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Jump training with blood flow restriction has no effect on jump performance

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ABSTRACT: This study investigated whether jump training with blood flow restriction (BFR) improves jump performance compared to jump training without BFR under similar exercise intensity in healthy young humans. The participants were twenty healthy males who were assigned to either jump training with BFR (n = 10) or jump training without BFR [control (CON); n = 10] groups. All subjects completed five sets of 10 repetitions with one-minute intervals of half-squat jumps (SJ) at maximal effort, four days a week for four weeks. In the BFR group, circulatory occlusion around both thigh muscles was applied at a pressure of 200 mmHg, and physical characteristics, muscle strength and jump performance were evaluated before and after training. A significant main effect of training period on lean body mass, percentage of body fat and leg circumference in both groups was observed ($P < 0.05$). For jump training with BFR, only knee flexion strength increased ($P < 0.05$), while in the CON group, both knee extension and flexion strength increased ($P < 0.05$). BFR training did not improve SJ or counter-movement jumps (CMJ) ($P > 0.05$), whereas training without BFR (CON) improved the performance of both jumps (SJ: pre 35.7 ± 5.1 vs. post 38.9 ± 4.1 cm, $P = 0.002$: CMJ: pre 41.6 ± 3.6 vs. post 44.6 ± 3.8 cm, $P < 0.001$). These results indicate that jump training with BFR may not be an effective strategy for improving jump performance.

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INTRODUCTION

The central goal of muscle strength or power training in any sport is to improve players' specific and relevant athletic activities inherent to each sport. It has been suggested that low and/or moderate intensity resistance exercises with blood flow restriction (BFR) lead to dramatically greater muscle hypertrophy and strength gain [1-6] and result in adaptations equal to those of high-intensity resistance training [5]. However, most previous studies on BFR training have focused on muscle strength and/or muscle volume [1-6], and few have investigated whether BFR training improves sports performance and muscle strength in relation to unaltered jump performance [7].

BFR training increases the muscle cross sectional area, which is assessed using magnetic resonance imaging (MRI), but it does not affect counter movement jump (CMJ) performance [8]. This could be due to training methods; improved jump performance results from high-intensity resistance training or jump training [9], and training with sport-specific movements can significantly improve sports performance (e.g., basketball specific plyometric training [10], sports specific background [11], and plyometric jump training [12]). Previous studies have included classical BFR training, such as low-intensity resistance training with BFR (i.e., combined squats and leg curls at 20% of one-repetition maximum (RM) for eight days) followed by performance evaluations of three types of jumps (i.e., standing jumps, standing triple jumps and standing five-step jumps) and horizontal squats at 30-40% of the one RM followed by evaluation of CMJ height [7, 8]. Thus, little is known about whether or not actual sport movement with BFR training may have beneficial effects on sports related performance.

From these considerations, we hypothesized that jump training with BFR improves jump performance induced by an increase in muscle strength compared to jump training without BFR. To test this hypothesis, we compared two young groups under jump training with or without BFR.

MATERIALS AND METHODS

Subjects

Twenty healthy young male subjects participated in this study. The subjects were untrained and did not engage in regular physical activity. After a detailed description and explanation of all study procedures and the possible risks and benefits of participation, each subject signed an informed consent form. All subjects underwent a familiarization session to allow them to become accustomed to the experimental measurements and procedures. All procedures in the present study were approved by the ethical committee for human research of Hokusho University in Japan and were performed in accordance with the guidelines of the Declaration of Helsinki. All studies were performed at an ambient temperature of 24 ± 1°C. The subjects were divided into two groups: normal jump training without BFR [CON (control), n = 10] and jump training with BFR (BFR, n = 10).

Training protocol

Jump training with or without BFR consisted of a vertical jump from a half squat position with an individual maximal effort. The subjects completed five sets of 10 repetitions at one-minute intervals, four days a week for four weeks. During jump training, participants' upper arms were maintained at their waist, with no pauses between jumps in each set. Between 10 repetitions, each subject performed without an interval; i.e., after landing, each subject was asked to jump again immediately. In the BFR group, circulatory occlusion was applied using a custom-made cuff inflator around both thighs at a pressure of 200 mmHg, according to the methodology of a previous study [8] and the preliminary test results in the current study. Between sets, circulatory occlusion was maintained to enhance muscle metabolites and to promote greater training effects [13]. The inflator consisted of a motor driven air pump (DM-707S-25-V, Enomoto Micro Pump, Co. Ltd., Tokyo, Japan), pressure sensor (AP-C30, KEYENCE, Tokyo, Japan), power supply (MS-2-H50, KEYENCE, Tokyo, Japan) and thigh cuff with a width of 11 cm (SC10, Hokanson, Inc, WA, USA).

Outcome measures

Physical characteristics, i.e., body weight and percentage of body fat, were assessed by body composition analyzed using the impedance method (In Body 720, Biospace, Tokyo, Japan). Both pre- and post-training measurements of physical characteristics were taken in the morning at approximately the same time of day after 12 hours of fasting. In addition, subjects were asked to refrain from caffeine and to avoid strenuous exercise for 24 hours before each study day. Maximum thigh circumference of both thighs was measured using a non-elastic tape, and jump performance was evaluated based on subjects performing a half squat jump (SJ) and CMJ. During the pre- and post-training period, each subject performed 3 SJ and CMJ with a one-minute interval between each set, and each maximal value was defined as the jump performance. For this measurement, a multi-jump tester (DKH Co., Ltd., Tokyo, Japan) was used, and this device can measure hang time in the air. The height of the vertical jump was calculated by the following equation:

$$\text{Height of vertical jump} = 1/8 \times 9.81 \times (\text{hang time})^2$$

Bilateral maximal knee extension (KE) and knee flexion (KF) strengths were used as indicators of muscle strength. KE and KF strengths were measured using a dynamometer (Biodex system 3, Sakai Medical Co., Ltd., Tokyo, Japan). Subjects were seated in the adjustable chair of the dynamometer and stabilized with straps across the shoulders, waist, and thighs throughout the test to prevent additional body movement. Before each measurement, the full range of motion was set. Neutral position (0°) was defined as perpendicularity to the long axis of the tibia measured with a digital goniometer. Gravity correction was obtained by measuring the torque exerted on the dynamometer resistance adapter with the knee in a relaxed state at full extension. Subjects were instructed to fully extend and flex their knees and to work maximally during each set of exercises. After a warm-up, they performed five maximal isokinetic extensor and

TABLE 1. Changes in physical characteristics between the two groups.

	CON (n = 10)		BFR (n = 10)		P values		
	Pre-training	Post-training	Pre-training	Post-training	Group	Time	Group×Time
Age (years)	22.4 ± 1.7	-	23.3 ± 2.5	-	0.353	-	-
Height (cm)	172.1 ± 5.5	-	172.8 ± 6.1	-	0.787	-	-
Body mass (kg)	65.7 ± 5.8	66.3 ± 6.3	65.8 ± 7.4	65.9 ± 8.2	0.966	0.083	0.245
LBM (kg)	54.3 ± 5.5	55.0 ± 6.0*	54.0 ± 5.0	54.3 ± 5.6	0.847	0.041	0.423
% Body fat (%)	17.4 ± 2.3	16.9 ± 2.6	17.6 ± 3.7	17.2 ± 4.3	0.860	0.041	0.962
Maximum leg circumference (cm)	51.4 ± 3.1	51.9 ± 3.1*	51.3 ± 2.5	51.8 ± 2.8*	0.948	<0.001	0.938

Values are mean ± standard deviation. CON, jump training without blood flow restriction (BFR); BFR, jump training with BFR; LBM, lean body mass; *P* values in age and height were obtained from unpaired t-test: other *P* values were obtained from two-way repeated measured analysis of variance. * $P < 0.05$ between pre- and post-training interventions within the same group.

TABLE 2. Coefficient of variations in jump performance and muscle strength between the two groups.

	CON		BFR	
	Pre	Post	Pre	Post
SJ	14.3	10.5	10.7	11.4
CMJ	8.7	8.5	17.5	15.0
KE	13.8	18.2	11.2	14.0
KF	19.6	20.4	18.4	17.4

All units are represented as percentages. SJ, squat jump; CMJ, counter movement jump; KE, knee extension; KF, knee flexion.

flexor contractions at 60°/s as one set for both legs, separately. Subjects performed this test three times, and after each set they took a 90-second rest between the sets. The details of the position were checked carefully and used as the same position in the second test session. The thigh strap was released during each rest period to ensure unrestricted blood flow to the quadriceps muscle. Strong verbal encouragement was given throughout the test session. The tester established contraction velocity because most daily activities are related to the ability to generate power at low velocity [14]. Bilateral maximal KE and KF strengths were calculated by averaging values of three measurement sets.

Statistics

Data are expressed as mean ± standard deviation (SD). An unpaired t-test was used for comparison in age and height between groups. Two-way repeated measured analysis of variance (ANOVA: groups × time) was conducted for comparison in all other variables. A Bonferroni post-hoc test was used for further analysis, and $P < 0.05$ was set for statistical significance.

RESULTS

Physical characteristics

Pre- and post-training physical characteristics are shown for both groups in Table 1. In both groups, thigh circumference significantly increased ($P = 0.011$ in CON vs. $P = 0.009$ in BFR), whereas no statistically significant main effect of time on lean body mass or percentage of body fat was observed in CON and BFR groups.

Jump performance

No significant effect of BFR training on jump performance in SJ or CMJ was observed ($P = 0.103$ for SJ and $P = 0.277$ for CMJ). However, jump training without BFR significantly improved the performances (9.0% improvement for SJ, $P = 0.002$, and 7.2% improvement for CMJ, $P < 0.001$; Figure 1).

Muscle strength

Figure 2 shows changes in KE and KF strength between the pre- and post-training for both groups. BFR training did not increase KE

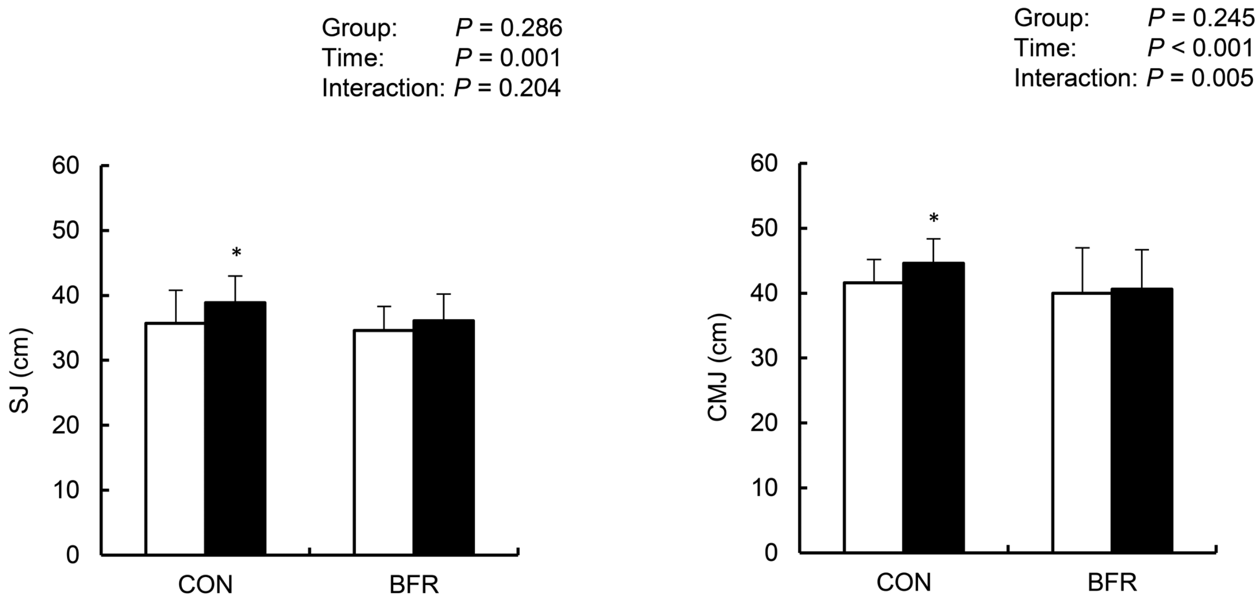

FIG. 1. Comparison of squat jump (SJ) and countermovement jump (CMJ) between the control (CON) and blood flow restriction (BFR) groups. Values are mean ± standard deviation (SD). White bars represent pre-training values and black bars represent post-training values. * $P < 0.05$ between pre- and post-training within the same group.

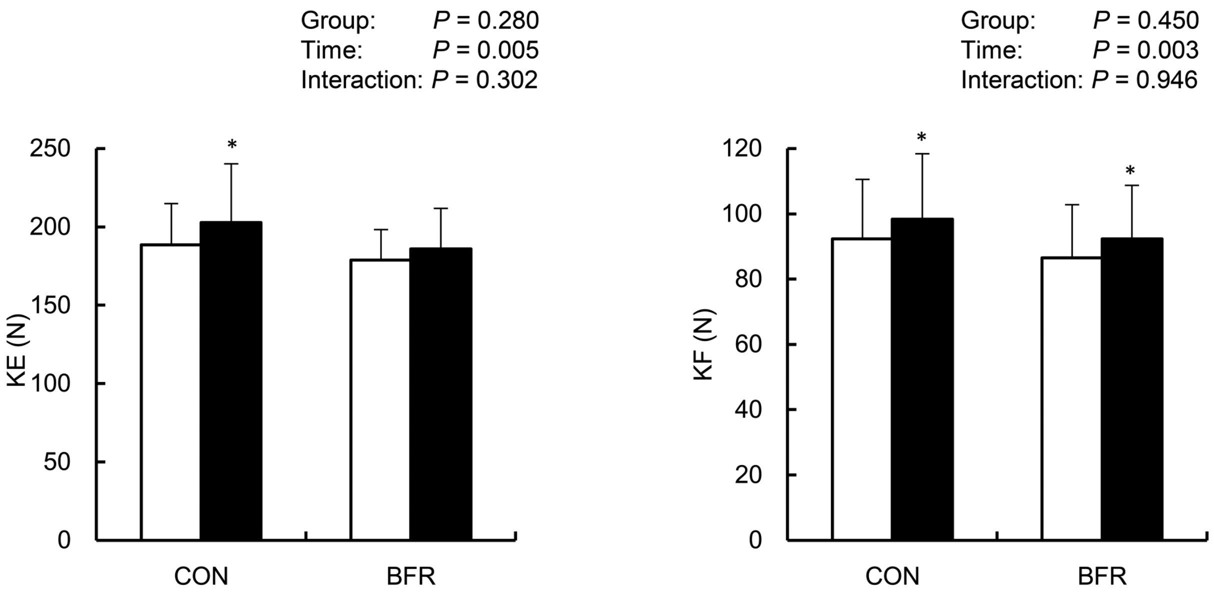

FIG. 2. Comparison of knee extension (KE) and knee flexion (KF) strengths between the CON and BFR groups. Values are mean ± SD. Bar representation is the same as in Figure 1.
* $P < 0.05$ between pre- and post-training within the same group.

significantly (3.9%, $P = 0.151$), while jump training without BFR significantly increased KE (7.4%, $P = 0.008$). Both training types significantly increased KF (5.7% for BFR, $P = 0.030$, and 6.5% for CON, $P = 0.025$). There was no post-hoc statistically significant difference in the pre-values for KE and KF in the training sessions between groups ($P > 0.05$, respectively).

Coefficient of variation

Table 2 shows the coefficient of variation for SJ, CMJ, KE, and KF for both groups. The coefficient of variation values for CMJ in the BFR group and for KE in the CON group were greater compared to CON and BFR; however, there was no significant trend in the coefficient of variation.

DISCUSSION

The results of the present study can provide useful information for athletes who want to improve jump performance as well as muscle strength. Our results demonstrated that jump training with BFR did not improve jump performance and only increased KF strength, whereas jump training without BFR significantly improved jump performance as well as increasing KE and KF strength. These findings suggest that BFR training using sports-specific movements, at least jump performance, may not be an effective strategy for improvement of sports performance.

Significant improvements in jump performance were observed in the CON group, while no improvements in jump performance were observed in the BFR group. It has been reported that better jump performance is related to greater muscle strength and the rate of strength development in the lower limbs, suggesting that the muscle strength in lower limb joints is a primary determinant of vertical jump performance [15]. In addition, studies have demonstrated that strength-training-induced improvements in jump performance are the result of increased muscle strength and size [16, 17]. A previous study demonstrated that 14.6% and 21.7 % increases in one RM for leg presses and squats resulted in a 9.3% increase in the height of CMJ [18], while other studies using BFR training reported a 9.6% increase in one RM for leg presses and a 19.3% increase in one RM for squats, without improved jump performance [7,8]. In the present study, significant increases in maximal KE and KF strengths were observed in the CON group; however, the magnitude of these improvements were 7.4% and 6.5%, respectively, resulting in significant improvements in both SJ and CMJ. These lower magnitudes of improvement in muscle strength may be related to the different training modes and evaluation outcomes between the present study and the literature. In contrast, jump training with BFR significantly increased KF strength only by ~ 6% and did not increase KE strength, indicating that there were no beneficial effects of the BFR training on jump performance, although the reason for this result remains unclear. The current researchers previously reported that four weeks of plantar flexion training with BFR at 20% maximal voluntary contraction significantly increased calf muscle cross sectional area (CSA) based on MRI results [14]. This may be attributed to enhanced metabolites [19]. Based on this past research, the training period used in the present study was of sufficient duration to improve muscle strength; thus, BFR training should be beneficial for improving muscle bulk and strength [19]. However, the results presented here do not support these expectations, despite both group having used maximal effort in the training, which could be due to different training volumes and loads between the CON and BFR groups. BFR training might restrict movement during exercise due to vascular occlusion, but because training intensity in this study was vertical jump training at individual maximal effort, it was difficult to control exercise intensity between participants. Therefore, it is possible that variability exists in the study results, even though each subject performed jump training under the supervision of a training specialist throughout the training period. A recent study demonstrated that differences in physical characteristics, such as body mass index, thigh circumference and thigh muscle–bone CSA, may relate to different degrees of BFR [20]. We applied the same absolute pressure of ~ 200 mmHg for blood occlusion to all subjects in the present study; therefore, training with BFR might have constrained jump movement throughout the training periods, resulting in different training loads and volume, no increases in KE strength and no improvements in jump performance. However, the precise mechanisms of these effects on muscle strength and jump performance are still unknown, and future studies are warranted.

Methodological considerations

Several limitations must be considered when interpreting the findings from the present study. First, this study conducted a subject comparison between legs, with one leg trained with BFR and the other leg without BFR. Therefore, we could not completely rule out between-subject effects although subjects had similar physical characteristics before and after training and similar physical activity levels. Second, jump performance was only evaluated based on muscle strength, and the influence of other related factors, such as muscle CSA and storage and release of elastic energy [21-24], on jump performance remains uncertain and requires future investigation.

CONCLUSIONS

In summary, the present results suggest that jump training with BFR does not improve jump performance, while normal jump training improved jump performance as well as KE and KF strengths. The results indicate that sport-specific movement training with BFR may not be necessary to improve sport performance, at least in this type of sports performance and with the population in this study.

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