

Circuit Weight Training on Stable and Unstable Surfaces: Differences in Energy Cost, Blood Lactate and Rate of Perceived Exertion

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Abstract: Unstable surfaces have been used in resistance training, but there are no studies that compared energy cost between stable and unstable surfaces in circuit weight training. This study compared energy cost, post-exercise peak blood lactate and perceived exertion rate between stable surface and unstable surface. Twenty healthy men (24.65 ± 3.48 years, 1.79 ± 0.08 m, 80.61 ± 9.14 kg and $11.86 \pm 3.49\%$ body fat) participated in the study. Test and retest of 15 maximum repetitions were performed on stable and unstable surfaces to define workload. The circuit weight training consisted of one set of 15 repetitions at 80% of 15 maximum repetitions in bench press, back squat, rowing bent prone, dead-lift, shoulder press, elbow extension and elbow flexion. Energy cost was measured by indirect calorimetry during and post-circuit weight training. Peak blood lactate and perceived exertion rate were measured post-exercise. Total energy cost was higher on unstable surface compared to stable surface (70.7 ± 10.0 vs. 66.6 ± 7.8 kcal; $p = 0.01$), as was perceived exertion rate (8.1 ± 0.9 vs. 7.6 ± 1.3 ; $p = 0.02$). However, peak blood lactate was higher on stable than unstable surfaces (13.6 ± 2.6 vs. 12.5 ± 1.9 mmol·L⁻¹; $p = 0.05$). In conclusion, circuit weight training on unstable surfaces can be performed with less weight in comparison to stable surfaces, thereby lowering mechanical stress on joints and bones, while still providing a higher metabolic impact.

Keywords: Circuit Method, Resistance Training, Energy Expenditure

1. Introduction

The effectiveness of resistance training to provide high energy cost (EC) during and especially after the training has been proven in several studies [1-4]. Such experiments show that during resistance exercise, EC changes according to various factors related to the training methodology and the use of additional equipment [5, 6]. Among them, it can be

mentioned exercises performed on unstable surfaces (US) [6] and the circuit weight training (CWT) [4, 7].

Studies involving resistance exercise on US and describing its effects in relation to the work produced are limited. Recently, higher EC in the bench press exercise on a Swiss ball was found, compared with the same exercise on a flat bench at 80% of one repetition maximum (1RM) [6]. On US, it is believed that the neuromuscular system is more

activated, compared with that on a traditional stable surface (SS), as it increases activation of the stabilizing muscles of the trunk [8, 9]. An increased activation would represent an additional stress to the musculoskeletal system, which could lead to an increase in EC. In addition, the CWT consists of a greater volume of training and reduced recovery interval between resistance exercises as opposed to non-circuit workout, and these are essential factors to increase EC [10-12].

A previous study compared, in ten trained men, the acute effect of the CWT with the traditional method (three consecutive sets for each muscle group) on EC and peak blood lactate (PBL) [13]. The results showed that the EC was similar in both protocols, except anaerobic EC was higher in the traditional method, together with PBL, due to consecutive sets and a subsequent increase in lactate production. In contrast, another study compared the PBL post- three different CWT in 11 women. The results were significantly higher in circuits with aerobic intervals between resistance exercises compared to other circuits [14]. However, the comparative measure of EC and PBL on different platforms of instability in CWT is still unknown.

The utilization of US during resistance training can change, EC, PBL and rate of perceived exertion (RPE), due to the degree of imbalance generated by the body. Previous experiments found a higher RPE assessed by the Borg scale in exercises performed on a Swiss ball compared with SS [15]. In contrast, a more recent study did not find a significant difference in RPE assessed by the OMNI_RES scale in the bench press exercise on a Swiss ball vs. traditional bench press. It is noteworthy that the studies above verified the responses after a single resistance exercise [6].

Thus, training methods performed in unstable surfaces may be an additional tool for professionals, as long its effects on metabolism are proven. Therefore, this study aimed to

compare the acute effect of CWT on EC, PBL and RPE on SS and US. It was hypothesized that EC, PBL and RPE would be higher in the unstable condition of exercise.

2. Methods

2.1. Subjects

Twenty healthy, recreationally active men (24.65 ± 3.48 years, 1.79 ± 0.08 m, 80.61 ± 9.14 kg and $11.86 \pm 3.49\%$ body fat) with previous experience in resistance training (6.25 ± 4.61 years) participated in the study. The sample was selected in a non-probabilistic way and inclusion criteria were: men aged between 19 and 30 years, who had not suffered any type of musculoskeletal injury, responded negatively to all items of the Physical Activity Readiness Questionnaire (PAR-Q) and who had been involved in resistance training for more than 12 months. The sample excluded subjects who consumed drugs, alcohol and/or who smoked and had previous experience in resistance exercise on US. The research was approved by the Ethics Committee for Human Research (Protocol n^o 204.521/2013). All subjects signed the Informed Consent in accordance with Resolution 196/96 of the National Health Council.

2.2. Experimental Design

The research was conducted across seven testing sessions. In session 1, after measurement of anthropometric variables, the subjects underwent a series of familiarization with the US, performing three sets of 15 repetitions at approximately 60% of maximum RPE. In sessions 2, 3, 4 and 5, the volunteers were submitted to test and retest of 15 maximum repetitions (15RM) on both surfaces [16]. In sessions 6 and 7, EC, PBL and RPE were registered during the CWT on both surfaces, illustrated in Figure 1.

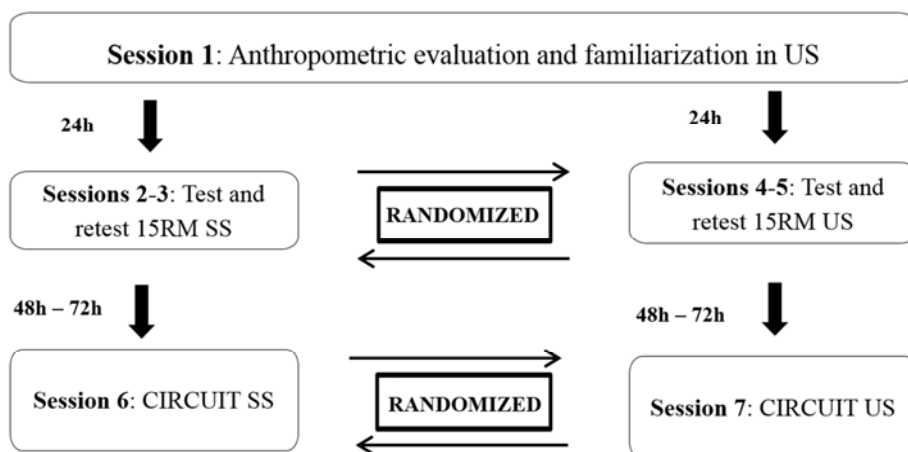


Figure 1. A summary of the study.

2.3. Procedures

The CWT was conducted on SS vs US in the following exercise order: 1) bench press on a bench (traditional exercise) (Righetto Fitness Equipment, Bench Press, São

Paulo, Brazil) vs. bench press on a Swiss ball (Mercur, Gym Ball, Rio Grande do Sul, Brazil); 2) back squat (traditional exercise) vs. Back squat on two balance disks (Pretorian, Balance Cushion, São Paulo, Brazil), one under each foot; 3)

rowing bent prone (traditional exercise) vs. rowing bent prone on a Bosu ball (Sport Balance Trainer – 55 cm, San Diego, USA); 4) dead-lift (traditional exercise) vs. dead-lift on two balance disks (Pretorian, Balance Cushion, São Paulo, Brazil), one under each foot; 5) shoulder press on a bench (traditional exercise) vs. shoulder press on a Swiss ball; 6) elbow extension (traditional exercise) vs. elbow extension on a Bosu ball and 7) elbow flexion (traditional exercise) vs. elbow flexion on two balance disks (Pretorian, Balance Cushion, São Paulo, Brazil), one under each foot (Figure 2). The subjects performed 15 repetitions for each CWT in a

random order, exercising at 80% of 15RM without rest between exercises. The pace of the metronome was set at 40 bpm for all exercises and the total time of the circuit was 7 minutes and 25 seconds on both surfaces. The intervals between randomly assigned CWT sessions were a minimum of 24 and maximum of 72 hours. Testing was performed under the supervision of a certified professional. Subjects were instructed to maintain the same food intake for 24 hours prior to each testing and refrain from coffee, tea or any other thermogenic substance.



Figure 2. Sequence of resistance exercises in the circuit weight training on unstable surfaces.

2.4. 15RM Test

Due to differences of the maximum loads between the two exercise conditions, 15RM was assessed for each subject in the two conditions in random order. To lower the estimation error for 15RM test, the following strategies were used: (i) familiarization prior to testing in order to let the participant become aware of the data collection routine; (ii) orientation about the technique and cadence of exercise, that was 40 bpm = 20 repetitions per minute (Metronome EMT-888 Tuner, São Paulo, Brazil); (iii) use of verbal orientation and (iv) the weights were previously checked on a precision scale. The load used for the determination of 15RM was accomplished through the use of 2, 5, 10, 15, 20 and 25 kg bars and disks (Righetto Fitness Equipment, São Paulo, Brazil). The range of motion was assessed by visual inspection by a certified professional to determine the start and end positions in each

exercise. After obtaining the weight for the first exercise, a 10-minute interval was adopted before moving on to the next exercise. The order of execution of the exercises was the same as the CWT, as shown in Figure 2.

The retest aimed to assess the reliability of the load. The heaviest weight obtained on both days with less than 5% difference was considered the 15-RM. In the case of a large discrepancy, subjects were tested again.

2.5. Measures of EC, PBL and RPE

Pre, during and post-exercise exercise, VO_2 , VCO_2 and ventilation were continuously measured using a portable open-circuit gas-exchange analyzer (COSMED K4b2, Rome, Italy) in order enable the calculation of ventilatory measures: VE , VO_2 , VCO_2 , ventilatory equivalents (VE/VO_2 , VE/VCO_2) and respiratory exchange ratio ($RER =$

VCO_2/VO_2). The equipment was calibrated for ambient air, reference gases, time delay, and turbine before each testing. The measurements were done at rest (10 minutes) with volunteers in a supine position, throughout the exercise (CWT) and at recovery (10 minutes) with volunteers again in a supine position. Aerobic EC was calculated using the following formula: aerobic EC = $((\text{mean exercise } VO_2 \times \text{body weight})/1000) \times 4686 \times \text{exercise time}$. Anaerobic EC was calculated using the excess post-exercise oxygen consumption (EPOC) using the formula: anaerobic EC (EPOC) = $((\tau/60) \times \Delta VO_2)/1000 \times 4686$ [17], τ being the mono-exponential curve time constant representing the recovery of VO_2 after exercise. τ represents the point on the curve where VO_2 reaches 63% of the peak value, that is, the time it takes to recover 63% of peak VO_2 . VO_2 delta is the difference between VO_2 and peak VO_2 of the final recovery. Total EC was calculated using the formula: total EC = aerobic EC + anaerobic EC [18].

PBL was obtained at rest and immediately after exercise with individuals in a supine position. A sample of capillary blood was taken from the distal phalange of the index finger of the left hand to determine the concentration of blood lactate. The finger was cleaned before and after blood collection with cotton and 70% liquid alcohol to avoid contamination of the data. Collection was started immediately after exercise and repeated measurements were done every 90 seconds until PBL was found. This procedure was performed using a portable analyzer (Accutrend Plus, Roche Diagnostics, USA), previously calibrated with known reference lactate values.

OMNI-RES for specific use in resistance training was used for RPE Assessment. The RPE scale was explained to the volunteers before exercise. Each subject was asked to point out on the scale the number that represented the effort of the active muscles (peripheral fatigue) and another number which represented the overall body (central fatigue) immediately after completion of the exercise. Low and high perceptual anchors for OMNI-RES were established using a visual-cognitive procedure [19]. This procedure instructs the subject to cognitively establish a perceived intensity of exertion that is consonant with that depicted visually by the weight lifter at the bottom (i.e., low anchor, rating 0) and top (i.e., high anchor, rating 10) of the incline as presented in the OMNI-RES. Subjects were instructed to use their memory of the least and greatest effort that they had experienced while lifting weights to help in establishing the visual-cognitive link. The OMNI-RES was in full view of the subject at all times during the experimental protocol [20].

The tests were conducted in the laboratory of the Faculty of Physical Education and Sports of the Federal University of Juiz de Fora, always in the morning, with the room temperature between 20 and 25°C and relative humidity between 45% and 60%.

2.6. Statistical Analysis

To test differences in EC and PBL between exercise performed on SS and on US, it was used Student's t-test,

after verification of the data normality assumption (Kolmogorov–Smirnov test, with Lilliefors significance correction). Differences in RPE between the two conditions were evaluated using the Wilcoxon test, after non-normal distribution of data was verified. To test correlations between continuous variables, we used the Pearson correlation. The effect size (ES) was calculated by Cohen's "d" [21]. The sample size calculation was performed using G-POWER software, considering the comparison of a continuous variable between two paired samples and using a confidence level of 95%, 80% power and ES 0.70. The results are presented as mean \pm standard deviation. The analyses were performed in SPSS statistical software version 20.0 (IBM Corp., Armonk, USA), adopting a significance level of 5% ($p \leq 0.05$).

3. Results

A significantly higher EC was observed during exercise performed on US when compared with that on SS. The exercises performed on US promoted greater aerobic EC (64.0 ± 9.4 vs. 60.9 ± 6.9 kcal; $p = 0.03$; ES = 0.38), anaerobic EC (6.7 ± 1.8 vs. 5.8 ± 1.3 kcal; $p = 0.04$; ES = 0.58) and consequently total EC (70.7 ± 10.0 vs. 66.6 ± 7.8 kcal; $p = 0.01$; ES = 0.46) compared with exercises on SS (Figure 3).

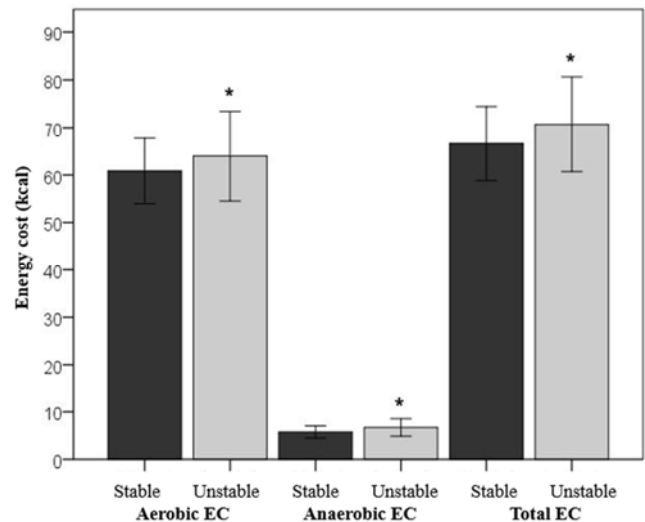


Figure 3. Mean and standard deviation of aerobic, anaerobic and total energy cost (EC) of a set of circuit weight training resistance exercises on stable and unstable surfaces ($n = 20$). Significant differences between the surfaces ($p < 0.05$).

During exercise, VO_2 was significantly higher on US compared with SS (23.4 ± 2.6 vs. 22.3 ± 1.7 mL·kg⁻¹·min⁻¹; $p = 0.05$; ES = 0.51). The 95% CI of the difference between the mean stable and unstable conditions was 0.4 to 5.8 kcal for aerobic EC, 0.1 to 1.8 kcal for anaerobic EC and 1.2 to 6.9 kcal for total EC. The ES observed for EC was of medium magnitude (ES < 0.80). There were no significant differences in peak VO_2 between exercise on US vs. on SS (2341 ± 420 vs. 2387 ± 337 mL·min⁻¹, respectively; $p =$

0.65).

The PBL post-exercise on SS was significantly higher, when compared with that on US (13.6 ± 2.6 vs. 12.5 ± 1.9 $\text{mmol}\cdot\text{L}^{-1}$; $p = 0.05$; $ES = 0.49$) (Figure 4). The 95% CI of the difference between the means of the PBL was 0.03 to 2.4 $\text{mmol}\cdot\text{L}^{-1}$.

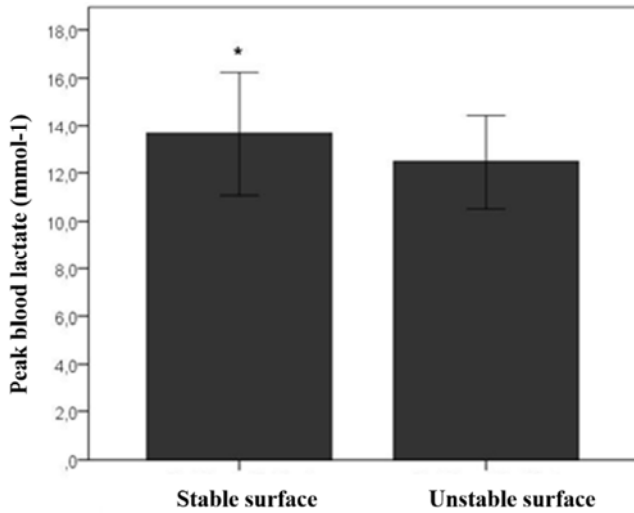


Figure 4. Mean and standard deviation of the peak blood lactate after the circuit weight training held on stable and unstable surfaces ($n = 20$). *Significant differences between the surfaces ($p = 0.05$).

The total load lifted was significantly higher on SS compared with US (402.2 ± 48.9 vs. 369.7 ± 35.9 kg; $p < 0.001$). Table 1 illustrates the mean load of each exercise on SS and US. However, no relationship was observed between the total load and PBL either on SS ($r = 0.34$; $p = 0.14$) or on US ($r = 0.16$; $p = 0.51$).

Table 1. Mean and standard deviation of the total load lifted (kg) on stable and unstable surfaces ($n = 20$).

	SS (kg)	US (kg)
Bench press	66.2 ± 10.1	64.2 ± 8.5
Back squat	84.3 ± 18.6	70.3 ± 10.0
Rowing bent prone	53.2 ± 8.8	48.6 ± 6.0
Dead-lift	67.3 ± 12.4	59.7 ± 9.8
Shoulder press	34.5 ± 4.6	30.1 ± 3.2
Elbow extension	50.4 ± 6.5	49.5 ± 6.9
Elbow flexion	48.2 ± 6.7	47.4 ± 7.3
Total load lifted	$402.2 \pm 48.9^*$	$369.7 \pm 35.9^*$

SS – stable surface; US – unstable surface; *Significant differences between the surfaces ($p < 0.001$).

The RPE was greater on US when compared with that on SS (Figure 5). Exercises performed with instability promoted greater peripheral RPE (8.5 ± 1.1 vs. 7.9 ± 1.4 ; $p = 0.02$), central RPE (7.8 ± 1.2 vs. 7.3 ± 1.4 ; $p = 0.02$) and hence total RPE (8.1 ± 0.9 vs. 7.6 ± 1.3 ; $p = 0.02$). There was no significant correlation among the EC variables, PBL and RPE ($p > 0.05$).

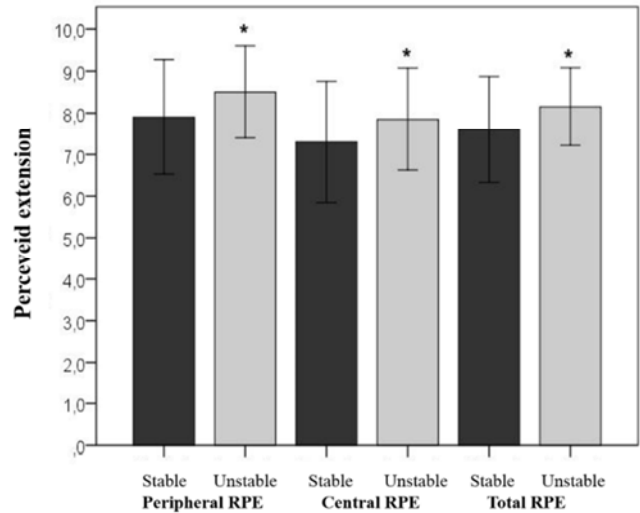


Figure 5. Mean and standard deviation of perceived exertion after the circuit weight training performed on stable and unstable surfaces ($n = 20$). *Significant differences between the surfaces ($p = 0.02$).

4. Discussion

This is the first study comparing EC, PBL and RPE in CWT performed on SS vs. on US in healthy men. The results confirm the hypothesis that the CWT on US increases EC and RPE, when compared with the same method on SS. There were also significant differences in relation to PBL, however the largest results were in SS, probably due to the fact that the total load lifted higher in this condition of exercise.

The anaerobic contribution is usually ignored in EC estimations, leading to an overall underestimation of the actual EC of a given exercise. It can be observed that aerobic, anaerobic and total EC on US were greater, compared with that on SS. The recent research describes the oxygen uptake and total EC (including both aerobic and anaerobic contribution) response during three different CWT protocols of equivalent duration composed of free weight exercises, machine exercises, and a combination of free weight exercises intercalating aerobic exercise in men and women. The results showed EC higher in the combined exercise (259 ± 65 kcal), compared with free weight (203 ± 58 kcal) and machine (173 ± 48 kcal). The combined exercise produced the highest total EC but the lowest PBL and RPE [22]. The exercise protocol in that study differs from the present study because it comprised three sets of resistance exercises and our study was limited to one set. When extrapolating the results of our study for three series, we found values close to the findings described for free weight CWT.

A study quantified EC and PBL in eight exercises performed in CWT on SS. Three sets were performed in six circuits with intensities of 30%, 40%, 50%, 60%, 70% and 80% 15RM. Three sets of 15RM with an interval of 10 seconds between exercises and 5 minutes between sets were performed. Significant differences in total, aerobic and anaerobic EC at all intensities as well as between genders ($p < 0.05$) were found. Regarding the load of 80% of 15RM, a

total EC of $7.82 \pm 3.1 \text{ kcal} \cdot \text{min}^{-1}$ was found for men [23]. We found a lower result in the present study in both surfaces. The PBL in men at 80% of 15RM in the afore mentioned was $20.7 \pm 4.5 \text{ mmol} \cdot \text{L}^{-1}$, higher than that in the current study, possibly due to the greater number of sets performed. In contrast, a recent study comparing three different CWT through three sets of eight exercises identified a lower PBL value when the CWT was performed combined with running (5.8 ± 2.3), compared with that found in the CWT protocol with free weight (9.4 ± 3.2) and machines (10.7 ± 3.2) [22]. This shows that the accumulation of lactate is greater when performed in machines and with a higher load, as was done in the present study in SS (13.6 ± 2.6).

A similar intervention with the same variables as those in the present research, included a CWT using only the body weight of males and females on SS. Mean exercise EC was $289 \pm 82.2 \text{ kcal}$ in 28 minutes of activity (3 sets of the CWT), a value relatively close to the findings of the present research on a single circuit performed on SS ($66.6 \pm 7.8 \text{ kcal}$) and US ($70.7 \pm 10.0 \text{ kcal}$) over 7 minutes and 25 seconds. However, mean VO_2 was higher compared with that in our study ($27.8 \pm 5.4 \text{ mL} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$), likely due to the inclusion of more aerobic exercises. This idea is reinforced by the $6 \text{ mmol} \cdot \text{L}^{-1}$ PBL in that study, a lower result than our observations [24]. Indeed, in this study, the inclusion of single-joint exercises was done to develop a high level of intramuscular pressure, thereby restricting blood flow and consequently increasing the dependency of active muscle on anaerobic metabolism [24, 25].

The CWT is mainly characterized by the total absence or small rest intervals between sets, thereby featuring a high-intensity training. The acute effect of EC and PBL between the CWT and the traditional method was compared in a study [13] which found similarity for total and aerobic EC; however, anaerobic EC and PBL showed higher mean values in the traditional method ($13.68 \pm 3.4 \text{ kcal}$, about $12 \text{ mmol} \cdot \text{L}^{-1}$) relative to the CWT ($12.3 \pm 3.6 \text{ kcal}$, about $10 \text{ mmol} \cdot \text{L}^{-1}$). These findings may be due to the interval of 60 seconds between sets in two the training sessions. Contrary, in the present study, there was no interval between subsequent exertions, thereby explaining the higher anaerobic EC and PBL herein.

Despite the similar relative intensity in the two surfaces used in the present study (80% of 15RM) the absolute load was higher in the SS condition of exercise. Moreover, the highest total volume of load lifted by volunteers on SS produced a greater PBL in the CWT ($p < 0.001$).

The RPE is a variable used to obtain an estimate of exercise intensity and the degree of the subject's tolerance for a certain action [20]. The central, muscular and full RPE in this study was higher on US compared with that on SS. This result reflects the increased difficulty that individuals experienced while performing the task on US. Corroborating with these findings, a previous study conducted in 14 trained subjects compared the bench press at 60% of 1RM on US (Swiss ball) and SS (flat bench). RPE using the Borg was significantly higher in exercises on US ($p < 0.01$). Others

describe higher RPE in push-up exercise and double leg hold, both performed on the Swiss ball, as compared with those on SS [15].

A study conducted only on SS in the CWT using the OMNI-RES scale found a lower result (5.9 ± 1.5) than our observations herein, probably due to the absence of load in CWT exercises [24].

According to the American College of Sports Medicine (ACSM), the daily EC recommended for physical activity is between 150 and 400 kcal [26]. Thus, the findings of this research show that resistance training practitioners with similar age, sex and anthropometrics to those studied herein, can use three CWT series in about 21 minutes to obtain an EC within the range recommended by the ACSM, both on SS and on US (ES was of medium magnitude < 0.80). The inclusion of a high-intensity CWT on US could be a tool for people seeking greater EC in little training time. Training with loads on US allows for lower overhead stress and may generate a high metabolic impact. Hence, this alternative type of exercise seems an acceptable alternative to traditional strength training.

In the current study, there was no electromyographic analysis, no goniometer assessment of the range of motion, and the absence of RPE anchorage. Moreover, no extrapolation of the data to other populations is enabled by the current analysis (i.e. sedentary, women, elderly or athletes).

5. Conclusion

The findings of this study showed that when circuit weight training is performed on a unstable surface, it elicits a higher energy cost and a higher rate of perceived exertion; when compared to the same training performed on a regular stable surface. These are promising data as a greater energy cost is often the major target of exercise programs. Moreover, the peak blood lactate was lower during exercise in the unstable surface, which may also be viewed as a pro factor to choose this type of exercise. Indeed, the lower lactic load may allow for a faster recovery post-training when the unstable surface is used.

In short, we conclude that circuit weight training on unstable surfaces can be performed with less weight as compared with stable surfaces, thereby lowering the mechanical stress on joints and bones, and still providing a high metabolic impact and potential greater benefits.

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