Growth Hormone & IGF Research 27 (2016) 33–40

Contents lists available at ScienceDirect

Growth Hormone & IGF Research

journal homepage: www.elsevier.com/locate/ghir

Exercise training with blood flow restriction has little effect on muscular strength and does not change IGF-1 in fit military warfighters

Andrew E. Jensen [a,b], Laura J. Palombo [a], Brenda Niederberger [a], Lorraine P. Turcotte [b], Karen R. Kelly [a,b,*]

[a] Warfighter Performance Department, Naval Health Research Center, San Diego, CA, USA
[b] Department of Biological Sciences, Human and Evolutionary Biology Section, Dana and David Dornsife College of Letters, Arts and Sciences, University of Southern California, Los Angeles, CA, USA

ARTICLE INFO

Article history:
Received 20 October 2015
Received in revised form 12 February 2016
Accepted 16 February 2016
Available online 17 February 2016

Keywords:
Blood flow restriction
Exercise
Insulin-like growth factor-1
IGF axis
Warfighters

ABSTRACT

Objective: Aerobic exercise with blood flow restriction (aBFR) has been proposed as an adjunctive modality in numerous populations, potentially via an enhanced growth factor response. However, the effects of aBFR on highly trained warfighters have yet to be examined. The purpose of this study was to determine if adjunctive aBFR as part of a regular physical training regimen would increase markers of aerobic fitness and muscle strength in elite warfighters. In addition, we sought to determine whether the changes in blood lactate concentration induced by aBFR would be associated with alterations in the insulin-like growth factor (IGF) axis.
Design: Active-duty US Naval Special Warfare Operators ($n = 18$, age $= 36.8 \pm 2.2$ years, weight $= 89.1 \pm 1.2$ kg, height $= 181.5 \pm 1.4$ cm) from Naval Amphibious Base Coronado were recruited to participate in 20 days of adjunctive aBFR training. Peak oxygen consumption (VO_2 peak), ventilatory threshold (VT), and 1-repetition max (1-RM) bench press and squat were assessed pre- and post-aBFR training. Blood lactate and plasma IGF-1 and IGF-binding protein-3 (IGFBP-3) were assessed pre-, 2 min post-, and 30 min post-aBFR on days 1, 9, and 20 of aBFR training.
Results: Following aBFR training there were no changes in VO_2 peak or VT, but there was an increase in the 1-RM for the bench press and the squat (5.0 and 3.9%, respectively, $P < 0.05$). Blood lactate concentration at the 2-min post-exercise time point was 4.5–7.2-fold higher than pre-exercise levels on all days ($P < 0.001$). At the 30-min post-exercise time point, blood lactate was still 1.6–2.6-fold higher than pre-exercise levels ($P < 0.001$), but had decreased by 49–56% from the 2-min post-exercise time point ($P < 0.001$). Plasma IGF-1 concentrations did not change over the course of the study. On day 9, plasma IGFBP-3 concentration was 4–22% lower than on day 1 ($P < 0.01$) and 22% lower on day 9 than on day 20 at the 30-min post-exercise time point ($P < 0.001$).
Conclusions: Our data suggest that aBFR training does not lead to practical strength adaptations or alterations in the IGF axis in a population of highly trained warfighters.

1. Introduction

Blood flow restriction (BFR) exercise has been shown to be an effective training tool in a variety of populations [1,2] and has been proposed as an adjunctive training tool [3], particularly in athletic populations [4]. Its use as an adjunctive training tool stems from the low-intensity modality of the exercise, which minimizes exercise-induced muscle damage while eliciting a hormonal response that is similar to that observed with high-intensity exercise [5]. In theory, this mechanism of action would lead to accelerated recovery from regular training regimens due to an additional (and beneficial) hormonal response [1,6]. Data show that this holds true in sedentary individuals and some athletes [2,7]; however, it has yet to be shown as an effective training tool in highly trained and active individuals.

Data have shown that BFR resistance training (i.e., weight training) is associated with increases in growth hormone, skeletal muscle hypertrophy, and maximal strength [4,6,8]; however, little is known about BFR training in conjunction with aerobic exercise. There are some indications that low-intensity aerobic exercise with blood flow restriction (aBFR) increases maximal aerobic capacity similarly to a high-intensity endurance training program [9]; as well as, skeletal muscle cross-sectional area, and muscular strength [1,7], which is atypical of aerobic exercise alone. Furthermore, this training modality has never been assessed within an elite military population that is concurrently engaged in rigorous physical fitness regimens.

While the precise mechanisms behind favorable adaptations to BFR training have yet to be elucidated, it has been hypothesized that the increase in blood lactate concentration induced by exercise with BFR may stimulate growth hormone secretion via a decrease in pH [5]. Indeed, it has been shown that the drop in pH induced by rhythmic handgrip exercise and vascular restriction increases sympathetic nerve activity and growth hormone secretion [10,11]. However, the link between

* Corresponding author at: Warfighter Performance Department, Naval Health Research Center, 140 Sylvester Rd., San Diego, CA 92106, USA.
E-mail address: Karen.R.Kelly8.civ@mail.mil (K.R. Kelly).

http://dx.doi.org/10.1016/j.ghir.2016.02.003
1096-6374/Published by Elsevier Ltd.

exercise-induced lactate concentration and insulin-like growth factor (IGF)-1 concentration remains unknown.

It is well understood that IGF-1 is a potent anabolic peptide; however, the biological effect of IGF-1 is complicated by other IGF axis factors, such as IGF-binding proteins (BPs), which bind to IGF-1 and alter cellular interactions [12]. In humans, the primary IGFBP found in the blood is IGFBP-3. The molar ratio of IGF-1 to IGFBP-3 is of particular interest because it can provide a sense of how much free or unbound IGF-1 is in circulation. Secretion and production of IGF-1 are directly stimulated by growth hormone (via negative feedback cycle), a molar ratio that can also provide a depiction of the biological activity of growth hormone [13,14].

Therefore, the purpose of this study was to determine whether 20 days of adjunctive aBFR, as part of a regular physical training regimen, would increase markers of aerobic fitness and muscle strength in highly fit US warfighters. Furthermore, we wanted to determine whether the changes in blood lactate concentration induced by aBFR would be associated with alterations in the IGF axis.

2. Materials and methods

2.1. Experimental approach to the problem

Our study presents a novel approach in the assessment of aBFR, an increasingly popular exercise training modality. A repeated-measures design was used to assess the adjunctive effects of a 20-day aBFR training regimen in highly trained and physically fit US Naval Special Warfare (NSW) Operators concomitantly engaged in regular physical activity/training operations.

To assess any physical fitness changes due to the aBFR, the following dependent variables were measured before and after completion of the training program: peak oxygen consumption (VO_2 peak), peak heart rate (HR peak), ventilatory threshold (VT), 1-repetition maximum (1-RM) bench press, and 1-RM back squat. In addition, to assess physiological changes, blood lactate concentration and plasma IGF-1 and IGFBP-3 levels were measured during aBFR at three time points during the training sessions (pre-session, 2 min post-session, and 30 min post-session) on days 1, 9, and 20. Mean power output and HR during aBFR were also assessed on training days 1, 9, and 20.

2.2. Subjects

Participants were recruited from Naval Amphibious Base Coronado, San Diego, California. All subjects were healthy, active-duty, male NSW Operators, 23–54 years of age (Table 1). All participants were actively engaged in rigorous physical fitness training regimens that typically consisted of ≥6 h/day of physical activity including 1–3 h/day of aerobic activity (>50% VO_2 peak), ≥1.5 h/day resistance training (>75% 1-RM), in addition to ≥3 h/day of tactical training [15,16]. The participants were instructed to maintain their regularly scheduled training exercises as well as their dietary intake, and caffeine, nicotine, and alcohol consumption during the duration of this study since the goal of this study was to assess the efficacy of regular aBFR as a supplementary training tool. The study was approved by the Institutional Review Board at Naval Health Research Center, and all participants gave their free and informed written consent.

Table 1
Subject Characteristics.

	Pre-Training	Range
Age (yr)	36.8 ± 2.2	23–54
Height (cm)	181.5 ± 1.4	170.2–193.0
Weight (kg)	89.1 ± 1.2	80.9–102.3
BMI (kg/m^2)	27.1 ± 0.4	24.2–31.4

BMI, body mass index.
Values presented as means ± SE.

2.3. Demographic and anthropometric assessment

During the first visit to the lab, subjects completed a basic health history questionnaire and anthropometric data were recorded. Height and weight for each subject were recorded to the nearest 0.1 cm and 0.05 kg, respectively, using a digital scale with height rod (ProMed 6129, Detecto, Webb City, MO, USA).

2.4. Pre- and post-training physiological measurements

Three days prior to the first aBFR training session (day 1), and within 3 days of completing the last aBFR training session (day 20), a modified Balke treadmill test [17] was completed to assess each subject's VO_2 peak. Subjects were instructed to warm up for 5–10 min by walking or jogging on the treadmill at a self-selected, comfortable pace. During the graded exercise test (GXT), the initial speed and grade of the treadmill were set at 3.5 mph and 0%. The speed and grade were increased by 0.5 mph and 2%, respectively, every 2 min until volitional exhaustion, at which point the GXT was terminated. During the GXT, respiratory gases were continuously collected and analyzed using the Parvo Medics TrueOne 2400 (Parvo Medics, Inc., Sandy, UT, USA) metabolic cart system, and HR was measured using a Polar monitor (Polar Electro, Inc., Lake Success, NY, USA). Blood lactate concentrations were measured at the onset of the GXT, within the last 15 s of each 2-min stage and at 2 min post-GXT. Capillary whole blood was collected via finger stick and used immediately to assess blood lactate concentration via a handheld lactate meter (Lactate Plus, Nova Biomedical, Waltham, MA, USA). Ratings of perceived exertion (visual 15-point Borg scale) were collected upon reaching volitional exhaustion [18]. Successful achievement of VO_2 peak was based on the following objective criteria: respiratory exchange ratio (RER) ≥ 1.1, HR ± 10 bpm of age-predicted maximum, blood lactate concentration ≥ 8.0 mmol/L, and a rating of perceived exertion ≥18 on the Borg 15-point scale [19]. All subjects met all of the criteria during each GXT. For each subject, the VT was determined via the V-slope method as described [20].

Following recovery from the GXT (defined as a HR ≤ 90 bpm), muscular strength was measured using a 1-RM test for bench press and squat as described [21]. Subjects were instructed to warm up with 3-sets of incrementally increasing weights (i.e. increase each set 5–10% for bench press and 10–20% for squat) and rest periods (i.e. 1 min, 2 min, and 2–4 min) to warm-up for their testing 1-RM testing sets. Following the last warm up set, and a 2–4 min rest period, weights were increased again (5–10% for bench press and 10–20% for squat) and subjects were instructed to attempt a 1-RM; if the subjects were successful they would complete this step again until failure. Following a testing failure the weight lifted would decrease (2.5–5% for bench press and 5–10% for squat) and the subject would attempt another lift after 2–4 min of rest. All 1-RMs are defined as the maximal weight lifted successfully for a single repetition.

2.5. Training session protocol for aBFR

Each of the 20 training sessions consisted of 20 min of exercise on a modified NuStep recumbent cross trainer (NuStep Inc., Ann Arbor, MI, USA) (contralateral elbow flexion/extension and knee flexion/extension) followed by 30 min of passive recovery (no physical activity in a prone position). At the beginning of each training session, participants were fitted with liquid cooled compression cuffs, which were kept cool via circulation of a refrigerated liquid maintained at 15–18 °C. In addition, a liquid cooled vest was worn and maintained at the same temperature. The cuffs were attached to each arm (2 in. distally from axilla) and thigh (4 in. proximally from patella), and the pressure of the compression cuffs was continuously maintained between 60 and