Whole-body Functional and Traditional Resistance Training are equally effective in increasing Muscular Fitness and Performance Variables in Untrained Young Men

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Abstract

Background

Functional resistance training (FRT) has been proposed as a safety alternative to traditional resistance training (TRT) for increasing neuromuscular adaptation capacity and improving certain muscular strength and competitive performance. The present study sought to compare the effects of 6 weeks of whole-body functional and traditional resistance training on muscular fitness and performance variables in untrained young men.

Methods

29 untrained healthy young males aged 18–29 years who were randomly assigned to 6 weeks of functional resistance training (at 40% 1RM, 4-5 sets of 20 repetitions, 3 times/week) or traditional training (at 70% 1RM, 4-5 sets of 12 repetitions, 3 times/week). All subjects underwent numerous tests before and after the 6-week training such as upper and lower limb circumferences, maximal strength (barbell squat, bench press, dead lift, right leg flexion), power (throwing ability, jumping ability) and physical performance (sprint achievement, pull-up, handgrip strength). Internal training load variables was assessed by ratings of perceived exertion (RPE).

Results

(1) Both resistance training protocols improved muscular fitness and physical performance, no difference was observed between groups. However, only TRT protocols decreased body mass (-1.5kg, p < 0.05) and BMI (-0.5 kg/m², p < 0.05). Internal training load variables between groups were no difference over a 6 weeks training period.

Conclusions

In conclusion, there is no difference between 6 weeks of whole-body functional resistance training compared to traditional resistance training on muscular fitness and performance.

Trial registration: ChiCTR2100048485. Registered 09 July 2021, http://http://www.chictr.org.cn/

Background

Functional resistance training (FRT) with unstable state is a new form of specific training for fitness, although it was originally used to prevent and treat functional and partial deterioration in elderly, patients with stroke[1, 2], and postoperative rehabilitation patients[3]. It is reported that resistance training under unstable or unbalance condition may provide the instability that can happen with performance of daily activity, job, and sport environment, providing more beneficial training adaptations transfer[4]. Moreover, similar exercises performed under unstable condition (e.g., BOSU ball, swish ball, balance disc) as compared to stable condition (e.g., bench, ground) shown to increase athletic physical capacities (e.g., muscular strength, power and speed, etc.)[4–6] and ratings of perceived exertion (RPE), because physical capacities play a crucial role to determine players' competitive ability. Conceptually, FRT, which emphasizes synchronized, multidimensional, and multiple joint movement modes to train muscles with dynamic exercises and continuous changes on unstable surfaces[7]. Also, Boyle [8] believed that the essence of FRT is purposeful training. It is a multidimensional exercise in stable control and weight training supported by body part. Therefore, instability and low-load are the most dramatic characteristics of FRT, which is different from traditional resistance training (TRT). While TRT methods are generally designed for exercise single individual muscle to enhance physical capacities by gradually increasing training load in fixed position or stable position. However, TRT has been reported that improving physical capacities is rarely transferred to competitive performance on the arena[5], and most of TRT approaches are not multi-articular and multiplanar as these characteristics seem to provide a foundation for improving competitive performance[9, 10].

Previous studies have reported the effects of FRT were generally center on athletes, older adults and patients with certain disease and seldom involved in healthy untrained young individuals. For example, a systematic review[5] concluded that FRT significantly improves athletes’ muscular strength, power, speed, agility, but no significant impacts were found in muscular endurance and anthropometric variables where FRT was performed. Bale and Strand[11] reported that 4-week FRT of the lower limbs promoted functional performance and muscular strength more that TRT in 18 subacute phase post stroke patients. Similarly, Abbaspoor et al. [12] also indicated that 8-week combined FRT might be a useful training mode in increasing walking speed, quadriceps and handgrip
strength in the multiple sclerosis (MS) women. Tomljanović et al.[4] studied healthy, young kinesiology students during 5-week program, and demonstrated that FRT improved postural control and coordination, while TRT augmented the energetic potential of trained musculature, which brought about an increase in power qualities. Among the few studies that dealt with healthy, inexperienced individuals suggested that instability resistance training, which implemented lower forces, can improve strength (1RM)[13], power[14], movement velocity and jump ability[15] similarly to the TRT program under stable conditions employing heavier loads. Nevertheless, these studies only involved the effects of local exercise on physical capacities. There are no studies to date that have compared whole-body instability and traditional resistance training programs and resistance training-induced internal training load changes in consecutive weeks under unstable and stable conditions.

It is obvious that from the brief literature results above, which are lack of studies on the effects of whole-body FRT and TRT under equal-volume in young and untrained individuals. Also, data are in pressing demand for the different effects of whole-body FRT and TRT programs on muscular fitness, certain specific performance variables, and internal training load changes. Thus, the objective of the current study was to compare the difference effects of 6-week whole-body FRT and TRT on maximal muscle strength (1RM test and handgrip strength), power (throwing ability, jumping ability), muscle endurance and physical performance measures (e.g., sprint achievement, pull-up,) in young, untrained men. Furthermore, to assess the training-induced internal training load changes throughout the training period using PRE scale. Our hypothesis is that the whole-body FRT program will enhance muscular fitness and performance variables more than TRT program of young untrained men.

Methods

General design

The current study was designed as a randomized controlled trial. All the participants were randomly assigned using the website http://randmizer.org/ (Social Psychology Network, Connecticut, USA) into either a 6 weeks traditional resistance training group or a functional resistance training group. The trial was prospectively registered at the http://www.chictr.org.cn/ as ChiCTR2100048485, and ethical approval was granted by the Capital University of Physical Education and Sports ethical committee. Prior to study initiation, all the participants were informed of the risks and requirements of the training program, and voluntary consent was obtained from all of them, and this paper also follows the CONSORT statement[16].

Participants

The sample size was estimated based on a similar experimental design[17]. In view of an effect size $r^2 = 0.30$ with a power of 0.80 and significance level of 0.05[18], the minimum sample size of 24 (12 per group) was found to be adequate using repeated measures within–between interaction (G*Power 3.1; Heinrich Heine, Dusseldorf, Germany). Considering the 15% sample loss, a sample size of 28 was deemed sufficient for the present study. A total of 31 untrained individuals volunteered to participate in this study who were initially screened at the Capital University of Physical Education and Sports in Haidian District, Beijing, China. All the participants were recruited through printed advertisement and by word-of-mouth. The inclusion criteria for the selection of participants were as follows: (1) ≥18 years of age, (2) had not underwent any regular resistance-type training for at least 6 months before the initiation of the study, (3) did not regularly smoke, drink alcohol, or consume any medication, (4) without overt chronic diseases and sports injury. Consequently, 29 participants met the recruitment conditions, and two participants were dropped out because of personal reasons All the participants were randomly assigned into either the TRT group (n = 15) or the FRT group (n = 14). The participants in both groups were instructed not to attend any extra training and maintain normal eating habit throughout the 6 weeks training period.

Intervention

TRT protocols

The participants in both groups were trained for 6 consecutive weeks, 3 times per week, 18 sessions in total, with each session lasting for at least 60min. Each session time length was divided as 5-10min warm-up on a wind ergometer before every workout, and the remaining 50min were regarded for performed the whole-body workout. The TRT program comprised 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 in stable condition at 70% of their 1-repetition maximum (1RM) to volition fatigue, 4–5 sets of 12 repetitions, with 1–2 min of rest between the sets.
FRT protocols

The FRT group performed same training exercises as the TRT group; however, unstable devices (e.g., BOSU ball, swish balls, and balance discs) were used to provide unstable condition. In addition, an unstable training condition may not provide the same intensity of overload as TRT under stable conditions considering safety factors[19]. 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. We controlled the equivalent of the total training volume between the two groups, and the repetition in the FRT group was calculated using the following formula: 70% 1RM lifting weight (kg) × repetition (TRT group)/40%1RM to volition fatigue, with 1–2 min of rest between the sets. Thus, FRT group performed at 40% 1RM, 4-5 sets of 20 repetitions, with 1–2 min of rest between the sets. Table 1 presents the specific training protocol for the TRT and FRT groups. The

| Variables                  | Group       | S | Rep | TI (KG)             | Rest | TV (kg) |
|----------------------------|-------------|---|-----|---------------------|------|---------|
| 1-3 week                   | TRT         | 4-5| 12  | 70%1RM (81.2)       | 1-2min | 974.4   |
| Barbell Squat              |             | 4-5| 12  | 70%1RM (52.5)       | 1-2min | 630     |
| Bench Press                |             | 4-5| 12  | 70%1RM (82.5)       | 1-2min | 990     |
| Deadlift                   |             | 4-5| 12  | 70%1RM (52.5)       | 1-2min | 150     |
| Reverse Arm Curl           |             | 4-5| 15  | 10kg                | 1-2min | 630     |
| Leg Flexion                |             | 4-5| 15  | 70%1RM (29)         | 1-2min | 435     |
|                           |             |    |     |                     |       | 3179.4  |
| Barbell Squat&BOSU         | FRT         | 4-5| 20  | 40%1RM (54.8)       | 1-2min | 1096    |
| Bench Press&Swissball      |             | 4-5| 20  | 40%1RM (35.5)       | 1-2min | 710     |
| Deadlift&BOSU              |             | 4-5| 20  | 40%1RM (55.7)       | 1-2min | 1114    |
| Kettlebell Swing&BOSU      |             | 4-5| 15  | 10kg                | 1-2min | 300     |
| Bulgarian Split Squats&BOSU|             | 4-5| 15  | 70%1RM (29)         | 1-2min | 240     |
|                           |             |    |     |                     |       | 3460    |
| 3-6 week                   | TRT         | 4-5| 12  | 70%1RM (95.6)       | 1-2min | 1147.2  |
| Barbell Squat              |             | 4-5| 12  | 70%1RM (60)         | 1-2min | 720     |
| Bench Press                |             | 4-5| 12  | 70%1RM (91)         | 1-2min | 1092    |
| Deadlift                   |             | 4-5| 15  | 15kg                | 1-2min | 225     |
| Reverse Arm Curl           |             | 4-5| 15  | 70%1RM (32.5)       | 1-2min | 487.5   |
| Leg Flexion                |             | 4-5| 15  | 70%1RM (29)         | 1-2min | 3671.7  |
|                           |             |    |     |                     |       | 1222    |
| Barbell Squat&BOSU         | FRT         | 4-5| 20  | 40%1RM (61.1)       | 1-2min | 1222    |
| Bench Press&Swissball      |             | 4-5| 20  | 40%1RM (36.4)       | 1-2min | 728     |
| Deadlift&BOSU              |             | 4-5| 20  | 40%1RM (55.2)       | 1-2min | 1104    |
| Kettlebell Swing&BOSU      |             | 4-5| 15  | 24kg                | 1-2min | 360     |
| Bulgarian Split Squats&BOSU|             | 4-5| 15  | 20kg                | 1-2min | 300     |
|                           |             |    |     |                     |       | 3714    |

S sets, Rep repetitions, TI training intensity, TV training volume
strength assessments for all the participants were performed again after 3 weeks of intervention to ensure that the participants readjusted training intensities based on strength gains. To minimize 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.

**Testing procedures**

All participants performed the assessment process before and after the 6 weeks intervention. On the testing day, anthropometric measurements were carried out first, followed by 1RM barbell squat, 1RM bench press, 1RM dead lift, 1RM right leg flexion, and handgrip strength. After the strength tests, power (throwing and jumping ability) and physical performance (sprint achievement, pull-up) were assessed sequentially. In order to avoid the influence of muscle endurance test on the results of other tests, the muscle endurance measurements were arranged as the last item of all assessments. Participants were asked to not take any physical exercise on the day before.

**Maximal Strength measurements**

Each participant completed the baseline and follow-up 1RM before and after the 6 weeks training program 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[20]. Participants were measured by gradually increasing the weight lifted until failed to lift the current weight through the whole exercise process. The specific test was completed through approximately 5 trials, with the rest period between each trial being approximately 1–2 min. Firstly, the participant warmed up for 5 min on a paddle ergometer at a perceived exertion level 3 (on the CR 10 Borg scale), followed by familiarization with each testing movement pattern, especially the leg flexion machine for lower limbs. Because the participant was in a seated position, the hip angle was approximately 110°. With verbal encouragement, the participants attempted to perform a concentric of the dominant 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.

**Power — throwing ability**

To assess upper limbs power, a medicine ball throw (MBT) test was used. The participants seated behind a line marked on the floor in a sit position and were instructed to sit on the floor with their head, shoulder and back against the wall. The legs extended apart and facing the direction to which the medicine ball should be thrown. A 2 kg medicine ball was held using hands with arms in 90 ° of shoulder abduction, similar to a chest pass in basketball, as far as they could horizontally throw the ball. Additionally, participants were further instructed not to use their lower body for power generation and as far as possible with head, shoulder and back remaining full wall contact. Each participants completed three practice trials with 1-min rest between each trial. For further analysis, the mean throw being used.

**Power — jumping ability**

The Quattro Jump System (Kistler 9290AD, Switzerland) was used. All participants performed a countermovement jump (CMJ) test without arm swing from the portable force plate. Initially, participants stood straight on the force plate with the hands on the hip as the starting position and, when cued by the instructor, he squatted down rapidly to a 90 ° knee angle position and jumped straight up as high as possible with the hands on the hip consistently. During the ascending phase the participants left the force plate with the lower limbs fully extended and landed on the force plate with the 2 feet keeping knees straight to ensure that airtime was measured. As suggested by previous authors[21], the best of three consecutive trials, with appropriate rest between each trial, was used as final test result.

**Muscle endurance measurements**

Approximately 5-min after all tests were completed, participants were instructed to complete as many as possible for bench press and leg flexion. The same load (70%1RM) was used for pre and post intervention measurements as the previous study suggested[22]. According to 1RM test, participants were asked to achieve a full range of motion and proper technique. The repetition cadence was performed in 1 sec eccentric and 1sec concentric contraction. The maximal number of repetitions achieved and the volumed-load for each exercise was recorded for statistical analysis.

**Handgrip strength**

Isometric force 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 mean handgrip value was recorded. The relative value of the
mean handgrip strength data was transformed by weight as follows: Handgrip strength (N/kg) = measured values × 9.8/body weight. The constant 9.8 illustrates the conversion factor from kg to N.

**Physical performance measurements**

Measures consisted of a 30-m sprint and pull-ups. In the 30-m sprint test, participants were asked to sprint a distance of 30 m while passing through a photocell (Brower Timing System, USA). The participants commenced on the sound signal, which commenced the timer system. A photocell was used and placed at the 30-m gates. The timing results were recorded as a result of 30-m. The best of two consecutive test was selected for the statistical analysis.

The pull-ups test is performed starting position from a dead hang with the arms fully extended and locked and feet off the floor. The bar is clasped with hands in pronation separated by a distance wider than the shoulder. From this position, the body is lifted until the chin is higher than the bar. On the way down, our body must be straight hanging down from the bar with the arms are fully extended. This procedure is repeated until they can no longer finish a pull-up and record the number of pull-ups completed.

**Anthropometric measurements**

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. Additionally, body fat and lean body mass were assessed using bioelectrical impedance (Tanita MC-980MA, Tokyo, Japan), with the participants wearing light clothes and no footwear. Anthropometric measurements of the participants who fasted overnight (> 8 h) were simultaneously assessed before and after intervention.

**Quantifying internal training load**

The internal training load (ITL) was calculated using rating of perceived exertion scale (RPE-10). The total training volume were similar, but intensities of the training was different between the groups. The participants were inquired how intense their training was after the end of each training and filled in a category ratio scale (RPE-10). All participants were already previously instructed to the know the RPE-10 scale well. The recorded value was multiplied by the total duration of each training in minutes, resulting in internal training load (ITL). According to the formula as following: weekly internal training load (WITL) = the sum of 7 days ITL. Mean weekly ITL (MWITL) = WITL divided by 7. Monotony index (MI) = WMITL divided by its respectively standard deviation. Training strain (TS) = WITL multiply MI.

**Statistical analysis**

Statistical analyses were performed using SPSS version 22.0 Windows (SPSS, Inc., Chicago, IL, USA). All baseline and post-intervention data were initially confirmed to be normally distributed by using the Shapiro-Wilk's W test and it showed an appropriate normality of the distributions for all variables. All pre- and post-intervention data are presented as mean ± standard deviation. Independent sample t test was used to test the pre-intervention parameters difference between the two groups.

Training effects were analyzed using a mixed ANOVA of repeated analysis (2 training group and 6 times) was used to verify the internal training load (MI, TS, WITL, WMITL) within and between the different training conditions (stability and instability) over 6 weeks of resistance training. A mixed two-way repeated measures analysis of variance (ANOVA) ([time (pre and post training)] — training group (TRT and FRT)] was used to verify differences in muscular strength and physical performance between groups. When the significant interaction effects were found, additional independent t tests were performed to determine between-group differences.

The mean difference of change of muscular strength and physical performance for each group are presented, then the effect sizes calculated as partial eta square and converted to Cohen d, being classified as: "small" from 0 – 0.2, "medium" from 0.2 – 0.8, "large" higher than 0.8. A p value of <0.05 was considered statistically significant.

**Results**

**Participants**

Of 31 young men assessed for eligibility 29 participants in this study, as showed in the flow diagram (Fig. 1). Two men were dropped out of the personal reasons, mainly meniscus injury and not attend pre-test. All participants were randomly assigned into the
traditional resistance training (n=15) and functional resistance training group (n=14). Table 2 presents the main characteristics of the participants at baseline. No significant differences between groups were observed in terms of the age, height, body weight, body mass index, body fat and lean body mass. Additionally, all the participants in groups adhered to the 18 scheduled training sessions during the intervention period. No training-related injuries were observed and no participant quit the study.

**Anthropometric measurements**

After 6 weeks of intervention, a significant time x training group interaction (p = 0.044) was observed for body weight, with a decrease in body weight in TRT group (- 1.5kg, p = 0.027), but not in FRT group (+ 0.2kg, p > 0.05) (Table 2). Similarly, BMI also decreased in TRT group (- 0.5 kg/m², p = 0.030), but not in FRT group (+ 0.1 kg/m², p > 0.05). A main effect of time (p = 0.000) was observed in body fat percentage, which decreased in both groups without significant difference between training groups. Similar results were also observed when lean body mass was assessed. The lean body mass significantly increased in both groups (TRT +0.8kg, p = 0.031; TRT +1.1kg, p = 0.018, Cohen d = 0.18).

**Table 2 Change in anthropometric measurements as mean difference, statistical test of group difference and effect sizes as Cohen d**

| Metric            | TRT group (n=15) | FRT group (n=14) | P value | ES    |
|-------------------|------------------|------------------|---------|-------|
| Age (y)           | Pre 22.1±2.9     | Post 20.9±2.7    | NA      | NA    |
| Height (cm)       | Pre 176.6±5.4    | Post 176.7±6.0   | NA      | NA    |
| Body weight (kg)  | Pre 77.9±11.6    | Post 73.4±10.2   | 0.2     | 0.044 |
| BMI (kg/m²)       | Pre 24.9±3.1     | Post 23.4±2.6    | 0.1     | 0.041 |
| Body fat (%)      | Pre 18.8±5.8     | Post 16.7±4.6    | -1.4    | 0.050 |
| Lean body mass (kg)| Pre 59.5±5.4   | Post 57.7±6.7    | 1.1     | 0.633 |

BMI, body mass index, TRT, traditional resistance training, FRT, functional resistance training, differ difference, a p value for change between groups, ES effect sizes between groups as Cohens d, * p < 0.05, ** p < 0.01, main effect of time

**Muscle strength**

Table 3 presents the strength results. All the results of the 1RM tests showed significant main time effects (p < 0.05), and both groups improved dynamic strength in dynamic strength in all exercise analyzed. But no significant differences were observed in mean difference between training protocols (between group all p > 0.05), and the effect sizes indicated small to medium effects (Cohen d = 0.02 – 0.59).

Similarly, the training protocols increased muscle endurance (repetitions) for the bench press (TRT +10.1, p = 0.000, FTR +12.4, p = 0.000, Cohen d = 0.34), right leg flexion (TRT +8.1, p = 0.000, FTR +7.9, p = 0.000, Cohen d = 0.04) with a main effect of time (p < 0.001) and no difference between groups. Additionally, muscle endurance expressed as volume-load also significantly increased in both groups for the bench press (TRT +508.7, p = 0.000, FRT +587.9, p = 0.000, Cohen d = 0.25) and right leg flexion (TRT +251.3, p = 0.000, FRT +214.8, p = 0.000, Cohen d = 0.06) without significant difference between training groups (Table 3).

Isometric force was assessed via mean handgrip improved significantly (TRT +4.0, p = 0.000, FRT +4.9, p = 0.000, Cohen d=0.32), and the relative mean handgrip also revealed significant improvements (TRT +0.6, p = 0.000, FRT +0.7, p = 0.000, Cohen d=0.21). However, no significant difference was observed between training groups.
### Table 3
Change in muscle strength variables, muscle endurance and handgrip strength as mean difference, statistical test of group difference and effect sizes as Cohen d

| TRT group (n=15) | FRT group (n=14) | P value | ES    |
|------------------|------------------|---------|-------|
|                  | Pre              | Post    | Mean diff | Pre              | Post    | Mean diff |       |       |
| BS (kg)          | 116.0±19.9       | 147.5±15.1** | 31.5   | 114.3±16.0       | 148.9±15.1** | 34.6 | 0.590 | 0.20 |
| BP (kg)          | 75.0±9.8         | 89.3±10.9** | 14.3   | 71.4±10.3        | 85.9±10.4** | 14.5 | 0.959 | 0.02 |
| DL (kg)          | 118.7±21.3       | 139.0±16.7** | 20.3   | 110.0±25.4       | 129.8±18.4** | 19.8 | 0.913 | 0.04 |
| R-LF (kg)        | 43±6.5           | 50.7±8.0** | 7.7    | 39.3±6.8         | 49.6±8.9** | 10.4 | 0.126 | 0.59 |
| BP Rep           | 19.5±5.5         | 29.7±6.3** | 10.1   | 17.6±5.3         | 30.0±7.1** | 12.4 | 0.374 | 0.34 |
| VL (kg)          | 1033.2±341.4     | 1541.9±330.2 | 508.7 | 897.1±361.1      | 1484.9±375.5** | 587.9 | 0.510 | 0.25 |
| R-LF Rep         | 21.6±5.2         | 29.7±8.3** | 8.1    | 23.3±9.2         | 31.1±7.8** | 7.9  | 0.907 | 0.04 |
| VL (kg)          | 661.0±207.8      | 912.2±327.8** | 251.3  | 679.0±357.4      | 893.8±304.9** | 214.8 | 0.570 | 0.21 |
| M Hg (kg)        | 41.8±6.0         | 45.9±5.2** | 4.0    | 40.5±8.4         | 45.8±8.4** | 4.9  | 0.392 | 0.32 |
| M Hg (N/kg)      | 5.4±1.0          | 5.9±0.8** | 0.6    | 5.4±0.8          | 6.1±0.8** | 0.7  | 0.495 | 0.26 |

BS barbell squat, BP bench press, DL dead lift, R-LF right leg flexion, Rep repetition, VL volume-load, M Hg mean handgrip, TRT traditional resistance training group, FRT functional resistance training group, differ difference, a p value for change between groups, ES effect sizes between groups as Cohens d, ** p < 0.01, main effect of time

### Power and physical performance

As showed in Table 4 we observed a significant difference in power variables. Medicine ball throw increased by 0.4m in TRT group and by 0.3 in FRT group. CMJ increased by 6.7cm and 5.0cm, respectively, in TRT and FRT, while no significant difference was found between groups, and the effect sizes indicated medium effects (Cohen d = 0.25 for MBT and 0.26 for CMJ) in favor of the functional resistance training group.

We observed a general improvement in the physical performance test in both groups; however, any of the parameters analyzed were significant different from baseline. 30-m sprint increased in TRT group by 0.3s (p = 0.002) and by 0.3 in FRT group (p = 0.000), and similarly, when expressed for pull-ups, TRT group improved by 4.5 compared to 4.0 in FRT group. However, these results were not found to differ between training protocols, and the effect sizes indicated medium effects for 30m sprint (Cohen d = 0.39) and pull-ups (Cohen d = 0.36), respectively.
The present study was designed to compare the effects of the 6-week supervised whole-body TRT and FRT protocols with equal volume on the muscular fitness and physical performance in untrained healthy men. The main finding of this study was that both whole-body resistance training modalities (traditional and functional resistance training) produced similar training effects in untrained healthy young men over a 6-week intervention period. No significant differences were detected with the training-induced improvements between training protocols in pre to posttest maximal strength, repetitions of bench press and leg flexion, isometric force production, MBT distance, CMJ height, 30m sprint time, pull-ups, body fat and lean body mass. Regarding internal training load, no significant in MI, TS, WITL, WMITL between training groups were observed over the 6-week training protocols. In a study, Sparkes and Behm[15] reported that unstable resistance training had a tendency for a smaller instability-induced force deficit compared to the force produced with the stable training. However, there was no difference between TRT and FRT groups when we assessing muscular

### Table 4
Change in power variables and physical performances as mean difference, statistical test of group difference and effect sizes as Cohen's d

|                      | TRT group (n=15) | FRT group (n=14) | P value | ES |
|----------------------|------------------|------------------|---------|----|
|                      | Pre              | Post             | Mean diff | Pre | Post | Mean diff |       |     |
| MBT (m)              | 5.9±0.4**        | 6.2±0.4**        | 0.4      | 5.9±0.7      | 6.3±0.6**      | 0.3      | 0.513 | 0.25 |
| CMJ (cm)             | 59.1±9.1**       | 65.9±5.2**       | 6.7      | 61.3±10.7    | 66.3±10.3**    | 5.0      | 0.483 | 0.26 |
| CMJ power            | 20.7±2.9**       | 23.4±2.8**       | 2.7      | 20.1±3.8     | 23.1±3.0**     | 3.0      | 0.753 | 0.11 |
| 30m sprint(s)        | 4.1±0.3**        | 3.8±0.3**        | -0.3     | 4.1±0.2      | 3.7±0.2**      | -0.3     | 0.343 | 0.39 |
| Pull-ups             | 8.1± 3.5         | 12.5±3.7**       | 4.5      | 8.9±4.0      | 12.9±4.2**     | 4.0      | 0.303 | 0.36 |

MBT medicine ball throw, CMJ countermovement jump, TRT traditional resistance training group, FRT functional resistance training group, differ difference, a p value for change between groups, ES effect sizes between groups as Cohens d, ** p < 0.01, main effect of time

### Quantifying internal training load

There were no significant interaction effects between training groups for monotony index, training strain, weekly ITL, and weekly mean ITL (Table 5). However, there was only a difference in the FRT group for monotony index in week1 and week3 compared with week4 (increase 0.4 and 0.6, p < 0.05). Similarly, the training strain was also significantly increased in FRR group (increase 283.8 and 511.8, p < 0.05). No training group effect was observed for monotony index, training strain, weekly ITL, and weekly mean IT (all p > 0.05).

|                      | Group | Week1 | Week2 | Week3 | Week4 | Week5 | Week6 |
|----------------------|-------|-------|-------|-------|-------|-------|-------|
| MI                   | TRT   | 4.6±1.1 | 4.3±1.6 | 4.1±1.6 | 4.9±0.9 | 4.8±1.1 | 4.4±1.3 |
|                      | FRT   | 3.8±1.7 | 3.6±1.9 | 3.6±1.6 | 4.2±0.9*# | 4.5±1.4 | 4.3±1.5 |
| TS                   | TRT   | 5636.5±2304.1 | 5500.6±2599.4 | 5166.1±2345.4 | 6168.0±1741.9 | 6076.9±1901.7 | 5456.1±1793.9 |
|                      | FRT   | 4977.3±2599.5 | 4806.3±3028.3 | 4749.3±2222.1 | 5261.1±1199.6*# | 6187.4±2332.2 | 5724.1±2095.9 |
| WITL                 | TRT   | 1191.4±215.5 | 1230.0±177.3 | 1204.3±180.0 | 1221.4±170.7 | 1234.3±155.6 | 1242.9±106.4 |
|                      | FRT   | 1268.6±211.6 | 1290.0±202.1 | 1302.9±163.8 | 1234.3±180.3 | 1320.0±174.5 | 1320.0±150.7 |
| WMITL                | TRT   | 170.2±30.8 | 175.7±25.3 | 172.0±25.7 | 174.5±24.4 | 176.3±22.2 | 177.6±15.2 |
|                      | FRT   | 181.2±30.2 | 184.3±28.9 | 186.1±23.4 | 176.3±22.2 | 188.6±24.9 | 188.6±21.5 |

### Discussion

The present study was designed to compare the effects of the 6-week supervised whole-body TRT and FRT protocols with equal volume on the muscular fitness and physical performance in untrained healthy men. The main finding of this study was that both whole-body resistance training modalities (traditional and functional resistance training) produced similar training effects in untrained healthy young men over a 6-week intervention period. No significant differences were detected with the training-induced improvements between training protocols in pre to posttest maximal strength, repetitions of bench press and leg flexion, isometric force production, MBT distance, CMJ height, 30m sprint time, pull-ups, body fat and lean body mass. Regarding internal training load, no significant in MI, TS, WITL, WMITL between training groups were observed over the 6-week training protocols. In a study, Sparkes and Behm[15] reported that unstable resistance training had a tendency for a smaller instability-induced force deficit compared to the force produced with the stable training. However, there was no difference between TRT and FRT groups when we assessing muscular
fitness, so it was possible that unstable resistance training may be more effective in force production as well during a brief training period[15].

As mentioned previously, the most notable difference between the resistance training program used in the present study and other studies is the strictly controlled training volume of the two groups during the training process in the present study. Despite differences in the training intensity and condition, the increased muscular strength and lean body mass exhibited no difference between both groups in our study. Several studies have employed fewer exercises[23, 24], more sets[25], or lower training frequencies[26], all of which are not favorable for ideal muscular strength and lean body mass gains. Probably, skeletal muscle adaptations (strength and muscle mass) were determined in response to equal-volume resistance training with divergent training strategies. Kubo et al.[27] reported that the increase in muscle volume was similar among the three training protocols, namely 4RM, 8RM, and 12RM, under equal training volume. Similarly, Colquhoun et al.[28] found that three resistance training sessions per week provided similar increase in muscle strength and fat-free mass compared with six sessions per week under equal volume condition. Hence, we assume that the muscle adaptation status could be same in response to TRT and FRT protocols under an equal volume.

Two modalities of resistance training, which differed in terms of surface condition and intensity, were considered in the present study. The 1RM strength parameters of the upper and lower limb and muscle mass observed in our study are consistent with those indicated in similar studies[29–31]. Kibele and Behm[19] reported that the traditional resistance training characteristics were to perform higher overload weights than in functional resistance training, which could also obtain similar muscle strength responses with the use of lower resistive load under unstable condition. The comparison of data between the two groups exhibited that despite 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[32], sympathetic transmission, and recruitment of motor neurons, which may endorse intramuscular and intermuscular coordination and cooperation[33] and make the agonist muscle activation more economic, thereby enhancing the strength performances. Furthermore, the greatest strength enhancements were observed in the lower limbs (e.g., Barbel Squat, 29.8% and 31.6% increase for the TRT and FRT groups, respectively) because the selected motor patterns in both groups were mainly standing and lower limbs such as the Bulgarian split squats. Peter[34] reported that the center 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[32] and intramuscular and intermuscular coordination.

However, there were limited literatures obtainable comparing the effects of TRT and FRT on muscular endurance, which highlights the significance of this study. Interestingly, improvements on repetition of bench press and leg flexion, TRT and FRT protocols were similar between groups. In relation to volume-load, improvements were also detected in the two groups after 6 weeks training. Although resistance training consisting of high-intensity compared to lower-intensity seem to elicit greater metabolic stress, according to the present study the specific stimuli provided by traditional protocol does not to appear to translate into enhanced muscular endurance.

The evidence suggests that high repetitions (≥20RM) in lighter loads is efficient for enhancing muscular endurance under equal training volume. For example, Campos[35] reported that no difference was observed between low, moderate and high repetition groups under approximately equal volume despite excellent muscular endurance for the high repetition group, and our results also test and verify this point. Therefore, we speculate that traditional high-intensity/instability low-intensity induces similar capillarization and mitochondrial adaptation, and the potential mechanism for enhanced muscular endurance following instability resistance training could also be the result of better tolerance of unstable condition.

Our study is the first to investigate the effect of whole-body FRT on the CMJ in untrained young men and compare the effects of 6 weeks TRT and FRT and indicates that both were equally beneficial in promoting the jumping height. So far, most studies have found that traditional resistance training improves jumping ability[4, 6, 36]. However, fewer studies focused on the effects of whole-body functional resistance training on vertical jumping ability. Two studies on athletes demonstrated that vertical CMJ was increased after long-term functional resistance training[6, 37], whereas these two studies do not seem to prove the idea that functional resistance training is of great advantage for improve explosive power, and it is important that a study from non-athletes has verified and supported this objective[38]. Additionally, two studies results showed that FRT protocol did not improve jumping abilities[4, 15]. This finding is inconsistent with our study. We found that two main reasons are responsible for why the FRT protocol did not improve participants jumping abilities. Firstly, their FRT protocol mainly performed upper limb exercise, which is the biggest difference from our whole-body exercise. Secondly, their participants were previously trained men that may not be affected by the same degree of stimulation as the untrained young men. In view of the reasons mentioned above, the improvement of jumping abilities induced by
our FRT protocol may be primarily related to neuromuscular coordination and adaptation. And meanwhile, previous studies indicated that strength training can promote jumping performance, approximately by 5-15% [39, 40]. Thus, our TRT protocol seem to increase the force produced by joint, which lead to an improvement of jumping ability.

Several dominant factors determining the explosive strength performance, such as force produced by joints, force development rate/muscle power produced by muscles and neural coordination of movement [4]. Considering that our FRT protocol belonged to whole-body exercises, it seems that, accord with the development of throwing abilities, the FRT group obtained enough training stimulation for this variable, which made their throwing ability significantly improved. We deduced that the improvement of throwing is mainly relevant to the neuromuscular coordination. Especially, when training using instable device, more emphasis is placed on trunk region control and muscular coordination. Seeing that multiple joints participate in action during MBT test, including eccentric-concentric contractions of the shoulders and trunk regions mostly. Therefore, significant improvement on throwing ability is logical by our FRT protocols.

In regard to the physical performance tests, we observer a significant improvement in 30-m sprint and pull-ups from baseline, and no difference was noted between the groups; therefor, the TRT and FRT protocols improved the performance of 30-m sprint and pull-ups. Previous studies showed that the functional resistance training yielded significant positive results on straight line sprint ability [6, 37]. The inconsistent study results probably caused by different training protocols. Especially, the effects on explosive performance may be result of improvements in functional status [5]. Campa et al. [41] indicated that functional movement patterns could improve the synergistic interaction between motor control and core stability compared with other resistance training methods. This finding may be attributed to the advantage of neuromuscular adaptation on eliciting better transfer of the strength growth to physical performance.

Regarding the body composition, our results indicated significant changes in body fat percentage and lean body mass between the groups, although the difference between the groups was nonsignificant in terms of these parameters. This result is consistent with that of a previous study [42]. Several studies have demonstrated the efficiency of resistance training in neuromuscular and metabolic stimulation to endorse tissue structure changes such as reduced adipose and muscle tissues [43, 44]. Another interesting result of the present study is that the body weight and BMI decreased significantly in the TRT group but not in the FRT group, which does not seem logical. Previous studies on the metabolic response to FRT found an average caloric expenditure of approximately 10.1 kcal for one-minute functional resistance training, which is higher than the expenditure of 5–9 kcal/min reported in studies examining traditional resistance exercise [45, 46]. Probably, the reason should be that the TRT group in the present study performed a high-intensity workout (at least 4–5 sets of 12 repetitions per training) until exhaustion and produced more energy consumption. Thus, we assume that the caloric expenditure of the TRT protocol is somewhat higher than that of the FRT protocol [4].

Finally, in term of internal training load, no difference in MI, TS, WITL and WMITL in the TRT group were observed over the 6 weeks training. On the other hand, a significant increased in MI and TS in the FRT group in week four. The American College of Sports Medicine suggested that periodic monitoring the training load to mitigate the adverse adaptation, because excessive training loads associated with low recovery is one of the main manifestations of overtraining. Also, the adjustments and willingness of workload in accordance with the training status of participants is indicated an effective strategy for improving physiology adaptation and promoting increased performance. The result of present study showed that the WITL of FTT group and TRT group are 1289.3 and 1220.7, respectively, which is slightly below the results presented by previous researchers [47, 48] who used RPE to quantify internal training load in players. Gabbett [49] demonstrated that the weekly internal training load of 3000-5000 increased more chance of injury by 50%–80%; however, less than 1250 per week also revealed the potential injury risk and did not improve physical fitness [50]. Therefore, using PRE during training period can help trainer adjust the training load when necessary. At the same time, in order to avoid high MI and TS [51], respecting the personality of participants, which is also an effective method to limit injury, since abrupt raise stemming from MI and TS were related to the occurrence of disease. Ferrari et al. [52]. reported significant associations between upper respiratory symptoms and TS throughout a competitive season in well-trained cyclists. However, the MI in two groups was higher than 2.0 (MI>2.0, means higher injury risk) in this study, no injury cases were observed, indicating that the use of PRE scale to monitor training load can reduce the adverse impact on participants.

Some limitations in this study should be noted. First, this study involved a limited number of performance variables, it would be necessary to include additional motor tests, such as static and dynamic balance, and agility tests in future research, since it is possible that the FRT protocol produced even more changes than TRT protocols in certain variables we observed in this study. Therefore, it would be interesting to compare the effects on specific motor-performance variables induced with FTR and TRT.
protocols. Next, the study participants were limited to untrained young men; thus, the outcomes could not be generalized to women or experienced individuals such as athletes. Moreover, the intervention duration was relatively short (only 6 weeks). Therefore, it is hardly to cause significant difference in muscular fitness and physical performance between the two groups. Future studies with a larger sample size and different participant types, and longer study periods are required to determine the excellent resistance training pattern for health promotion.

Conclusions

In summary, there is no difference between 6 weeks of whole-body functional resistance training compared to traditional resistance training on muscular fitness and performance. Hence, instability (FRT) and stable (TRT) resistance training were both effective method in the enhancement of fitness. Nevertheless, given the limitations summarized in this study, it is necessary to be cautious about the results. For enhanced muscle strength or performance, it is recommended based on this study that untrained youth first incorporate functional resistance training into their training regimes because of its lower load and more safety.

Abbreviations

FRT
Functional resistance training

TRT
Traditional resistance training

1RM
1-repetition maximum

BMI
Body mass index

RPE
Ratings of perceived exertion

MBT
Medicine ball throw

CMJ
Countermovement jump

ITL
Internal training load

WITL
Weekly internal training load

MWITL
Mean weekly internal training load

MI
Monotony index

TS
Training strain

Declarations

Ethics approval and consent to participate

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 all the participants of this study.

Consent for publication

Not applicable
Availability of data and materials

Datasets used and/or analyzed during the study are not publicly available but are available from the first author on reasonable request.

Competing interests

The all authors declare no conflict of interests.

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Authors’ Contributions

CW. Z and SM. B contributed to the conceptualization and designed 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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Investigator from the Capital University of Physical Education and Sports design the trial that this study was derived from, as a sub-study. The first author had full access to all the data of this study and had final responsibility for the decision to submit for publication. The first authors would like to thank all the patients who are willing to join in the study.

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Figures

**CONSORT 2010 Flow Diagram**

**Assessed for eligibility (n=31)**
- Excluded (n=2)
  - Not meeting inclusion criteria (n=1)
    - Suffer meniscus injury (n=1)
  - Declined to participate (n=0)
  - Other reasons (n=1)
    - Not attend pre-test (n=1)

**Randomized (n=29)**

**Allocation**
- Traditional Resistance Training group
  - Assessment Pre (n=15)
  - Allocated to Traditional Resistance Training for 6 Weeks
    - Received Allocated intervention (n=15)
    - Did not receive allocated intervention (n=0)
  - Assessment Post (n=15)
  - Missed Assessment Post (n=0)

- Functional Resistance Training group
  - Assessment Pre (n=14)
  - Allocated to Functional Resistance Training for 6 Weeks
    - Received Allocated intervention (n=14)
    - Did not receive allocated intervention (n=0)
  - Assessment Post (n=14)
  - Missed Assessment Post (n=0)

**Figure 1**

CONSORT flow diagram of participants’ training schedule through the study