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Case study

Bilateral muscle strength symmetry and performance are improved following walk training with restricted blood flow in an elite paralympic sprint runner: Case study

Amadeo Félix Salvador*, Karla Rochana Schubert, Rogério Santos de Oliveira Cruz, Rogério Bulhões Corvino, Kayo Leonardo Pereira, Fabrizio Caputo, Mariana Fernandes Mendes de Oliveira

Human Performance Research Group, Center for Health and Sport Sciences, Santa Catarina State University, Florianópolis, Brazil

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ABSTRACT

Objectives: Investigate the influence of 4 weeks of walk training with blood flow restriction (BFR) on muscle strength, metabolic responses, 100-m and 400-m performances in an athlete with cerebral palsy.
Methods: An elite Paralympic sprinter (20 years, 176 cm, 64.8 kg) who presented with moderate hemiplegic cerebral palsy (right side impaired) completed four visits before and after 4 weeks of the BFR training: 1) anthropometric measurements, familiarization of maximal voluntary contraction (MVC), and an incremental test; 2) MVC measurements; 3) 400-m performance, and 4) 100-m performance. The walk training with BFR consisted of four bouts of 5 min at 40% of maximal aerobic speed with 1 min of passive rest with complete reperfusion.
Results: All performance times were lower with training (100-m: 1%; 400-m: 10%), accompanied by adaptations in aerobic variables ($\dot{V}O_2$max: 6%; OBLA: 24%) and running economy (9–10%). Lactic acid energy metabolism was reduced (25–27%), even in the presence of a higher lactate efflux from the previously active muscles after training. MVC (right leg: 19%; left leg: 9%) increased in both legs unevenly, decreasing the muscle strength asymmetry between limbs.
Conclusions: These results indicate that cardiovascular and neuromuscular adaptations can be simultaneously induced following BFR training in a paralympic sprinter.

1. Introduction

Motor impairment in cerebral palsy (CP) is multifactorial and includes complications such as spasticity, dystonia, muscle contractures, bony deformities, coordination problems, loss of selective motor control, and muscle weakness (Gormley, 2001). Fortunately, some of these symptoms can be mitigated by either aerobic or strength training programs (Holland & Steadward, 1990; Nsenga, Shephard, & Ahmaidi, 2013). Nevertheless, increases in muscle strength and aerobic fitness concurrently continue to be a challenge for coaches aiming to improve the performance of world-class parathletes with CP, because of an inability to progressively increase workloads (Gawronski, 2014).

As an alternative for populations with difficulties in training with high loads and velocities, blood flow restriction (BFR) training at low intensities has been shown to improve muscle strength (Laurentino et al., 2012; Takarada, Takazawa, Sato, Takebayashi, Tanaka, & Ishii, 2000) and aerobic parameters (Abe et al., 2010; Park, Kim, Choi, Kim, Beekley, & Nho, 2010), even under disease conditions (Gualano et al., 2010). Consequently, BFR training could induce advantageous adaptations in paralympic sprint runners with CP aiming at performance enhancement, because the aerobic improvements induced by BFR do not result in strength losses as observed after traditional aerobic training programmes (Bamman, Hunter, Newton, Roney, & Khaled, 1993; McCarthy, Pozniak, & Agre, 2002; van der Ploeg, Brooks, Withers, Dollman, Leaney, & Chatterton, 2001). Therefore, the aim of the present study was to investigate the effects of 4 weeks of treadmill walk training with

* Corresponding author. Laboratório de Pesquisas em Desempenho Humano – CEFID/UDESC Pascoal Simone, 358, Coqueiros, Florianópolis, SC, CEP – 88080-350, Brazil. Tel.: +55 48 3321 8641; fax: +55 48 3321 8607.
E-mail address: amadeofelixsalvador@gmail.com (A.F. Salvador).

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BFR on muscle strength, metabolic responses, and 100- and 400-m performances in a paralympic sprint runner with CP.

2. Methods

One male elite Paralympic athlete (20 years old, 176 cm in height, and 64.8 kg in weight) participated in this study. He presented with moderate hemiplegic CP (right side impaired) with associated epilepsy caused by head trauma due to a domestic accident at the age of 7 months. With a 5-year training experience for 100 m, 200 m, and 400 m running races and 1-years experience in 'traditional' resistance training, the athlete is the national record holder in 200-m and 100-m sprint in his category (T37). All methodological procedures were explained to the participant, and written informed consent was obtained. The ethics committee of the local institution approved this study (reference number: 209-705). In order to avoid detraining effects and any influence in the outcomes, the load and volume of the strength and conditioning training were kept constant, and during the intervention period only BFR training was added to increase the overload. The subject was instructed to maintain the same dietary profile, which was checked by personal reports informing that no change in the diet plan occurred, as well as in the use of nutritional supplements.

The athlete performed four visits to the laboratory before and after the training program, containing as follows: 1) anthropometric measures, familiarization with the maximal muscle strength test and an incremental test; 2) measurement of maximal muscle strength and rate of force development (RFD); 3) 400-m performance and; 4) 100-m performance. All sessions were performed at the same time of day (±2 h). The participant was instructed to arrive fully rested for the experimental sessions and to have abstained from caffeine and alcohol in the 24 h prior to testing. The athlete was always verbally encouraged to give his best effort. Throughout the incremental and running performance tests, he wore a facemask and pulmonary oxygen uptake ($\dot{V}O_2$) was measured breath-by-breath using a portable gas analyser (Cosmed K4^{b2}, Rome, Italy). In addition, capillary blood samples were collected at specific time points for the determination of blood lactate concentration (BLC) by enzyme electrode technology (YSI 1500 SPORT, Yellow Springs, Ohio, USA).

2.1. Pre-post measurements

Weight (kg), height (cm) and skinfold thickness (subscapular, triceps, suprailiac and medial calf; in mm) of the participant were inserted into a specific equation for adults from southern Brazil to estimate corporal density (Petroski & Pires-Neto, 1996). The total body fat was then obtained with the Siri's equation (1993). Muscle plus bone volumes of both legs were calculated according to Jones and Pearson (1969). An incremental exercise test was performed on a motorized treadmill (Millenium Super Atl, Inbramed, Porto Alegre, Brazil) in order to measure maximal pulmonary oxygen uptake ($\dot{V}O_2$max), the maximal aerobic speed (MAS), and the intensity associated with the onset of blood lactate accumulation (OBLA). The test started with a 7 km/h speed and it was increased by 1 km/h by every third minute until exhaustion. The slope of treadmill was maintained at 1% during all tests. At the end of each stage, a 30 s rest period was necessary to take capillary blood samples (25 μL) from non-hyperemic earlobe in order to measure BLC. The test ended at the point of voluntary exhaustion, and the MAS was calculated as the speed of the last stage fully completed plus the fraction of time spent in the stage at which exhaustion occurred multiplied by 1 km/h (Kuipers, Verstappen, Keizer, Geurten, & van Kranenburg, 1985). The OBLA speed was determined by linear interpolation (lactate vs. speed) given a fixed concentration of 3.5 mmol/l according to Heck, Mader, Hess, Mucke, Muller, and Hollmann (1985).

Maximal isometric quadriceps contractions were performed during static knee extension at a knee joint angle of 60°. After 5 min of warm-up on the treadmill at 7 km/h, the subjects was seated in a test chair (Knee extension – Tonus®; São Paulo, Brazil) and firmly strapped at the hip and distal thigh. Two maximal efforts of 5 s were performed with both legs to determine bilateral maximal voluntary contraction (MVC). Thereafter, two more unilateral maximal efforts of 5 s were performed alternating the legs. A 5 min rest period was given between MVC measurements. The participant was carefully instructed to contract "as fast and forcefully as possible". The MVC was measured by a load cell (SDS 200 kg) adapted in the test chair. For the data collection, a 4-channel acquisition system with an analogic digital converter (14-bit) with sampling rate set as 2000 Hz (Miootol 400, Miotec Biomedical Equipment LTDA) was used. Subsequently, the signal was converted to Newtons and multiplied by the lever arm length to calculate the moment of force ("torque"). All recorded moments were corrected for the effect of gravity on the lower limb according to procedures described previously (Aagaard, Simonsen, Trolle, Bangsbo, & Klausen, 1995). The positioning of the seat, backrest, and lever arm length was similar pre- and post-training. Contractile RFD was determined from the trial with peak isometric moment of force. RFD was derived as the average slope of the moment–time curve (Δmoment/Δtime) over time intervals of 0–30, 0–50, 0–100, and 0–200 ms relative to the onset of contraction (Aagaard, Simonsen, Andersen, Magnusson, & Dyhre-Poulsen, 2002).

The 100- and 400-m time trials were performed on a 200-m synthetic outdoor track with flat bends. Before both performances the athlete warmed-up for 5 min at 7.8 km/h (60% MAS) followed by three practice sprints of 3 s (interspersed with 30-s of jogging). After that, the athlete was required to rest passively for 5-min. Performance times were recorded using a photocell system (Speed Test 6.0, Cefise, São Paulo, Brazil). Specifically for 400-m running performance, the time of initial and final 200-m were recorded and the sum of these two sub-distances provided the total time of performance. At rest and immediately before performance trials, capillary blood samples (25 μL) were taken. Additional samples were collected at 1, 2, 5, 7, 10 minutes post 100-m running performance. After 400-m, samples were collected every min from 0 to 10 min, 2 min from 10 to 20 min and 5 min from 25 to 60 min for the determination of BLC kinetics. The $\dot{V}O_2$ was also continuously registered during the early phase of recovery period (10 min).

2.2. Training protocol

The training protocol consisted of 12 sessions (4 weeks) of treadmill walk training with bilateral cuff inflation on the upper thighs, with the aid of a manual sphygmomanometer 18 cm wide. In the first week, the athlete completed four bouts of 5 min at 5.2 km/h (40% MAS) with 140 mmHg of pressure (1 min of passive rest between bouts with complete reperfusion). At every third session, an additional bout and 10 mmHg of pressure in the pneumatic cuffs were added. In this way, by the end of the training period, the runner completed seven bouts at 170 mmHg in the last week of intervention. Before each session, the athlete warmed-up at 7.8 km/h (60% MAS) for 5 min. This protocol was applied to provide a greater training stimulus, i.e., a higher tolerable training intensity and/or duration and occlusion pressures leading to high order fibre recruitment. Additionally, the brief episodes of low and high O_2 exposure in skeletal muscle, generated by the cycles of cuffs inflating and deflating (i.e., ischemia-reperfusion), could also induce additional training-effects on oxidative metabolism and