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TOTAL ENERGY COSTS OF 3 ALL-OUT TABATA ROUTINES: CALISTHENIC, PLYOMETRIC AND RESISTANCE EXERCISES

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ABSTRACT

We examined the total energy costs – aerobic and anaerobic, exercise and recovery – of 3 all-out Tabata routines: calisthenics (burpee and lunge), plyometric (jump step and incline push-up) and resistance exercises (squat and dumbbell press). Eleven men and four women (22.1 ± 1.9 years, 175.5 ± 5.9 cm, 71.6 ± 9.7 kg) volunteered. Subjects performed as many repetitions as possible within each 20 second exercise routine followed by 10 second recovery periods, with each routine being completed four times, for a total of four minutes. The lowest overall cost was found with the resistance exercises 174.3 ± 32.2 kJ (41.7 ± 7.7 kcal) ($p < 0.005$) as compared to the calisthenic 287.8 ± 64.3 kJ (68.8 ± 15.4 kcal) and plyometric 241.4 ± 49.3 kJ (57.7 ± 11.8 kcal) routines; the calisthenic and plyometric routines did not differ statistically. A rating of perceived exertion (RPE) indicated the highest scores for the calisthenic (16.0 ± 1.3) and resistance (15.2 ± 1.7) routines with statistical significance only found between calisthenic and plyometric (13.8 ± 1.5) routines ($p = 0.01$). With caloric costs ranging among routines by as much as 40% with all subjects, 36% between genders and 56% among routines and gender, we conclude that the energy costs of Tabata-type exercise are different among all-out routines - no single energy cost estimate effectively describes a given all-out Tabata-type exercise routine.

Key words: high intensity exercise, workout, metabolism, perceived exertion

COSTE TOTAL ENERGÉTICO DE 3 RUTINAS TABATA: CALISTÉNICAS, PLIOMÉTRICAS Y EJERCICIOS DE RESISTENCIA

RESUMEN

Hemos examinado el coste total energético (aeróbico y anaeróbico, ejercicio y recuperación) de 3 rutinas Tabata completas: calisténicas (burpee y lunge), pliométricas (paso de salto y flexiones inclinadas) y ejercicios de resistencia (sentadillas y presión de pesas). Once hombres y 4 mujeres (22.1 ± 1.9 años, 175.5 ± 5.9 cm, 71.6 ± 9.7 kg) se ofrecieron voluntarios. Los sujetos realizaron tantas repeticiones cómo fue posible durante los 20 segundos de cada ejercicio, seguidos de periodos de 10 segundos de recuperación, repitiendo cada rutina 4 veces, durante un total de 4 minutos. El coste total más bajo fue encontrado en los ejercicios de resistencia 174.3 ± 32.2 kJ (41.7 ± 7.7 kcal) ($p < 0.005$) en comparación con las calisténicas 287.8 ± 64.3 kJ (68.8 ± 15.4 kcal) y las rutinas pliométricas 241.4 ± 49.3 kJ (57.7 ± 11.8 kcal); las rutinas calisténicas y las pliométricas no mostraron diferencias estadísticamente. Una medida de esfuerzo percibido (RPE) indicó las puntuaciones más altas para las calisténicas (16.0 ± 1.3) y las rutinas de resistencia (15. ± 1.7) con significancia estadística únicamente entre las rutinas calistenias y pliométricas (13.8 ± 1.5) ($p = 0.01$). Los costes calóricos van entre las rutinas de hasta un 40% con todos los sujetos, 36% entre los géneros y 56% entre las rutinas y el género, llegamos a la conclusión de que los costes de energía del ejercicio tipo Tabata son diferentes entre las rutinas. La estimación de costes describe de manera efectiva una rutina de ejercicios tipo Tabata completa.

Palabras clave: ejercicio de alta intensidad, entrenamiento, metabolismo, esfuerzo percibido

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INTRODUCTION

Tabata-type exercise routines have become a popular fitness trend although the self-inflicted intensity can lower exercise enjoyment (Foster et al, 2015). Intensity is the key component of any exercise format that has the ability to increase both aerobic and anaerobic capacity (Tabata et al, 1997). In terms of health benefits however, exercise need only be of moderate intensity with a required *amount* of physical activity considered to be about 150 kcal per day (1000 kcal per week) (Kokkinos, 2012). Our pursuit in the present investigation is the use of all-out Tabata exercise for the examination of its total energy costs – aerobic and anaerobic, exercise and recovery.

Under controlled as opposed to all-out conditions, the caloric cost of 4-minutes of Tabata-type exercise was un-impressive, ranging from 15 kcal for an isometric squat routine to 38 kcal for a jump-squat routine (Scott et al, 2015). Olson (2013) has shown an energy cost of 54 kcal using an all-out effort during a Tabata squat-jumps routine. If a minimum standard of 150 kcal per day of physical activity is recommended to improve health, then this latter figure suggests that as many as 3 all-out Tabata routines would be required to meet that standard – a difficult task for perhaps most people. We asked the question, what type of all-out Tabata routine would elicit the highest caloric cost? Using the Tabata format we compared the total energy costs of 3 exercise routines: calisthenics (burpee and lunge), plyometric (jump step and incline push-ups) and resistance (squat and dumbbell press).

METHOD

All participants were classified as being physically active and exercising at least 2-3 times per week for a period of 3 months. Eleven males and four females (22.1 ± 1.9 years, 175.5 ± 5.9 cm, 71.6 ± 9.7 kg) were informed of the study design, volunteered to participate and signed an informed consent approved by the University's Human Subject Institutional Review Board before any data were collected.

Volunteers reported to the lab on seven separate occasions (typically 1 week between visits). The first visit had age, height and weight data collected as well as instructions for the three Tabata routines. During the following 6 visits volunteers were randomly assigned to and performed one of the three Tabata routines; each routine was completed twice (on separate days) and the results averaged. Subjects were instructed not to eat or drink (other than water) for 4 hours prior to testing.

Each all-out Tabata routine consisted of 20 seconds of exercise followed by a 10 second recovery period that was repeated eight times (4 minutes total): each routine consisted of two exercises, one following the other after subsequent 10 second rest periods. Volunteers were instructed to complete as many repetitions of each exercise as possible in the 20 second exercise periods; verbal encouragement was provided. The calisthenic all-out Tabata routine consisted of a burpee exercise followed by a lunge. The plyometric all-out Tabata routine consisted of jumping up and down onto a 25.4 cm step followed by a plyometric incline pushup from a bar placed 71 cm above the floor. The resistance all-out Tabata routine consisted of a squat exercise using a weight at 40% of body mass followed by a dumbbell shoulder press with a weight of 15% body mass (divided between hands). The squat was performed on a Smith machine with a depth set by a 63.5 cm stool.

Oxygen uptake was measured using a ParvoMedics MMS-2400 metabolic cart (Sandy, Utah) that was calibrated at least twice before testing began. Room air (20.93% O_2 and 0.03% CO_2) and calibration tank air (16.1% O_2 and 3.9% CO_2) were used to calibrate the analyzers while a 3-liter syringe was used to calibrate the pneumotach. Gas exchange was collected via a breathing tube, mouthpiece (Rudolph-Collins) and noseclip. Oxygen uptake was displayed on the computer screen in 15 second sampling periods; tabular data were collected in minute periods. Data were summed to provide a cost per task measurement in liters of oxygen. Before each test subjects stood quietly for 5 minutes, these data were averaged per minute and subtracted from all exercise and excess post-exercise oxygen consumption (EPOC) measurements. After the completion of each all-out Tabata routine volunteers were seated and gas exchange was recorded until a standard value of 5.0 ml $O_2 \cdot kg^{-1} min^{-1}$ was reached or a recovery time span of 15 minutes was completed. Assuming glucose oxidation for each 20 second period of exercise and fat and lactate oxidation during the 10 second recovery periods, an energy cost conversion of 1L VO_2 = 20.6 kJ (4.9 kcal) was used; during EPOC the conversion was 1L VO_2 = 19.6 kJ (4.7 kcal) (Scott, 2008).

Anaerobic energy costs were determined as the difference between averaged duplicate resting and peak blood lactate measures taken from a finger stick (Lactate Pro, Arkray Inc., Kyoto, Japan). A pilot project revealed that blood lactate peaked at 2.5 minutes post-exercise. Blood lactate energy cost conversion as taken as mmol lactate multiplied by 3.0 ml O_2 per kilogram of body weight, then as 1L VO_2 = 20.9 kJ (5.0 kcal) (Scott, 2008).

Immediately post-exercise (before seated recovery) subjects were provided a 6-20 Borg scale rating of perceived exertion (RPE) and were asked to rate the all-out Tabata routine.

Statistical analysis

Statistical analysis was completed using IBM SPSS statistics 23. Descriptive analyses are depicted as mean ± standard deviation. Among group differences were determined using standard ANOVA. Post Hoc differences were determined by Bonferroni analyses with the alpha level set at $p < 0.05$.

RESULTS

The aerobic (VO_2) energy cost estimation for the 4 minute all-out Tabata exercise and recovery periods was significantly less for the resistance 109.0 kJ ± 15.1 kJ (26.1 ± 3.6 kcal) as compared to plyometric 155.1 ± 24.7 kJ (37.1 ± 5.9 kcal) and calisthenic routines 178.6 ± 30.1 kJ (42.7 ± 7.2 kcal) ($p < 0.0001$).

The anaerobic (blood lactate) energy cost estimation revealed significance only between the calisthenic 43.9 ± 13.2 kJ (10.5 ± 3.1 kcal) and resistance 28.3 ± 8.9 kJ (6.8 ± 2.1 kcal) protocols ($p = 0.011$). No statistical difference was found among the calisthenic and resistance protocols and the plyometric protocol 34.3 ± 11.2 kJ (8.2 ± 2.7 kcal).

As with the anaerobic analyses, EPOC differences were significant only between the calisthenic 66.8 ± 24.5 kJ (16.0 ± 5.9 kcal) and resistance 37.1 ± 12.9 kJ (8.9 ± 3.1 kcal) ($p = 0.001$). No significant difference was found with the plyometric 52.1 ± 17.3 kJ (12.5 ± 4.1 kcal) and other Tabata protocols.

Total energy costs were significantly less for the resistance protocol 174.3 ± 32.3 kJ (41.7 ± 7.7 kcal) as compared to calisthenic 287.8 ± 64.3 kJ (68.8 ± 15.4 kcal) and plyometric protocols 241.5 ± 49.3 kJ (57.7 ± 11.8 kcal) ($p \leq 0.005$).

Repetition numbers for each exercise are shown in Table 1.

Rating of perceived exertion (RPE) was highest for the calisthenic all-out Tabata protocol 16.0 ± 1.3 but a statistical difference was apparent only with the plyometric protocol 13.8 ± 1.5 ($p = 0.01$) and not the resistance protocol 14.9 ± 1.7.

TABLE 1
Repetition number for the 3 all-out Tabata routines (Mean ± SD).

Exercise and set number:			
burpee1 - lunge 1	burpee2 - lunge2	burpee3 - lunge3	burpee4 - lunge4
9.8±1.0 13.7±2.4	9.6±1.0 13.9±2.2	9.5±1.1 13.7±2.3	9.5±1.2 14.2±2.5
jump1 - pushup1	jump2 - pushup2	jump3 - pushup3	jump4 - pushup4
20.1±2.7 15.9±3.3	20.9±2.8 15.6±3.6	21.3±2.9 15.6±3.8	21.9±3.0 15.5±3.6
squat1 - press1	squat2 - press2	squat3 - press3	squat4 - press4
14.0±2.4 19.8±4.2	15.4±2.5 20.6±4.5	15.5±2.6 19.3±4.0	16.0±2.7 16.9±3.8

Mean ± standard deviation. Jump = jump step from 25.5 cm; pushup = plyometric push-up off a 71 cm bar; squat = 40% body mass; press = dumbbell shoulder press 15% body mass.

Rating of perceived exertion (RPE) was highest for the calisthenic all-out Tabata protocol 16.0 ± 1.3 but a statistical difference was apparent only with the plyometric protocol 13.8 ± 1.5 ($p = 0.01$) and not the resistance protocol 14.9 ± 1.7.

DISCUSSION

Tabata exercise routines are well known for their intensity and ability to increase measures of aerobic and anaerobic performance and capacity – this was the very focus of the exercise design (Tabata et al, 1997). In terms of overall caloric expenditure however, with caloric costs ranging from 42 to 69 kcals, our data and those of others indicate that these values are not particularly high for a single Tabata routine. Indeed, from the perspective of higher exercise intensity's potential adverse effect on exercise adherence (Parfitt and Hughes, 2009), at an approximate 100 kcal of energy cost per mile, walking may be preferred to repeated 4-minute bouts of all-out Tabata exercise. From the perspective of time however, exercisers would certainly expend more calories with 5 or 6 consecutive Tabata routines than within a single 20-25 minute one mile walk. It also needs to be recognized that in terms of health, as little as 1 full minute of all-out exercise (20 second sprints repeated 3 times) performed 3 times per week has promoted similar benefits as compared to 45 minutes of continuous aerobic exercise (performed 3 times per week) (Gillen et al, 2016). It therefore appears that with the brief format of higher intensity intermittent training (HIIT) it is quite possible that the daily or weekly counting of calories as well as the amount of time spent exercising cannot be used as a "barometer" of health related benefits (the American College of Sports Medicine recommends ~150 kcal per day or ~150 minutes per week of moderate intensity aerobic exercise in the promotion of cardiovascular health and reduced pre-mature mortality; ACSM 2014, pg. 177).

Olson (2013) used a jump-squat Tabata routine that produced a caloric expenditure of 54 kcal – these data do not include an anaerobic energy cost estimate and excess post-exercise oxygen consumption had not returned to baseline levels 30-minutes post exercise, so an under-predicted energy cost is possible. The Olson investigation also had 12 women and 3 male subjects and it's likely that a separation of subjects by gender would reveal higher and lower energy cost values for males and females, respectively. Emberts (2013) revealed somewhat similar 4-minute aerobic-only energy cost estimates for two all-out Tabata routines: 57 kcal and 59 kcal. Based on gender one of these routines had female subjects ($n = 8$) expending 48 kcal and the other routine 45 kcal. With men ($n = 8$), these values were 66 kcal and 72 kcal. It is of interest that the Emberts (2013) investigation expanded their Tabata routine into a 20-minute workout using 16 different calisthenic exercises that expended an average of 300 kcal. The use of such a varied exercise routine was apparently "well tolerated" with an RPE of "hard" (Emberts et al, 2013).

With 11 males and 4 females our aerobic and anaerobic, exercise and recovery energy costs ranged from 42 to 69 kcal for a 4-minute Tabata routine. Based on gender, males and females respectively, calisthenic routine costs were 76.3 and 48.7 kcal, plyometric routine costs were 61.3 and 45.9 kcal and resistance costs were 45.4 and 33.3 kcal. Energy cost differences appear large among any given routine and between genders.

The design of any all-out 4 minute Tabata routine can have a rather dramatic impact on total energy costs as each of our routines differed by 10 to 20 kcal overall (~40%). For example, while even the best burpee competitors can fit only so many repetitions into a 20 second time period, the use of a burpee exercise alone may result in a greater cost as compared to pairing it with the lunge exercise. Moreover, the assignment of a 25.4 cm jump step and 71 cm inclined pushup to the plyometric routine will likely, when altered, result in caloric cost differences. The same appears true for the resistance routine where a heavier weight and subsequent lower repetition number as compared to a lower weight with subsequent higher repetition number would also likely affect overall energy costs (Scott et al, 2011).

With caloric costs ranging among routines by as much as 40% with all subjects, 36% between genders and 56% among routines and gender, we conclude that the energy costs of Tabata-type exercise are different among all-out routines - no single energy cost estimate effectively describes a given all-out Tabata-type exercise routine.

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