Effects of 6-week Traditional and Functional Resistance on Arterial Stiffness in Healthy Young Men

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Abstract

(1) Background: The present study attempted to determine and compare the vascular impact of traditional and functional resistance training on arterial stiffness.

(2) Methods: The present study was conducted in 29 untrained healthy young males aged 18–29 years who were randomly divided into two groups, namely traditional resistance training (TRT, $n = 15$) and functional resistance training (FRT, $n = 14$). All subjects underwent numerous tests before and after the 6-week training such as body composition, cardio-ankle vascular index (CAVI), blood pressure, heart rate, and maximal strength. The exercise training comprised whole-body strength training exercises 3 days a week for 6 weeks. The total training volume and number of sets (4–5 sets) were kept constantly similar in each group. The TRT group completed 4–5 sets of 8–12 repetitions [70% of 1 repetition maximum (1RM)], whereas the FRT group completed 4–5 sets of 15–22 repetitions (40–50% of 1RM).

(3) Results: After the 6-week intervention, lean body mass (TRT: Pre: 59.5 ± 5.4 kg; Post: 60.4 ± 4.9 kg vs. FRT: Pre: 57.7 ± 6.7 kg; Post: 58.8 ± 5.9 kg) significantly increased in both TRT and FRT groups, whereas body fat (TRT: Pre: $18.8\% \pm 5.8\%$; Post: $16.5\% \pm 5.3\%$ vs. FRT: Pre: $16.7\% \pm 4.6\%$; Post: $15.3\% \pm 4.7\%$), R-CAVI (TRT: Pre: 6.2 ± 0.6 m/sec; Post: 5.7 ± 0.6 m/sec vs. FRT: Pre: 5.9 ± 0.5 m/sec; Post: 5.3 ± 0.6 m/sec), and L-CAVI (TRT: Pre: 6.2 ± 0.6 m/sec; Post: 5.7 ± 0.6 m/sec vs. FRT: Pre: 6.0 ± 0.6 m/sec; Post: 5.4 ± 0.6 m/sec) decreased. Additionally, the maximal strength increased significantly in both the groups ($p < 0.01$). However, no significant difference was observed between the two groups.

(4) Conclusions: A similar training volume of TRT and FRT with unstable surface significantly decreased body fat and arterial stiffness and improved lean body mass and maximal muscle strength in young men.

1. Background

Cardiovascular disease (CVD) is a major public health problem. Increased central arterial stiffness (AS) reduces the arterial buffering function and blood flow, increasing the systolic blood pressure (SBP) and pulse pressure. Additionally, AS is a strong independent predictor of cardiovascular events and mortality[1]. Thus, the increase in AS must be both prevented and treated.

The American College of Sports Medicine (ACSM) and World Health Organisation recommended regular aerobic exercise and resistance training as effective conservative methods for the prevention and treatment of CVD and ageing-related frailty[2,3]. AS is closely related to age[4], and habits such as smoking[5], alcohol[6], insufficient sleep[7], inactivity, and sedentariness[8] accelerate arterial sclerosis. Regular aerobic exercise has been proved to inhibit the increase in arterial stiffening associated with ageing and attenuate the incidence of CVD in healthy adults[9,10]. However, the relationship between traditional resistance training (TRT) and progression of AS is still controversial[11,12], whereas the overall influence of functional resistance training (FRT) with unstable surface on age-associated AS is poorly understood. Studies have reported the improvement of vascular function and arterial compliance through

traditional intensity resistance training in both the young and old populations[13–17]. On the other hand, young- and middle-aged men who underwent resistance training regularly demonstrated higher levels of AS[18–20]. Moreover, a meta-analysis[21] and two randomized control trials[22,23] observed no changes in AS after isolated resistance training sessions in healthy individuals. Although TRT is effective in improving skeletal muscle mass and function and reversing osteoporosis, ascertaining its effect on AS requires further studies.

FRT, which emphasises synchronised, multidimensional, and multijoint movement modes to train muscles with dynamic exercises and continuous changes on unstable surfaces (e.g., BOSU ball, swish ball, balance disc) for enhancing physical fitness, has been used to improve the physical condition and health level in patient. FRT improves the physical capabilities (muscle mass, strength, and dynamic balance) and physical performance similar to TRT, although with a lower training intensity[24,25]. Additionally, FRT is the most promising method for promoting multisystemic adaptations as it uses resistance training not only for central body strength gains but also for multiple capabilities (e.g. coordination, agility, flexibility, and cardiorespiratory endurance)[26,27].

To the best of our knowledge, the effect of functional training with unstable surfaces resistance training on AS has not yet been demonstrated. Thus, the present study attempted to explore and compare the influence of a 6-week FRT and TRT on AS and muscle strength in healthy young men.

2. Materials And Methods

2.1. Subjects and general design

The present study was conducted in 29 healthy young males aged 18–29 years at the Capital University of Physical Education and Sports in Haidian District, Beijing, China after institutional ethics clearance. All the subjects were recruited through printed advertisement and by word-of-mouth. Patients who had not underwent any regular resistance-type training for at least 6 months before the initiation of the study; those with BP within the normal range ($< 140/90$ mmHg)[17]; those who did not regularly smoke, drink alcohol, or consume any medication; and those without overt chronic diseases and contraindications to exercise were included in the study. All the participants were randomly assigned to either the TRT ($n = 15$) group or the FRT ($n = 14$) group. Table 1 presents the patient characteristics. All subjects were asked not to attend any extra aerobic sports training throughout the 6-week training period. Fig. 1 illustrates the flow of participants through the study. The study conformed to the principles outlined in the Declaration of Helsinki. Prior to study initiation, all the participants were informed of the risks and requirements of the training, and voluntary consent was obtained from the

Table 1

Subject 's characteristics

Variables	TRT (n = 15)	FRT (n = 14)
Age(y)	22.1 ± 2.9	20.9 ± 2.7
Height(cm)	176.6 ± 5.4	176.7 ± 6.0
Body weight(kg)	77.9 ± 11.6	73.4 ± 10.2
BMI (kg/m ²)	24.9 ± 3.1	23.4 ± 2.6
Body fat (%)	18.8 ± 5.8	16.7 ± 4.6
Lean body mass(kg)	59.5 ± 5.4	57.7 ± 6.7
Resting HR(b/min)	59.0 ± 10.0	64.2 ± 11.3

BMI: body mass index; HR: heart rate; TRT: traditional resistance training; FRT: functional resistance training. Data are presented as mean ± standard error

2.2. TRT and FRT protocols

All participant in both the groups were trained 3 days per week for 6 weeks. The training programme comprised a whole-body workout and five exercises, namely barbell squat for the lower limb, horizontal bench press for chest muscles, dead lift for back and leg muscles, reverse arm curl for biceps, and seated leg flexion for quadriceps. A warm-up and cool-down including static and dynamic stretching were performed before and after the training intervention. Subjects in the TRT group performed 4–5 sets of 8–12 repetitions at 70% of their 1-repetition maximum (1RM) to volition fatigue, with 1–2 min of rest between sets. The FRT group performed the same training exercises as the TRT group. However, unstable devices (e.g., BOSU ball, swish balls, and balance discs) were used to increase both core trunk strength and neuromotor and proprioceptive demand. The horizontal bench press, dead lift, and barbell squat were performed on the swish ball, balance disc, and BOSU ball, respectively. Additionally, kettlebell swings and Bulgarian split squats were performed on the BOSU ball. Regarding to the repetitions of the FRT group, each set training repetitions of the FRT group were calculated by the total training volume (70% 1RM lifting weight × repetition) of the TRT group because the training set and rest period were similar between the TRT and FRT groups. Thus, participants in the TRT group performed 4–5 sets of 15–22 repetitions at 40%–50% of their 1RM (70% 1RM lifting weight × repetition_{TRT group}/40%–50% 1RM) to volition fatigue, with 1–2 min of rest between the sets. Table 2 presents the training protocol from 1 to 3 weeks and 3 to 6 weeks for the TRT and FRT groups. The strength assessments for all the participants were performed again after 3 weeks of intervention to ensure that they readjusted training intensities based on strength gains. To minimise any potential diet-induced variability in muscle strength and body composition measurement, all the participants were asked to maintain normal dietary habits and avoid overeating. Additionally, they were asked to refrain from any aerobic exercise throughout the study.

Table 2

Resistance training protocol during 6 weeks for TRT group and FRT group

Variables	Groups	S	Rep	TI (kg)	Rest	TV (kg)
1-3 week	TRT	-	-	-	-	-
BS		4-5	12	70%1RM (81.2)	1-2min	974.4
BP		4-5	12	70%1RM (52.5)	1-2min	630
DL		4-5	12	70%1RM (82.5)	1-2min	990
RAC		4-5	15	10kg	1-2min	150
LF		4-5	15	70%1RM (28-30)	1-2min	420-450
						3164.4-3194.4
BS&B	FRT	4-5	16-20	40-50%1RM (50-60)	1-2min	960-1000
BP&S		4-5	16-20	40-50%1RM (30-40)	1-2min	600-640
DL&BD		4-5	16-20	40-50%1RM (50-60)	1-2min	960-1000
KS&B		4-5	15	20kg	1-2min	300
BSS&B		4-5	15	16kg	1-2min	240
						3060-3180
3-6 week	-	-	-	-	-	-
BS	TRT	4-5	12	70%1RM (95.6)	1-2min	1147.2
BP		4-5	12	70%1RM (60)	1-2min	720
DL		4-5	12	70%1RM (91)	1-2min	1092
RAC		4-5	15	15kg	1-2min	225
LF		4-5	15	70%1RM (30-35)	1-2min	450-525
						3634.2-3709.2
BS&B	FRT	4-5	17-21	40-50%1RM (54-67)	1-2min	1134-1139
BP&S		4-5	18-22	40-50%1RM (32-40)	1-2min	704-720
DL&BD		4-5	18-22	40-50%1RM (50-62)	1-2min	1100-1116
KS&B		4-5	15	24kg	1-2min	360
BSS&B		4-5	15	20kg	1-2min	300
						3598-3653

S sets, Rep repetitions, TI training intensity, TV training volume, BS barbell squat, BP bench press, DL dead lift, RAC reverse arm curl, LF leg flexion, BS&B barbell squat & BOSU, BP&S bench press swish ball, DL&BD dead lift & balance disc, KS&B kettlebell swings & BOSU, BSS&B Bulgarian split squats & BOSU.

2.3. Testing Procedures

2.3.1 AS assessment

The cardio-ankle vascular index (CAVI) is a novel indicator for evaluating systemic AS[28,29]. The most significant feature of CAVI is AS from the aorta to the ankle and is theoretically adjusted by its independence from BP[28]. The degree of arteriosclerosis increases with the CAVI values. Therefore, CAVI is related to the CVD risk[28,30]. Initially, all subjects lay in the supine position for 15 min in a quiet, air-conditioned room (23°C–25°C), as described by Cortez-Cooper et al.[31]. All subjects were informed to fast for at least 6 h without ingesting caffeine and alcohol for 12 h before testing. Then, CAVI, BP, and heart rate (HR) were measured using an automated VaSera VS-1500AE/AN device (Fukuda Denshi, Tokyo, Japan)[28,30,32]. This automated device noted the BP and HR in both brachial and ankle locations of the supine subjects, and the procedure conformed strictly to the American Heart Association guidelines[33]. Both the left and right CAVI values were automatically calculated from an electrocardiogram (ECG), phonocardiogram, and brachial and tibial wave forms [34]. Prior to normal assessment, four standard cuffs were positioned around the left and right upper arm and ankles with ECG leads linked to the wrist and a microphone located on the mid breastbone for phonocardiography. Vascular length (VL) was indirectly assessed from the height of the subjects by using the following formula[34]: $VL = 0.77685 \times \text{height (cm)} - 1.7536$. The ECG on the wrist and the phonocardiogram at the mid breastbone was used to detect the initial notch of pulse wave at the heart and ankle joint. The upper and lower limb BP were measured using the oscillometric method, whereas the HR was recorded using the ECG module of the VaSera device. Then, the right and left CAVI values in each subject were automatically analysed using the device.

2.3.2. One-repetition maximal strength assessment

Each subject completed the baseline and follow-up 1RM before and after the 6-week training programme in the same order: barbell squat, bench press, dead lift, and seated leg flexion. The 1RM tests conformed to the prescription and guidelines of the American College of Sports Medicine[2]. The 1RM was measured by gradually increasing the weight lifted until each subject failed to lift the current weight through the whole exercise process. The 1RM test was completed through approximately 5 trials, with the rest period between each trial being approximately 1–2 min. Firstly, the subjects warmed up for 5 min on a paddle ergometer at a perceived exertion level 3 (on the CR 10 Borg scale), followed by familiarisation with each testing movement pattern, especially the leg flexion machine for lower limbs. Because the subject was in a seated position, the hip angle was approximately 110°. With verbal encouragement, the subjects attempted to perform a concentric of the right and left leg flexion starting from the extended position of 180° to reach the approximate flexion of 70° against the resistance determined by the loads (kg) selected on the weight back.

2.3.3. Handgrip strength assessment

Handgrip strength was assessed using a WCS-99.9 Grip-A manual dynamometer (Yilian, Shanghai, China) with a precision of 0.1 kg. The left and right hands of subjects were assessed twice separately, and the highest value was recorded. The relative value of the handgrip strength data was transformed by weight as follows: Handgrip strength (N/kg) = measured values $\times$ 9.8/body weight. The constant 9.8 illustrates the conversion factor from kg to N[35].

2.3.4. Body composition

The height and weight were measured using a portable stadiometer and an electronic scale before and after a 6-week regular resistance training intervention. Then, the body mass index (BMI) was calculated according to the following formula: BMI = weight (kg)/height(m)². The body composition was assessed using bioelectrical impedance (Tanita MC-980MA, Tokyo, Japan), with the subjects wearing light clothes and no footwear. This detection method can measure the changes in human body composition accurately with high validity[36].

2.4. Statistics

All baseline and post-intervention data were initially confirmed to be normally distributed by using the Bartlett's and Levene's test. Homogeneity of variance was tested before further statistical analyses. Thus, no transformation was required. Statistical analyses were performed using SPSS version 22.0 Windows (SPSS, Inc., Chicago, IL, USA). All pre- and post-intervention data are presented as mean $\pm$ standard deviation (SD). Pre-intervention parameters and body compositions between the two groups were compared using independent Student's *t* test. Changes in parameters were compared using a two-way repeated measures analysis of variance (ANOVA [time (pre vs post)] – group (TRT vs FRT)]. The Turkey's method was performed for post-hoc multiple comparisons when a significant F value was detected. A *p* value of <0.05 or <0.01 was considered statistically significant.

3. Results

Tables 3, 4, and 5 present the characteristic parameters of healthy men before and after 6 weeks of resistance training. No significant differences were observed between the two groups before intervention for body composition, hemodynamic characteristics, and 1RM strength (all *p* > 0.05). No training-related injuries were observed in the TRT and FRT groups. No participant quit the study.

After 6 weeks of intervention, body fat decreased significantly (*p* < 0.01) and lean body mass increased significantly (*p* < 0.05) in both groups. However, body weight and BMI decreased significantly (*p* < 0.05) in the TRT group (Table 3). No significant difference was observed in the resting HR between the two groups.

Table 3

Changes in body composition following 6 weeks of resistance training in the two groups

Variable	TRT(n=15)		FRT(N=14)	
	Pre	Post	Pre	Post
Age(y)	22.1±2.9	NA	20.9±2.7	NA
Height(cm)	176.6±5.4	NA	176.7±6.0	NA
Body weight(kg)	77.9±11.6	76.4±9.6*	73.4±10.2	73.5±9.5
BMI (kg/m ²)	24.9±3.1	24.4±2.5*	23.4±2.6	23.5±2.4
Body fat (%)	18.8±5.8	16.5±5.3**	16.7±4.6	15.3±4.7**
Lean body mass(kg)	59.5±5.4	60.4±4.9*	57.7±6.7	58.8±5.9*
Resting HR(b/min)	59.0±10.0	59.1±9.9	64.2±11.3	61.1±11.1

BMI, body mass index; HR, heart rate; TRT, traditional resistance training; FRT, functional resistance training; Pre, before intervention; Post, after intervention. * $p < 0.05$, ** $p < 0.01$, Pre vs Post. Data are means $\pm$ SE.

Table 4 presents the hemodynamic characteristics of the two study groups before and after 6-week resistance training. No significant difference was observed in the supine SBP, diastolic BP, mean BP, pulse pressure, R-CAVI, and L-CAVI (all $p > 0.05$) between the two groups, and no significant changes were observed between the two groups before and after training. After 6 weeks of training, although R-CAVI and L-CAVI were significantly decreased ($p < 0.05$) in both TRT and FRT groups, the L-CAVI in the TRT group did not exhibit a significant decrease (Fig. 2).

Table 5 presents the results of the 1RM strength taken for the two study groups before and after 6-week resistance training. Maximal muscular strength significant increases were observed over time in barbell squat, bench press, dead lift, leg flexion right, leg flexion left, handgrip right, handgrip left, and mean handgrip in the TRT and FRT groups ($p < 0.01$). No significant differences were observed in the strength between the TRT and FRT groups (all $p > 0.05$).

Table 4

Hemodynamic characteristics before and after 6 weeks of resistance training period

Variable		Pre	Post	Two-way ANOVA		
				Group	Time	Interaction
Systolic BP (mmHg)	TRT	127.1±12.3	124.8±12.1	F=0.310	F=0.757	F=0.002
	FRT	128.8±7.6	126.2±9.3	P=0.582	P=0.392	P=0.967
Diastolic BP (mmHg)	TRT	72.9±5.8	73.0±6.1	F=0.010	F=0.880	F=1.047
	FRT	74.6±6.0	71.6±7.0	P=0.920	P=0.357	P=0.315
Mean BP (mmHg)	TRT	91.0±7.6	90.3±7.0	F=0.128	F=0.996	F=0.379
	FRT	92.7±5.7	89.8±6.6	P=0.723	P=0.327	P=0.543
PP (mmHg)	TRT	54.3±8.5	51.8±10.7	F=0.293	F=0.206	F=0.469
	FRT	54.1±7.2	54.6±8.9	P=0.593	P=0.653	P=0.499
R-CAVI(m/sec)	TRT	6.2±0.6	5.7±0.6*	F=4.562	F=10.981	F=0.004
	FRT	5.9±0.5	5.3±0.6*	P=0.042	P=0.03	P=0.950
L-CAVI(m/sec)	TRT	6.2±0.6	5.7±0.6	F=3.470	F=9.826	F=0.244
	FRT	6.0±0.6	5.4±0.6*	P=0.073	P=0.04	P=0.625
BP blood pressure, PP pulse pressure, R-CAVI right cardio-ankle vascular index, L-CAVI left cardio-ankle vascular index. * p < 0.05, Pre vs Post. Data are means ± SE.						

Table 5

Changes of maximal muscular strength before and after 6 weeks of resistance training

	TRT(n=15)			FRT(N=14)		
Variable	Pre	Post	Δ%	Pre	Post	Δ%
BS (kg)	116.0±19.9	147.5±15.1**	29.8	114.3±16.0	148.9±15.1**	31.6
BP (kg)	75.0±9.8	89.3±10.9**	19.7	71.4±10.3	85.9±10.4**	20.9
DL (kg)	118.7±21.3	139.0±16.7**	18.7	110.0±25.4	129.8±18.4**	20.6
R-LF (kg)	43±6.5	50.7±8.0**	18.0	39.3±6.8	49.6±8.9**	26.9
L-LF (kg)	43.7±6.9	49.7±7.2**	14.2	41.1±8.4	49.6±9.9**	22.7
R-Hg (kg)	42.0±7.0	45.7±5.5**	9.9	41.4±8.9	47.0±6.9**	15.4
L-Hg (kg)	41.7±5.4	46.0±5.5**	10.9	39.7±8.4	43.9±8.4**	11.2
M Hg (kg)	41.8±6.0	45.9±5.2**	10.3	40.5±8.4	45.8±8.4**	13.4
M Hg (N/kg)	5.4±1.0	5.9±0.8**	12.4	5.4±0.8	6.1±0.8**	13.6

BS barbell squat, BP bench press, DL dead lift, R-LF right leg flexion, L-LF left leg flexion, R-Hg right handgrip, L-Hg left handgrip, M Hg mean handgrip, ** p < 0.01, Pre vs Post. Data are means ± SE.

4. Discussion

The present study exhibited that the 6 weeks of supervised TRT and FRT programme with similar training volume increased maximal strength and reduced R-CAVIA and L-CAVI in untrained healthy men. Additionally, it exhibited that the CAVI embodied AS from the aorta to the ankle and was adjusted by BP[30]. To the best of our knowledge, none of the studies have investigated the maximal strength and AS following short-term functional resistance pattern in healthy men. The present study exhibited that FRT with unstable surface can lead to a higher lean body mass and maximal muscular strength compared with TRT in healthy men. On the other hand, no significant changes were observed in the hemodynamic parameters (HR, systolic BP, diastolic BP, pulse pressure, mean BP, and R-CAVI_{TRT group}), indicating that the FRT programme was a better exercise pattern for improving muscular performance and vasculature in healthy men than TRT.

The TRT programme is effective for the enhancement of functional performance and prevention of sarcopenia[37]. However, studies conducted on different types of resistance training in individuals have indicated contradictory outcomes in AS changes. For example, Miyachi et al.[20]. demonstrated that 4 months of regular whole-body high-intensity resistance training decreased approximately 20% of cardio arterial compliance in young men. Ozaki et al.[17] also reported that carotid AS decreased and 1RM strength increased following 6 weeks high-intensity resistance training in young men. These findings are concurrent with those of our study. Thus, the present study suggested that the traditional high-intensity and moderate-intensity FRT may favourably influence AS. A lower training load was better than a higher

load when similar training volume was performed (R-CAVI decrease: 7.4% vs. 8.2%; L-CAVI decrease: 6.2% vs. 9.4%).

On the other hand, only two studies have demonstrated the effects of resistance training on CAVI in adults. Yasuda et al. used the blood flow-restricted low-intensity resistance training and exhibited an increase in the maximum muscle strength; however, no changes were observed in AS (CAVI)[38]. Li et al. exhibited that 70% 1RM of lower limb acute resistance training and whole-body resistance training can significantly reduce the levels of CAVI in young people[39]. However, a few studies have indicated that high-intensity resistance training has an undesirable effect on AS[20,40,41] as it caused an increase in AS in healthy young men. The mechanism of the reduced AS following resistance training is unclear. However, these conflicting outcomes may be explained by several factors such as training load, volume, sets, repetitions, and duration. The most notable difference between the current resistance training programme and those used in other studies is that we strictly controlled the training volume of the two groups during the training process. The training intensity in the TRT and FRT groups was 70% 1RM and 40%–50% 1RM, respectively. Moreover, several studies tended to perform fewer exercises[23,42], more sets[43], or lower training frequencies[44], all of which are not suggested for ideal muscular strength and lean body mass gains. Moderate-intensity resistance training is adopted to maintain health and safety in all populations[37]. Thus, we speculate that the FRT programme with a low training load plays a crucial role in promoting arterial function under the similar training volume, sets, repetitions, and interval periods.

Two different modalities of resistance training, which differed in surface condition and intensity, were considered in the present study. The 1RM strength parameters of upper and lower limb and muscle mass observed in our findings are consistent with those indicated by others in similar studies[45–49]. Kibele and Behm reported that the TRT characteristics were to perform higher overload weights than in FRT with unstable conditions[50], and to produce similar muscle strength responses by changing surface conditions[49]. The comparison of the data between the two groups exhibited that although forces were applied without overload to the upper and lower muscles in the FRT group when using an instability device for training, strength enhancements were probably related to the increase in trunk and lower muscle activation[51], sympathetic transmission, and recruitment of motor neurons, which may endorse intramuscular and intermuscular coordination and cooperation[52] and make the agonist muscle activation more economic as well, thereby enhancing the strength performances.

Additionally, the greatest strength enhancements were observed in the lower limbs (e.g., Barbel Squat, BS 29.8% increase for TRT vs 31.6% increase for FRT) because the selected motor patterns were mainly standing and lower limbs such as the Bulgarian split squats with BOSU ball. Peter[53] also reported that the centre of gravity tends to swing as the body moves along a vertical axis, increasing the degree of lower limb instability, which could be conducive to trunk and lower limb muscle activation[51] and intramuscular and intermuscular coordination.

The present study has certain limitations. The participants were limited to healthy young men, and therefore, the outcomes could not be generalised to women or individuals with other chronic diseases

such as diabetes, heart disease, and hypertension. Additionally, the intervention duration of 6 weeks may not have been long enough to cause significant changes in maximal strength and AS between the two groups. On the other hand, due to the lack of a control group, the results of maximal strength and hemodynamic characteristics between the two group only exhibited the main effects of time without the time $\times$ group interaction effect. Therefore, future studies with a larger sample size and intervention period are required to highlight which resistance training pattern is more beneficial for health promotion.

5. Conclusions

The 6-week TRT and FRT with unstable device decreased AS and body fat, and increased lean body mass and upper and lower limbs maximal strength in healthy young men. Although studies have indicated controversial effects of different resistance training patterns on AS indices, no significant effect has been observed on other vascular profiles from both the TRT and FRT programmes. Thus, both TRT and FRT with unstable surface and under similar training volume can be safely used for preventing and improving CVD in young men.

Declarations

Author Contributions:

CW. Z and SM. B contribute to the conceptualization and design of the study. CW. Z, Q. L and L. Z contributed to data collection. SM. B summited the methodology. CW. Z conducted the formal analysis and wrote the first draft of the manuscript. CW. Z and SM. B review the manuscript. All authors have read and agreed to the published version of the manuscript.

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Institutional Review Board Statement:

The study was conducted according to the guidelines of the Declaration of Helsinki, and approved by the Capital University of Physical Education and Sports in Haidian District, Beijing, China after institutional ethics clearance. Written informed consent has been obtained from the patient(s) to publish this paper.

Data Availability Statement:

Datasets used and/or analyzed during the study are available from the first author on reasonable request.

Competing interest:

The authors declare no conflict of interest.

Consent for publication:

Not applicable.

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Figures

Figure 1

Flow of participants through the study

(a)

(b)

Figure 2

(a) Comparisons of right cardio-ankle vascular index Pre and Post resistance training between TRT and FRT groups; (b) Comparisons of left cardio-ankle vascular index Pre and Post resistance training between TRT and FRT groups. *p < 0.05, Pre vs Post.