

CARDIO-RESPIRATORY RESPONSES TO STANDARDIZED LOAD RESISTANCE TRAINING IN RECREATIONALLY ACTIVE PARTICIPANTS

Nur Ikhwan Mohamad¹, Michael C. Rumpf^{2, 3}, Erik C. H. Tan⁴,
Nicholas Garaman Abas¹

¹Physical Conditioning Laboratory, Faculty of Sports Science & Coaching,
Sultan Idris Education University, Malaysia

²Sport Performance Research Institute New Zealand,
Auckland University of Technology, New Zealand

³National Sport Medicine Programme, Excellence in Football Project, Aspetar,
Qatar Orthopaedic and Sports Medicine Hospital, Doha, Qatar

⁴Conditioning Centre, National Sports Institute of Malaysia

Abstract

This paper aims to determine acute responses of standardized resistance training load on cardio-respiratory variables in recreationally active participants. The methodology involved twelve recreationally active males with an age of 23.5 (\pm 4.07) years, a mass of 70.5 (\pm 7.84 kg), a height of 1.69 (\pm 0.06 m), and a body mass index of 24.8 (\pm 2.14) kg/m². The participants performed an exercise protocol that comprises five exercises on a standardized load. Each exercise was performed in a duration of 60 seconds with uncontrolled lifting velocity. Cardio-respiratory responses were measured using a portable metabolic system analyzer during the exercises. A wrist digital blood pressure monitor was used to determine pre- and post-protocol blood pressure responses. Based on the results, pre- and post-protocol systolic ($p=0.744$) and diastolic ($p=0.758$) blood pressure indicated no significant responses. However, significant differences were observed in pre- and post-heart rate responses ($p=0.000$). Peak cardio-respiratory responses recorded during the protocol were 30.2 (\pm 4.02) ml/Kg/min for oxygen consumption, 138 (\pm 61.9) bpm for heart rate, and 633 (\pm 71.2) kcal for energy expenditure (estimated per hour). On average, the Metabolic Equivalent of Task (MET) was recorded at a value of 8.62 (\pm 1.19). For a short duration standardized load circuit training exercise protocol, cardio respiratory responses were similar to other protocols. The metabolic cost of the predefined exercises was nearly half of the recommended energy expenditure through exercise per week. The prescribed protocol was comparable with other exercise protocols for cardiorespiratory variables. The single set protocol used was efficient in terms of caloric expenditure, and was less strenuous over similar exercise duration. Furthermore, the prescribed protocol is applicable and beneficial for active and healthy individuals.

Keywords: Oxygen consumption, respiratory frequency, Metabolic Equivalent of Task (MET), energy expenditure, endurolift

Introduction

The main focus for strength and conditioning exercise prescription is the development of muscular strength and endurance. While various protocols and methods for training are available, athletes and coaches would prefer programs with minimal time of execution, as they improve physical capacities and affect health simultaneously. Due to time constraints for study, social life and training, university students are highly challenged in their daily lives to progress professionally, whilst maintaining good health, and even improving physical capacity. In order to achieve strength development and improvement in aerobic endurance parameters with limited training time, exercise protocols, such as circuit training, can be used.

Circuit training can be characterized as a training approach that involves a limited number of sets with high repetition and limited recovery time between exercises, in order to emphasize effects on the cardiovascular system, as well as the strength components (O'Shea, 1987). Research in the literature has shown the efficacy of circuit training on endurance, strength as well as on other health related measures, such as energy expenditure (Wilmore et al., 1978) and blood pressure (Katz & Wilson, 1992). It has been demonstrated that machine-based resistance circuit exercise significantly decreased blood pressure (Katz & Wilson, 1992) in healthy untrained females. Furthermore, circuit weight training is an acceptable form of physical activity to increase cardiovascular fitness in both overweight and normal weight middle-aged females (Jurimae, Jurimae, & Pihl, 2000), as well as in paraplegic adults (Jacobs, Nash, & Rusinowski, 2001). With regards to energy expenditure, specific circuit type resistance training research has shown a total expenditure of approximately 540 and 368 kcal/hr for men and women, respectively, and therefore, between 6.0-7.0 kcal/kg/hr relative to body weight (Wilmore et al., 1978). Additional resistance training protocols were based on either one exercise, or on single (Scott, Croteau, & Ravlo, 2009; Scott, Leighton, Ahearn, & McManus, 2011) or multiple sets (Bloomer, 2005; Scott, Leary, & Tenbraak, 2011). This altered recovery duration between sets (Ratamess et al., 2007), or between multiple exercises and sets (DeGroot, Quinn, Kertzer, Vroman, & Olney, 1998). Besides the circuit training forms, and from a time efficient and practitioner point of view, it is worthy to investigate the single set multiple exercises protocol, as investigated in older adults (Phillips & Ziuraitis, 2004), (Robergs, Gordon, Reynolds, & Walker, 2007) and the college-aged population (Phillips & Ziuraitis, 2003). While the study of Robergs et al. (2007) provided a regression equation to calculate the estimated caloric cost of bench presses and squats, two studies by Phillips et al. (Phillips & Ziuraitis, 2003, 2004) provided values of energy expenditure of the protocols employed. The older adults performed one set of 15 repetitions of eight exercises, and exhibited a total energy cost of approximately 84 and 70 kcal for males and females respectively (Phillips & Ziuraitis, 2004). The total values are equivalent to approximately 1.1 and 0.8 kcal/kg/min; 0.04 and 0.05 kcal/kg/min; and 3.3 and 3.0 METS; for males and females respectively (Phillips & Ziuraitis, 2004). Normal college students exhibited a total caloric expenditure of approximately 135 and 82 kcal, with METS of approximately 3.9 (± 0.4) and 4.2 (± 0.6), for men and women respectively (Phillips & Ziuraitis, 2003).

Powerlifting and weightlifting are two forms of resistance training which were not originally designed with a health perspective. However, both forms involved multiple joints (Harbili, 2012; McBride, Blaak, & Triplett-McBride, 2003), major muscle groups (Caterisano et al., 2002; Ebben et al., 2009; McCaw & Friday, 1994; McGill & Marshall, 2012), as well as tendons and ligaments (Collins, 1994), and therefore may be beneficial to other factors besides physical performance enhancement (Baechle & Earle, 2008). Powerlifting is the term used to describe maximal one time heavy lifting which consists of the squat, bench-press and deadlift (Chiu, 2007). All of these exercises have been regarded as essential exercises in strength training programs, and have been shown to improve physical fitness (Adams, O'Shea, O'Shea, Climstein, 1992; Mayhew, Ware, Johns, & Bembem 1997). Similarly, weightlifting exercises are performed in an explosive fashion (Hori, Newton, Nosaka, & Stone, 2005; Storey & Smith, 2012), and have shown benefits for sprinting (Hoffman, Cooper, Wendell, & Kang, 2004; Tricoli, Lamas, Carnevale, & Ugrinowitsch, 2005) and jumping (Tricoli et al., 2005) in athletes. Despite the original intention, it seems plausible that these forms of resistance training might be regarded as time-efficient, full body training, providing an effective option targeting health-related purposes. However, to the best of the researchers' knowledge, there is no scientific information available on the utilization of powerlifting and/or weightlifting exercises in circuit training with a health-related purpose. In order to possibly use these two forms of resistance training in a respective group, cross sectional studies should investigate acute effects of variables connected with possible health risks, such as blood pressure. For example, some studies raised the issue of the negative effect of valsalva manoeuvre (MacDougall, Tuxen, Sale, Moroz, & Sutton, 1985; Porth, Bamrah, Tristani, & Smith, 1984), which is typically used when performing explosive-based types of exercises, such as the snatch. Valsalva-associated increase of arterial pressure, which can be observed during execution of powerlifting manoeuvres, had resulted in the suggestion that powerlifting should be added to the list of activities that may cause purpura (Pierson & Suh, 2002). Furthermore, to the best of the researchers' knowledge, the caloric expenditure of weight- and powerlifting circuit training is unknown. In terms of time-efficient and effective training, it is worthy to maximize the individual's calorie expenditure per minute. Therefore, the primary purpose of this study is to assess the acute cardio-respiratory responses of a standardized resistance training load utilizing weight- and powerlifting. Secondly, the overall energy expenditure and the rate of perceived exertion across the protocol can be utilized for normative data for future research with regards to training efficacy.

Methods

Experimental Approach to the Problem

In this study, 12 recreationally trained males were recruited to investigate the effects of standardized resistance training load on cardio-respiratory responses, blood pressure and rate of perceived exertion. A specifically designed lifting exercise protocol (Endurolift Protocol 1) was used, which consists of five exercises, each performed for one set with a standardized load for 60 seconds. All variables of interest were assessed pre- and post-exercise. Standardization of load was performed with having a 20kg (Olympic bar only)

load for snatch, and a 40kg load (Olympic bar with two 10kg plates) for squat, bench press and deadlift. The dynamic plank load was based on each participant's own body weight. The standardized load was used by the University's (Sultan Idris Education University) physical conditioning coach in an introductory program for the University's athletes. Thus, this study also serves as an assessment on the effectiveness of current practice. Output of this study may also be used to improve the University's strength and conditioning programs.

Subjects

Twelve recreationally active males aged 23.5 (\pm 4.07) years old, with a body mass of 70.5 kg (\pm 7.84), a height of 1.69 meters (\pm 0.06 m), and a body mass index (BMI) of 24.8 (\pm 2.14) kg/m², were recruited for this study. Each participant had at least six months of resistance training, and was physically active 2-3 times per week. All participants were required to pass a movement competency screening (MCS) test (Kritz, 2012) and a Pre-Exercise Questionnaire (PAR-Q) (Thomas, Reading, & Shephard, 1992) prior to acceptance for this study for safety reasons. The study was approved by the university research committee, and prior to participation, the participants signed an informed consent letter.

Equipment

An Olympic bar (OB86, Body Solid Inc., Illinois, USA) and color-coded Olympic bumper plates of 10 kg (Orc series, Body Solid Inc., Illinois, USA) were used in the strength exercises. A portable metabolic analyzer (Fitmate pro, Cosmed, Italy) was used to measure cardio-respiratory variables. Blood pressure assessment was measured pre- and post-exercise using a digital wrist blood pressure analyzer (HEM-6200, Omron, Kyoto, Japan). The rate of perceived exertion (RPE) was obtained from the participants using an A4 size print of the Borg Scale (Scherr et al. 2013). Each of the participant's body weight was measured using a digital scale (HN-283, Omron, Kyoto, Japan).

Procedures

The procedures involved a familiarisation, and one testing session. A one-week gap was provided between the two sessions to ensure full recovery. All sessions were conducted at a similar time of day, and all participants were requested to avoid any strenuous physical activity for at least 48 hours prior to participation.

Preliminary Assessments and Familiarisation

The following anthropometric variables, standing height (cm) and body mass (kg) were measured. During the familiarization session, all exercises (snatch, squat, chest press, deadlift and plank) were introduced and explained in accordance to the National Strength and Conditioning Association guidelines (Baechle & Earle, 2008). Participants then performed all of the required exercises; techniques corrections were given if

necessary. Participants were also introduced to the 6-20 RPE-scale (Bloomer, 2005), which was used during the testing session.

One week after the familiarization session, participants then attended the testing session. The testing session started with a standardized warm-up that consisted of light jogging outside the laboratory until heart rate reached 50% of the targeted heart rate for warm-up, as suggested by Fox and Haskell (Fox, Naughton, & Haskell, 1971). Participants then performed a standardized dynamic stretching protocol, followed by a specific warm-up that consisted of the snatch exercise, for two sets and two repetitions, with a 20kg load. Upon data collection, participants' resting blood pressures and resting heart rates were measured. The order of the exercise protocol was as follows: snatch, squat, bench press on top of a fitball, deadlift and plank on top of a fitball. There was no rest-period between exercises. Spotters were used to help in the execution of the exercises for the squats and bench presses. A standardized cool-down technique that consists of stretching exercises was performed by all participants at the end of the testing session.



Figure 1: Participant's performing the squat exercise. One of the exercises (squat) performed with metabolic analyzer measuring respiratory responses during the performance.

Data Analysis

Cardio-respiratory variables were measured continuously throughout the session, with the researcher starting the metabolic analyser immediately after the start of the first exercise, and stopping it at the end of the last exercise. Blood pressure and RPE were measured prior the start of the exercise, and after the end of the last exercise. All variables of interest were transferred into a spreadsheet for further analyses.

Statistical Analysis

Mean and standard deviation was used to represent centrality and spread of data for all performance measures and cardio-respiratory variables. Paired sample t-test comparisons were used to determine if significant differences existed between pre- and post exercise data. The percentage difference between pre- and post blood pressure and heart rate levels were calculated as $\%Difference = (1 - Lowest\ Variable/Highest\ Variable)*100$. An alpha level of 0.05 was set to assess statistical significance for all tests.

Results

No significant differences were found in systolic and diastolic blood pressure between the pre- and post-exercise protocol. However, significant changes were observed between pre- and post-exercise heart rate responses (71.5 ± 12.6 bpm vs. 127 ± 25.3 bpm; Table 1).

Table 1: Pre- and post-exercise protocol blood pressure and heart rate responses comparisons (Mean \pm SD).

Variable	Pre-testing	Post-testing	%Difference	Significance (p-value)
Systolic blood pressure (mmHg)	129 (\pm 12.1)	127 (\pm 15.3)	-1.79	0.744
Diastolic blood pressure (mmHg)	84.9 (\pm 5.60)	83.2 (\pm 15.5)	-1.91	0.758
Heart rate (bpm)	71.5 (\pm 12.6)	127 (\pm 25.3)	43.5	0.000

In terms of the cardio-respiratory variables of the participants during performing the exercise protocol, all values can be observed in Table 2.

Table 2: Cardiorespiratory responses (Mean \pm SD) of the prescribed protocol.

Variable	Endurolift Protocol 1	
	Peak (maximal) value	Measured during anaerobic threshold
Exercise total duration (seconds)	401 (\pm 39.6)	-
Time in peak (seconds)	201 (\pm 123)	288 (\pm 105)
Oxygen consumption (VO ₂) (ml/Kg/min)	30.2 (\pm 4.02)	27.6 (\pm 4.67)
Fraction of expired oxygen (FeO ₂) (%)	17.0 (\pm 0.47)	-
Heart rate max (bpm)	138 (\pm 61.9)	151 (\pm 47.4)
Energy expenditure (kcal) (estimated per hour)	633 (\pm 71.2)	579 (\pm 93.4)
Respiratory frequency (Rf) (1/min)	43.2 (\pm 7.68)	41.6 (\pm 8.84)
Metabolic Equivalent of Task (MET)	8.62 (\pm 1.19)	-
Session RPE (6-20 scale)	13.8 (\pm 0.83)	-

Discussion

The primary purpose of this study was to assess the metabolic and cardio-respiratory responses of a standardized resistance training load utilizing weight- and powerlifting. In terms of blood pressure responses, there was no significant alteration to a standardized load training from all participants, with an even decrease observed throughout the literature (Sale, Moroz, McKelvie, MacDougall, & McCartney, 1994). Therefore, the protocol does not seem to cause any health-related issues with regards to blood pressure responses assessed at the beginning and end of the session. Nevertheless, further investigation is needed to assess blood pressure responses before and after each of the exercises for any possible significant differences.

The Endurolift Protocol 1 assessed in this study seemed to produce a higher energy expenditure rate during the performance, in comparison to a single-set exercise protocol used by Philips and Ziuraitis (2003). However, data presented were based on estimated energy expenditure for one hour performance of the protocol. The actual session's total duration for a single set performance in this study was approximately 7 minutes, resulting in an exact energy expenditure of 73.85 kcal per session. Philips and Ziuraitis (2003) indicated that their exercise protocol resulted in a total energy expenditure of 135 kcal (± 16.6) for men, and 81.7 kcal (± 11.1) for women, with an MET of 3.9 (± 0.4) and 4.2 (± 0.6) for men and women respectively (Phillips & Ziuraitis, 2003). Based on a comparison of energy expenditure, it would be appropriate to suggest that the protocol used in this study actually produced lower energy expenditure in comparison to the previous study by Philips and Ziuraitis (2003). A comparison was feasible due to similarity in the designs of both studies, as compared to other studies (especially single set, and using similar equipment). However, it is important to note that the current study assessed young teenagers, whilst the study by Philips and Ziuraitis (2003) assessed the geriatric population. Apart from single set loading, other training variables were manipulated differently (i.e., rest period, time under tension and exercise selection).

Additionally, the protocol in this study seemed to elicit superior metabolic responses in comparison to a non-peer reviewed articles investigating the acute effects of popular Crossfit™ protocols (Babiash, Porcari, Steffen, Doberstein, & Foster, 2013). Comparisons with the Crossfit™ protocols' respiratory responses (Babiash et al., 2013) can only be made with caution, as the variables in the study were not measured with similar types of equipment. Nonetheless, data from both Crossfit™ protocols assessed by Babiash et al. (2013) provided valuable insights on the cardio-respiratory responses during the execution of the exercises. As for the current comparisons, both Crossfit™ protocols have longer exercise durations. Their reports indicated that the total duration spent by each of the participants in their study ranged from 8 to 20 minutes per protocol. Both Crossfit™ protocols seemed superior compared to the Endurolift Protocol 1 in terms of intensity, heart rate responses and oxygen consumption. However, as a consequence of its higher energy expenditure (73.9 kcal vs. 20.6 kcal) within the given training time and the obtained RPE values, the protocol used in this study seemed to be superior in terms of training efficacy and convenience. Again, comparisons made should not be used as proof of effectiveness of one protocol against another. This is due to many differences that separated both studies, making each a 'standalone' profiling

study. Babiash et al. (2013) recruited well trained participants with better bodies built for the Crossfit™ study, eliminating technical issues such as difficulty in performing powerlifting and weightlifting based exercises. Well-trained strong participants will also mean movement economy in performing the exercises.

As far as energy expenditure is concerned, it seems plausible, if performed twice a week, that the Endurolift Protocol 1 could cover an almost equivalent energy expenditure suggested from physical activity for healthy lifestyle purposes per week (approximately 1000 kcal per week) (Garber et al., 2011).

The relatively high energy expenditure within a relatively short training period might be explained by a greater contribution of the anaerobic system. The average performance time for the protocol was 401 (\pm 39.6) seconds, with over half the total time 288 (\pm 105) seconds spent in the anaerobic threshold zone, despite a relatively high variation in total duration of exercise. The high variation was due to the time taken to move from one exercise to another, and getting in the appropriate position for the start of the next exercise. Although, cumulatively, some participants might have a completion time of ~20 seconds longer than others; the difference in transition time between each exercise was only between 5-7 seconds.

The relatively high standard deviation of the duration spent above the anaerobic threshold indicates that, while all participants completed the protocol given, and therefore produced relatively similar performances, as indicated by their MET or pre- and post-heart rate responses, the percentage of dominant energy systems used was different. This indicates that, where participants found it hard to complete the tasks relying solely on the anaerobic energy system, had shifted towards using the aerobic energy system in order to successfully complete all tasks given. With this, it is possible that longitudinal adaptations may differ from one person to another if the protocol is used for a prolonged period in training. Future studies should also consider using specific dynamic warm-up at higher heart rate responses (60% of the individual's age predicted maximal heart rate), as better physiological readiness may provide more insights into the cardio-respiratory and muscle metabolic responses.

Practical Application

This specifically designed program is suitable for health-orientated athletes who desire a time efficient full body workout. While the cardio-respiratory variables did not seem to impose any health risks to the participant, due to the technical aspects of all exercises of the Endurolift Protocol 1 (especially the snatch) in combination with the intensity of the protocol itself, it is suggested that interested participants only perform this protocol with proper guidance and monitoring from qualified strength and conditioning staff. The Endurolift Protocol 1 exhibited that it is comparable to other protocols for many cardiorespiratory variables, and elicits quite similar responses.

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