2002).

Although most BFR research has been done on healthy subjects, studies including athletes have revealed comparable performance advantages (Abe et al., 2005; Manimmanakorn et al., 2013; Yamanaka et al., 2012). Notably, this increase in muscle hypertrophy has led to better performance in acceleration and sprinting activities (Abe et al., 2005; Cook et al., 2014) and in change of direction, aerobic shuttle run, and muscular endurance tests (Manimmanakorn et al., 2013). BFR training may also increase lower-body power production (Cook et al., 2014). However, little is known about the potential benefits of bodyweight exercise combined with BFR training for sports-related performance (Abe et al., 2005; Madarame et al., 2011; Scott et al., 2017). With respect to some clinical situations, high mechanical loads might not be the most appropriate. Therefore, this study aimed to examine the impact of bodyweight BFR exercise on sprint and vertical jump performance in collegiate soccer players. We hypothesized that BWS exercise combined with BFR (via an autoregulated BFR device) would positively affect sprint and jump performance when compared to a bodyweight squat exercise without BFR in this population of collegiate soccer players.

METHODS

Research Design

We used pre- and post-test experimental designs to evaluate sprint and jump performance. This research was carried out during the preseason phase of the 2022-2023 season. Players underwent a two-day baseline measurement assessment at the start of the trial. On the first day, height, weight, and countermovement jump (CMJ) performance were evaluated, and on the second day, the 30m sprint performance was evaluated. Subjects performed a standardized warm-up protocol consisting of self-selected intensity jogging (5 minutes) and dynamic stretching exercises 5- 7 minutes (i.e., high knees, carioca) prior to all testing days, with all tests being performed in a university indoor athletic facility (Behm & Chaouachi, 2011; Pagaduan et al., 2012). Experimental research with pre-posttest was used to identify the effect of bodyweight squat exercise (BWS) on sprint and jump performance. After baseline testing, soccer players were randomly assigned to BWS with BFR group (BFR) or BWS without BFR (control). Forty-eight hours before and after the eight-week exercise program (3x/week), 30m sprint and CMJ performance were assessed.

Participants

Twenty-four male (age: 19.3±1.0 years; height: 178.8±5.8 cm; body mass: 73.5±10.7 kg) collegiate-level soccer players volunteered to participate in this study (Table 1). Athletes who were free of injury and did not show signs of or have a history of cardiovascular or blood clotting disorders were eligible to participate. Every participant gave written informed consent after noticing the objective of the study. The subjects trained together for the same squad and represented a variety of outfield positions: four attackers, ten midfielders, and ten defenders. Before each testing and training session, participants were instructed to refrain from engaging in vigorous activity outside team training for 24 hours. Participants also performed their regular soccer training team program during this period and were encouraged to continue their regular dietary and fluid intake routines throughout the study. A priori sample size calculation was performed using G-Power 3.1.9.7 (Dusseldorf, Germany) to determine the required sample size for an f-test via repeated measures ANOVA. The effect size used was $f = 0.25$ as a minimum effect, with an α significance level of $p = 0.05$ and a desired power level at $1-\beta = 0.80$. The calculated sample size was found to provide an 81.57% chance of effectively rejecting the null hypothesis of no difference in the variables studied. Ethical approval was obtained by the Gazi University ethics committee (2022 – 932/E-77082166-604.01.02-417889).

Data Collection Procedure

Anthropometric assessment. On arrival at the laboratory for the first visit, participants' height and weight were measured using a digital scale (Seca 813, UK) to the nearest 0.1 kg. and a stadiometer (Seca model 213, Germany) with a precision of 5 mm.

30m Sprint Performance Test. Participants warmed up before the performance tests by performing self-selected intensity jogging and sport-specific dynamic mobility exercises. 30m sprint assessment was conducted in an indoor sports hall. Participants began in a split stance behind a starting line and, when ready, sprinted as fast as possible until crossing the finish line. All tests were measured with a wireless electronic photocell (Seven Electronic Hardware & Software, Türkiye). Subjects performed two trials of the 30m sprint and the best result was recorded for the analysis (with a three-minute rest between trials; Haff & Triplett, 2016).

Countermovement Jump (CMJ) Test. A Fitjump (vertical jump performance test device; Sporsis, Afyonkarahisar, Türkiye) was used to assess CMJ performance, peak power, velocity, and flight time (Yıldız & Fidan, 2020). Participants completed two CMJ trials after performing the warm-up. They were encouraged to jump as high as possible for each jump (Haff & Triplett, 2016). Participants were instructed to move quickly and continuously in one constant movement from a standing posture (without arm swings) to a self-selected depth while performing the downward phase of the CMJ. Each participant completed two trials (with a one-minute rest between trials), and the maximum CMJ height (cm) was recorded for analysis.

Bodyweight Squat (BWS) Exercise. The duration of the BWS session lasted 7.5 minutes for both groups. BWS tempo was normalized by a metronome (MAD-Up Pro BFR device has an integrated metronome feature) with a 2-0-2-0 tempo (30 BPM), represented by a two-second eccentric and two-second concentric phase. BFR groups performed BWS with an automatic personalized tourniquet BFR device (MAD-Up Pro, France). Limb occlusion pressure (LOP) is the minimum amount of pressure that is required to fully occlude the blood flow (Patterson et al., 2019). LOP was measured in a supine position after 10 min of passive rest. LOP was recorded by the automatic BFR device (MAD-up pro, France) for both legs (Figure 1). BFR cuffs were attached to the most proximal part of the lower extremity. The cuff width was 10.5 cm, and the length was 75 cm. Progressive overload was achieved by increasing LOP % weekly. For the first four weeks, LOP% was set at 60%, the 5th-6th weeks increased to 70%, and in the last two weeks (7th-8th weeks) the pressure increased to 80% of LOP. LOP was recorded for the entire session (24 sessions) for both the right and left leg. Control groups performed BWS without BFR cuffs with the same tempo (2-0-2-0).

Figure 1
Bodyweight Squat With Blood Flow Restriction and the Applied Cuffs

Statistical Analyses

To evaluate the effects of predictors (fixed effects) such as intervention (0 = BFR, 1 = control), training experience, and time on countermovement jump, sprint, peak power, velocity, and flight time, the generalized mixed model (GMM) statistic was used. The participants were considered a random effect in the model (West et al., 2007). Using participants as a random effect was based on theory, as individuals differed in the training experience. Akaikes's information criterion (AIC) statistic was used to assess model fit. The model diagnosis was used to identify assumptions and use of the GMM. Residuals were analyzed to determine outliers or potentially influential observations. Additionally, the covariance structure used for the analysis was unstructured. After verifying the statistical significance of the effects of interventions, time, and intervention*time interaction, Bonferroni's post-hoc test was used. The GMM statistic was chosen because violations in the homogeneity of the regression slopes and independence are verified for General Linear Models (GLM) type statistics in repeated measures designs. For comparisons between groups, an independent t-test was applied. Pre/post effect sizes (Cohen's d) were calculated with the following formula: ([post mean – baseline mean]/baseline SD) and interpreted as trivial (0-0.19), small (0.20-0.49), medium (0.50-0.79) and large (0.80 and more significant; Cohen, 1988). All data are represented as mean ± standard deviation. The significance level adopted in this study was $p \leq 0.05$, and the software used for all analyses was SPSS 20.0 (SPSS Inc., Chicago, IL, US).

RESULTS

Baseline Participant Characteristics

Table 1 shows the differences between the BFR and control groups. No statistically significant differences between groups were observed in terms of age, height, weight, training experience, or BMI. However, although normality was verified for training experience during exploratory analysis, outliers were confirmed. Training experience was used as a predictor variable during statistical analysis and considered a random effect during analysis.

Table 1
Baseline Characteristics Between Groups

Variables	BFR Mean ± sd	Control Mean ± sd	*p*
Age (years)	19.25 ± 0,86	19.42 ± 1.24	0.70
Height (cm)	178.50 ± 7.03	179.00 ± 4.51	0.83
Body mass (kg)	73.67 ± 11.45	73.33 ± 10.31	0.94
Training experience (years)	2.92 ± 0.99	3.17 ± 0.83	0.51
BMI (kg/m^2)	23.09 ± 3.20	22.87 ± 3.09	0.86

Note. Sd: Standard deviation; BFR: Blood flow restriction; data are presented as mean and standard deviation

Countermovement Jump (CMJ) performance

There was no statistically significant difference in CMJ height for treatment F (1, 20.95) = 0.11; and group*time interaction F (1, 22.00) = 4.13; was verified. A statistically significant difference in CMJ was observed for time F (1, 22.00) = 14.30; p = 0.001 and training experience F (1, 21.00) = 36.38; p = 0.001. An increase in one unit of training experience is responsible for increasing a standardized β of 4.22 units in CMJ. Post-hoc differences between pre- and post-treatment (mean difference of 1.59; p = 0.001) were observed.

30m Sprint Performance

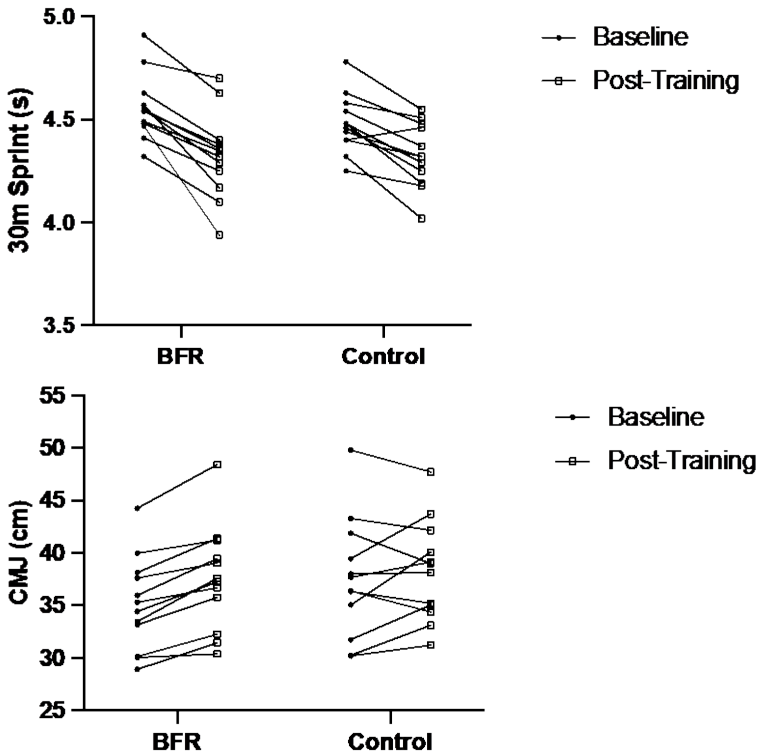
There was no statistically significant difference in sprint times for treatment F (1, 20.92), training experience F (1, 21.00) = 2.13, and group*time interaction F (1, 22.00) = 3.14. A statistically significant difference in sprint times was observed for time F (1, 22.00) = 68.74; p = 0.001. Post-hoc differences between pre- and post-treatment (mean difference of -0.193; p = 0.001) were observed.

Table 2
Comparison of Sprint and Jump Performance

	BFR		ES	Control		ES	p		
	Baseline	Post		Baseline	Post		Group	Time	G*T
CMJ (cm)	35.11±4.46	37.57±4.98	0.55/M	37.50±5.68	38.24±4.76	0.13 /T	0.734	0.001*	0.054
Flight Time (ms)	516.92±32.85	541.75±36.55	0.75/M	526.33±46.48	534.08±36.52	0.16 /T	0.511	0.003*	0.088
Peak Power (W)	3374.49±471.80	3561.93±494.39	0.39/S	3365.74±367.42	3449.41±303.07	0.22 /S	0.512	0.001*	0.135
Velocity (cm/s)	176.27±19.46	189.92±25.90	0.70/M	186.24±30.54	191.72±23.53	0.17 /T	0.904	0.002*	0.140
30m (s)	4.55±0.15	4.32±0.20	1.53/L	4.48±0.14	4.32±0.15	1.14 /L	0.696	0.000*	0.090

Note. *$p \leq 0.05$ Data are presented mean ± standard deviation; CMJ: Countermovement jump; BFR: Blood Flow Restriction; ES: effect size; S: Small, T: Trivial, M: Medium, L: Large; G*T: Group Time Interaction

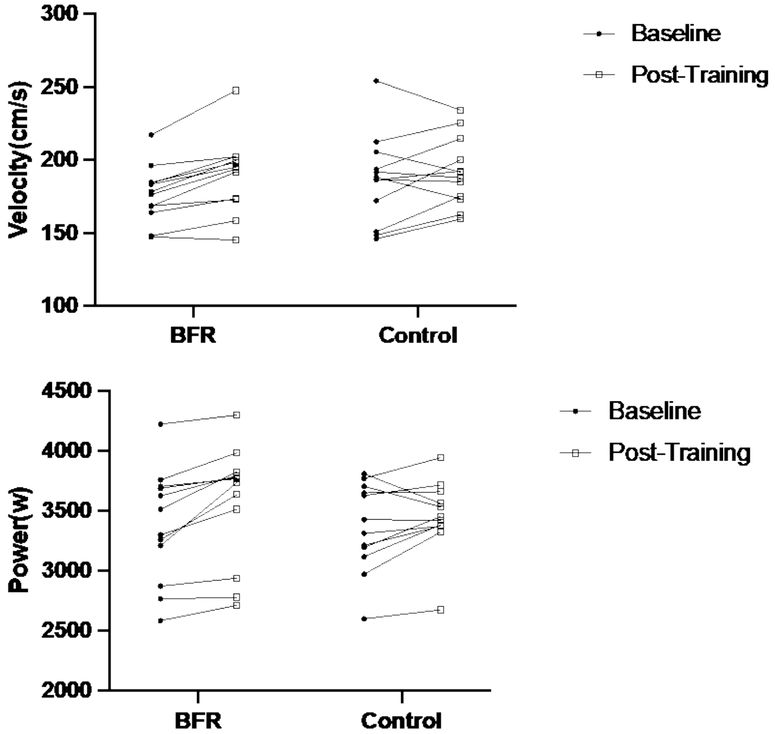
Figure 2
Graphical Presentation of Sprint and Jump Performance



Power and Velocity Performance

There was no statistically significant difference in muscular peak power output for treatment F (1, 21.00) = 0.44; p = 0.51, training experience F (1, 21.00) = 4.04; p = 0.057 and group*time interaction F (1, 22.00) = 2.41; p = 0.135 was verified. Also, for time F (1, 22.00) = 16.47; p = 0.001, a statistically significant difference in power production was observed. Post-hoc differences between pre- and post-treatment (mean difference of 135.55; p = 0.001) were observed.

Figure 3
Graphical Presentation of Velocity and Power



No statistically significant difference in velocity for treatment F (1, 21.00) = 0.11 and group*time interaction F (1, 22.00) =2.34 was verified. A statistically significant difference in velocity was observed for time F (1, 22.00) = 12.84; p = 0.002 and training experience F (1, 21.00) = 30.29; p = 0.001. Increasing one unit of training experience is responsible for increasing a standardized β of 20.32 units in velocity. Post-hoc (pairwise comparisons) differences between pre-and post-treatment (mean difference of 9.56; p = 0.002) were observed.

No statistically significant difference in flight time for treatment F (1, 20.70) = 0.44 and group*time interaction F (1, 22.00) = 3.18 was verified. Also, a statistically significant difference in flight time was observed for time F (1, 22.00) = 11.59; p = 0.003 and training experience F (1, 21.00) = 30.27; p = 0.001. An increase in one unit of training experience is responsible for increasing a standardized β of 31.88 units in flight time. Post-hoc (pairwise comparisons) differences between pre-and post-treatment (mean difference of 16.29; p = 0.002) were observed.

DISCUSSION

The current research investigated the effect of BWS with BFR on sprint and vertical jump performance in collegiate soccer players. The primary conclusions of this study suggest that BWS with BFR has a similar effect when compared with only performing BWS in terms of sprint and jump performance after eight weeks of training. The BFR group improved their CMJ and sprint performance by 7% and 5%, respectively, while the control group improved their sprint and jump performance by 2% and 3.5%, respectively, although effect estimates were favorable to BFR exercise (Table 2). Therefore, both exercise techniques may be an effective strategy to enhance jump and sprint performance, as there were no statistically significant differences between the groups.

A previous study identified that bodyweight exercise with BFR can elicit an acute improvement in jumping performance (Doma et al., 2020). Based on these findings, the authors suggest that lunge exercise with BFR may be an alternative strategy for warm-up protocols involving high-load exercise. Our study aimed to identify whether BWS with BFR could improve 30-meter sprint and jump performance in collegiate soccer players. The results identified in our study support performance improvements after the exercise program with BFR; however, this effect was also identified in the control condition (BWS without BFR). Although the CMJ and sprint performance increase were independent of groups, it tended to be more prominent in BWS with BFR group than in Control.

The results reported in the present study contradict those reported by Madareme et al. (2011). The authors identified no improvements in jumping performance after ten weeks of LL-RT with or without BFR. Unlike the current study, the authors used 30% of 1-RM as overload in a fixed repetition scheme. Additionally, they adopted arbitrary pressures (200-250 mmHg) (Madarame et al., 2011). These aspects may have contributed to the higher neuromuscular fatigue imposed in the study by Madarame et al. (2011), which may have resulted in null effects on jumping performance. Additionally, arbitrary pressures can generate variability in the level of BFR experienced by participants since LOP can be influenced by limb anthropometry (de Queiros et al., 2023). This aspect is of particular interest since BFR pressure can influence neuromuscular responses.

Although our results support improvement in the performance outcomes analyzed, this effect was not statistically significantly different from the control condition. However, we should point out that the effect estimates were more pronounced in the BFR condition. This effect may be due to neuromuscular adaptations elicited by BFR, primarily due to the methodological limitation in group allocation. We may conclude that the reason why both groups increased their performance is not only with BWS but also their regular soccer training program. Additionally, it can be argued that if the overall duration of 8 weeks of training were extended to 12+ weeks, those differences between conditions (favoring the BFR group) would continue to be pronounced.

Currently, several studies have investigated the effects of BFR training on sport-specific performance, such as jumping (Abe et al., 2005; Horiuchi et al., 2018; Madarame et al., 2011) and sprinting (Abe et al., 2005; Behringer et al., 2017; Chen et al., 2021). However, there is a lack of research on the effects of bodyweight exercise with BFR on athletic performance, especially among team sports athletes. Longer BFR training durations might result in more considerable muscular hypertrophy and enhancements to jumping ability (Abe et al., 2005). The present study performed BWS exercise 3x/week for eight weeks (24 total sessions). However, a major contributor to not observing any advantages of BFR is that body weight is not enough external stimulus (especially for athletes). Therefore, using external load may help to observe improvements in outcomes. In contrast, Abe et al., (2005) did not find any improvement in standing jump performance among track and field athletes.

The present study reported no negative adverse side effects across the training intervention. We implemented autoregulated BFR. Autoregulation involves using a BFR cuff that automatically adjusts the pressure applied to the limb in conjunction with the phase of muscular action (Rolnick et al., 2023). When autoregulated (automatic) devices are used, the total pressure applied to the limbs is kept constant by inflating and deflating the cuffs during muscle contractions (Ewoud et al., 2023; Hughes et al., 2018). In a recent study investigating the autoregulation of applied BFR training pressures in physically active adults, the authors concluded that the autoregulation seems to improve safety and performance in both fixed (30-15-15-15 reps scheme) and repetitions to failure BFR training protocols compared to non-autoregulation (Ewoud et al., 2023).

Limitations

It is important to acknowledge that this research does have some limitations. First, subjects only used their body weight as resistance during the training sessions. We did not implement any additional load, and progressive overload was achieved by increasing LOP% weekly. Using additional loads based on 1RM performances would have been a good option. Secondly, we implemented a single type of exercise (squat); therefore, integrating different multi-joint (i.e., deadlift) and single-joint exercises (i.e., leg extension) can play an effective role in enhancing performance. Finally, the duration of the current training phase was only 8 weeks. Longer continuous durations with this training model could produce even more notable results.

CONCLUSION

The primary conclusions of this study suggest that BWS with BFR has a similar effect when compared with only performing BWS in terms of sprint and jump performance after eight weeks of training. The BFR group showed a more significant effect size for sprint performance, suggesting that BFR may have a moderate to significant effect on performance. Future studies should analyze the effect of exercise with autoregulated versus non-autoregulated cuffs on power measurements as well as extended durations and training protocols.

PRACTICAL IMPLICATIONS

The results of the present study indicate that BWS with BFR can elicit improvements in physical performance variables. BWS also elicits this effect without BFR, although the magnitude of adaptations may be more significant in the BFR condition. Both exercise techniques may be an effective strategy to enhance jump and sprint performance, as there were no statistically significant differences between the groups. Considering the possibility of other relevant adaptations, BWS with BFR may be a more viable option during reload weeks of a periodized training program or for return-to-play protocols for players rehabbing injuries.

Acknowledgments

The study was supported by the Scientific and Technological Research Council of Türkiye, TUBİTAK 2209-A Research Project Support Programme for Undergraduate Students (Project Number: 1919B012107000). We would like to thank the participants. We also would like to thank Dahan C. Nascimento, Ph.D. from the Catholic University of Brasília, Brazil/DF, for supporting this project's statistical analysis and Victor S. de Queiros, PhD for valuable recommendations.

Authors' Contributions

The first author contributed to conceptualization, methodology, project administration, formal analysis, visualization, writing - original draft, writing- reviewing and editing. The second author contributed to conceptualization, methodology, project administration, writing - original draft. The third, fourth and fifth authors contributed to visualization, writing - original draft, writing - reviewing and editing. All authors reviewed the results and approved the final version of the manuscript.

Declaration of Conflict Interest

The authors declared no conflicts of interest.

Ethics Statement

This research was performed following the Declaration of Helsinki and approved by the Gazi University ethics committees (2022–932/E-77082166-604.01.02-417889).

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