BIOSCIENCE JOURNAL

ACUTE EFFECT OF DIFFERENT ORDERS OF CONCURRENT TRAINING ON GLYCEMIA

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How to cite: SILVA JUNIOR, O.T., et al. Acute effect of different orders of concurrent training on glycemia. *Bioscience Journal*. 2021, **37**, e37015. https://doi.org/10.14393/BJ-v37n0a2021-49851

Abstract

The present study verified the effect of a concurrent training (CT) session in different orders, Strength + Endurance (SE) and Endurance + Strength (ES), on the glycemic control. The crossover study included 20 young men, 21.80 ± 2.90 years, IMC ≥ 23 kg/m^2, 24.83 ± 3.68% of fat, who performed both CT sessions separated by 72 h. Capillary glycemia was measured at pre, immediately post the end of each exercise session, and during the recovery period at 30, 60, and 90 minutes. The comparisons were performed using Two-way ANOVA (order and time), paired test-t for the area under the curve, as well as Cohen's d effect size. There was effect of exercise order ($F = 5.973$; $p = 0.03$), effect of time ($F = 18.345$; $p = 0.001$) and interaction between order and time ($F = 2.835$; $p = 0.03$). The area under the curve presented a significant reduction ($p = 0.03$, effect size = 0.51, moderate). The area under the curve was smaller in SE, as well as glucose concentrations at end and post 30 min of exercise, suggesting better efficiency in glycemic control compared to ES.

Keywords: Aerobic training. Blood glucose. Exercise. Resistance training.

1. Introduction

Non-communicable chronic diseases (NCDs), such as obesity, diabetes mellitus (DM), systemic arterial hypertension, dyslipidemia, and cardiovascular diseases represent a growing health problem and are directly associated with insulin resistance (Carvalheira and Saad 2006). Data from the literature point to a specific link between body mass index ≥ 23 kg/m^2 (BMI) and insulin resistance as a risk factor for the development of diabetes mellitus (Chung et al. 2012; Okura et al. 2018). On the other hand, physical exercise participates in the prophylactic action of these alterations in glycemic metabolism (Sheri et al. 2016). However, the long-term results of training are obtained depending on the sequence of acute sessions, and thus, to promote the necessary results the effects of the training must be well known (Pescatello et al. 2014).

Regarding the type of exercise, it is well established in the literature that both aerobic and resistance exercises (Rodrigues et al. 2016) are considered a non-drug strategy to combat insulin resistance, aiding in glycemic control. The term concurrent training (CT) is used to refer to programs that systematically integrate strength (ST) and endurance training (ET) in a single session (Fyfe et al. 2014). In general, when comparing the effects of CT with one type of training in isolation, ET or ST, a phenomenon known as interference effect is observed (Bell et al. 2000). Although studies point to interferences in aerobic adaptations and performance-related muscular hypertrophy, there are still gaps in the literature on the influence of the order of stimuli on the acute response of glycemia, since altering exercise order can provoke different muscular, neural, and metabolic responses. Thus, the objective of the present study was to investigate the effects of a CT session performed in different orders on glycemic control in young adults with BMI ≥ 23 kg/m^2. It was hypothesized that glycemic responses would be influenced by the order of the exercises.

2. Material and Methods

Design

The crossover study design made it possible to verify capillary glycemia levels after two different orders of CT sessions. Collections were performed at pre (rest), immediately after exercise (60 min) and at 30, 60 and 90 minutes of recovery. Two session orders were adopted: session 1 - Strength + Endurance (SE) and session 2 - Endurance + Strength (ES), with a 72h interval between sessions (Figure 1). The strength training consisted of 4 sets with repetitions to eccentric failure and 90 second intervals based on 70% intensity of 1RM, and endurance training consisted of 30 minutes of continuous running on a treadmill at 70% of peak VO_2. The data were collected in the period between 4 and 6 p.m. To minimize the effect of diet, under the guidance of a nutritionist, all participants received 300 mL of whole milk blended with a banana and 50 grams of oat flakes one hour before the beginning of the exercise session, without added sugar.

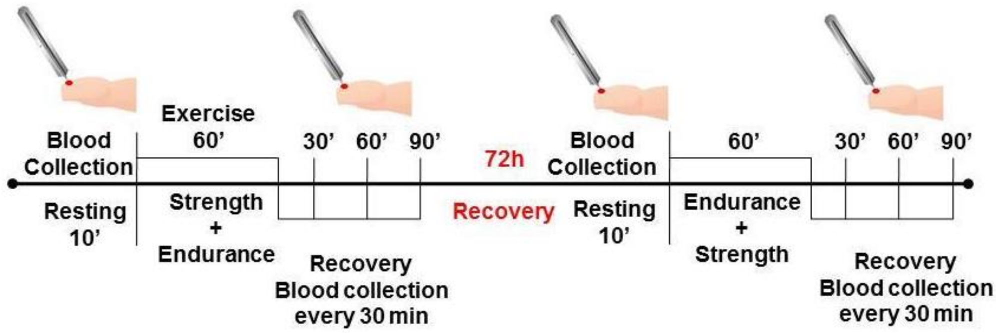

Figure 1. Experimental design.

Participants

Twenty male subjects between the ages of 20 and 25 were recruited through written invitation and, after acceptance and clarification of any questions, all participants signed the term of informed consent. Inclusion criteria were: no health restrictions or limitations identified by the Physical Activity Readiness Questionnaire (PAR-Q), exercising over six months previously to the study and presenting BMI ≥ 23 kg/m^2. The exclusion criterion was: not using hypoglycemic drugs. The study complied with the ethical rules for research in humans with approval by the Ethics and Research Committee of the Catholic University Center Unisalesiano Lins - Plataforma Brasil (n° 2.753.688/2018).

Body fat

Skin folds measurements were collected from the following points: triceps, abdominal and suprailiac. A scientific adipometer of the brand Cescorf@ was used, and the determination of body density and conversion into fat percentage were calculated following the guidelines and equations of Guedes (1994).

Capillary glycemia

Capillary glycemia was measured at the end of the 10-minute baseline period pre-exercise, immediately after the end of each 60 min session, and during the recovery period at 30, 60, and 90 minutes. Was used an Accu-Check Advantage® glucometer, Roche brand, with proven accuracy in accordance with International Organization for Standardization (ISO) 15197 of 2003 and 2013 as target pattern (King et al. 2018).

Aerobic power

Participants wore a mask connected to a portable gas analyzer (METALYSER 3B - CORTEX) and performed a progressive motorized treadmill test (Imbramed Millenium Super ATL) until voluntary exhaustion. The incremental test began at a speed of 8 $km.h^{-1}$ with load increments of 1 $km.h^{-1}$ every three minutes. Heart rate during each test was recorded at every five seconds by a heart rate monitor (Polar S810i, Polar Electro OY, Finland). The highest VO_2 obtained during the 30 seconds of each stage was considered as the peak VO_2. The peak VO_2 was the lowest intensity at which peak VO_2 was obtained. If the intensity of peak VO_2 was not sustained for at least 1 minute, the intensity of the previous stage was considered as the peak VO_2 (Weltman et al. 1990).

Determination of the repetition maximum (1rm)

The maximum strength test (1RM) was performed for the following exercises considering a classic split routine involving 4 consecutive workouts with 1 day rest (Lin et al. 2012): bench press, incline bench, dumbbell bench press, cable chest fly, triceps forehead, closed footprint bench press and parallel triceps. Up to six attempts were allowed to identify the maximum weight the volunteer could lift in one repetition for the same test, with a rest interval of two to five minutes. The maximum load was considered as the final load at which the subject performed a movement with the appropriate pattern of execution. When the maximum load was not found in up to six attempts, a new test was performed 48 hours after the previous test (Brown and Weir 2001). First, the subjects performed a session to familiarize themselves with the procedures and to determine an "ideal" load for the test in which they found a load to perform the maximal repetition test for each exercise. After 72h, in a second session the subjects performed the maximal repetition test for determination of 1RM. Through this procedure it is possible to minimize the error in the determination of 1 RM (Nascimento et al. 2013).

Statistical analysis

The data were tested for normality using the Shapiro-Wilk test and sphericity by the Mauchly's test. The two-way repeated measurements analysis of variance (ANOVA) followed by the Tukey's HSD post-hoc test was used to analyze measurements of capillary glycemia. Paired Student's t-test was performed to verify the number of repetitions between different orders in strength training. For interpretation of the final data, the area under the curve (AUC) was calculated by the trapezoidal method and compared using the paired Student t-test. The effect size (ES) was calculated by the mean standardized difference, considering effect trivial (< 0.20), small (0.20-0.49), moderate (0.50-0.79) or large (>0.80) (Cohen 1998). Data are expressed as mean and standard deviation. The value of $p \leq 0.05$ was adopted as statistically significant. For analysis of the data the program Statistical Package for Social Sciences (SPSS) was used, version 20.0 (IBM Corp, NY, USA).

3. Results

The general characteristics, anthropometric data, maximal aerobic capacity and maximum strength of study participants are shown in table 1.

Table 1. Characterization of study participants, presented as mean and standard deviation.

Variables	Mean ± SD
Age (Years)	21.80 ± 2.90
Weight (Kg)	86.45 ± 11.51
Height (m)	1.76 ± 0.05
BMI (Kg/m^2)	25.69 ± 2.55
Body fat (%)	24.83 ± 3.68
Peak VO_2 (ml/kg/min)	44.96 ± 5.41
1 RM Bench press (kg)	73.00 ± 21.61
1 RM Incline bench (kg)	62.00 ± 19.86
1 RM Dumbbell bench press (kg)	42.00 ± 14.75

1 RM Cable chest fly (kg)	68.50 ± 15.82
1 RM Triceps test (kg)	32.60 ± 9.84
1 RM Supine closed footprint (kg)	60.00 ± 20.96
1 RM Parallel triceps on machine (kg)	100.30 ± 36.26

SD: mean and standard deviation. BMI: body mass index.

When comparing the orders ES with SE, the number of repetitions in each exercise did not present significant difference, which suggests that the muscular fatigue induced by the strength training was similar between the different orders (bench press p=0.49, incline bench p=0.78, dumbbell bench press p=0.56, cable chest fly p=0.19, triceps forehead p=0.33, closed footprint bench press p=0.72 and parallel triceps p=0.46) in figure 2.

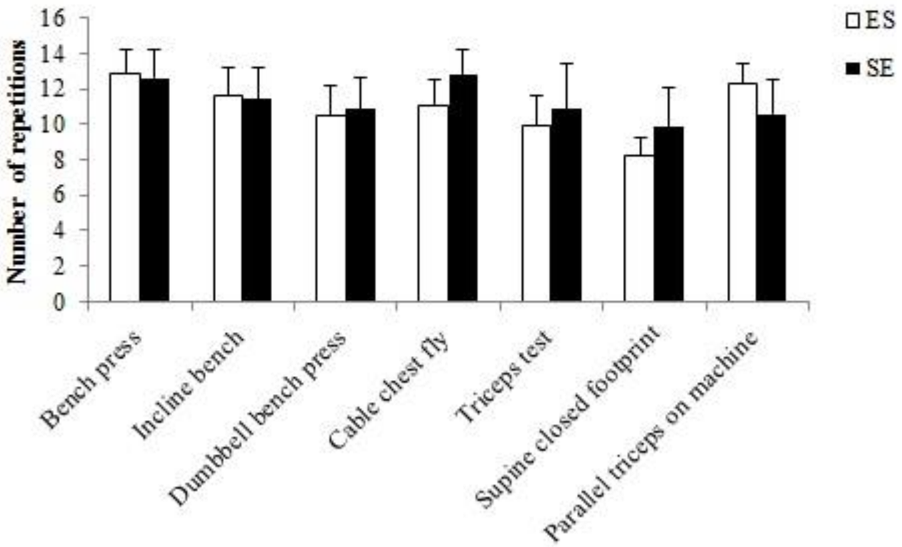

Figure 2. Number of repetitions performed during the 4 sets of weight in each exercise. SE = Strength + Endurance; ES = Endurance + Strength (n =20 per group).

Two-way ANOVA (order vs time) showed that there is effect of order (F = 5.973; p = 0.03) effect of time (F = 18.345; p = 0.001) and interaction between order and time (F = 2.835; p = 0.03). Kinetics of capillary glycemia performed in different orders was presented in figure 3. At rest, the groups presented no differences (p = 0.25), however a reduction in blood glucose concentrations was found at all collection times in the SE session, while in the ES session the hypoglycemic effect becomes significant only from 30 minutes after the session. A significant difference was observed between the groups at 60 immediately after post exercise (F = 5.901; p = 0.03) and 30 minutes of recovery (F = 8.992; p = 0.01), evidencing that the SE order caused a greater reduction in blood glucose concentrations immediately after exercise (30 min) and remained for a further 30 minutes during the recovery period when compared to the ES order. After 60 minutes of recovery there was no difference in serum glucose concentrations between the studied groups.

Figure 4 presents the data regarding the calculation of the area under the glucose concentration curve the two different orders of CT. The SE exercise session presented a smaller area on the glucose curve (p = 0.03) with magnitude of effect size (p≤0.05, effect size = 0.51, moderate).

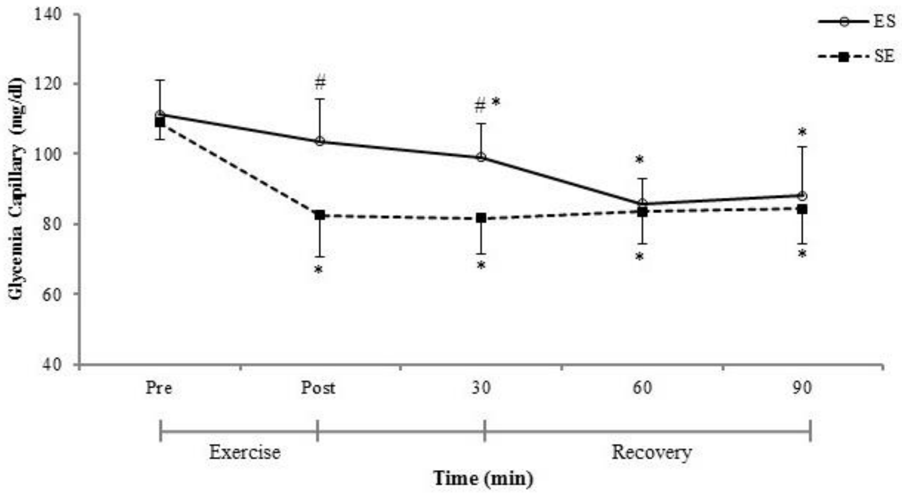

Figure 3. Comparison of the capillary glucose kinetics at pre (rest), immediately post 60 min exercise, 30-, 60-, and 90-min during recovery after the sessions of physical exercise performed in different orders. SE = Strength + Endurance; ES = Endurance + Strength (n =20 per group). Data presented as mean and standard deviation. *p ≤ 0.05 for the ANOVA test compared to time 0 (baseline) within each group, #p ≤ 0.05 for the ANOVA test compared at the same time of analysis between the different orders.

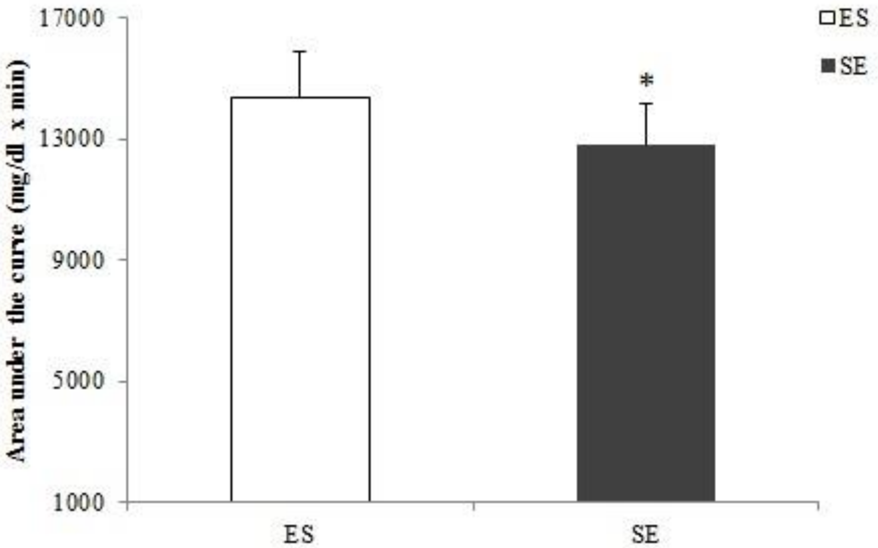

Figure 4. Comparison of area under curve of capillary glucose between different orders of execution of the concurrent training session. SE = Strength + Endurance; ES = Endurance + Strength (n =20 per group). Data presented as mean and standard deviation. *p ≤ 0.05 in relation to the group ES.

4. Discussion

The results of the present study demonstrate that both orders of execution of CT sessions had a significant effect on the reduction in glycemia concentrations over time. However, the glucose concentrations were smaller in SE order, this suggests higher glucose uptake compared to the ES order. Maintenance of adequate concentrations of glucose in the blood is fundamental for the homeostasis and survival of the organism. In rest situations, changes in glycemic flow in fasting and postprandial periods are controlled in a range appropriate for physiological and hormonal factors (James and Mcfadden 2004). In order to capture glucose at rest, after binding of insulin to its receptor, an intracellular cascade occurs, culminating in the translocation of type 4 (GLUT-4) glucose transporters (Pauli et al. 2010). During exercise, a glycemia-regulating effect may occur as a result of stimulation caused by muscle contraction, increasing the uptake of glucose by the muscle by up to 50-fold (Sylow et al. 2017). Glucose uptake in exercise occurs regardless of insulin level, and it is caused by adenosine triphosphate (ATP) depletion with increased adenosine monophosphate (AMP)/ATP ratio and consequent AMP-activated protein kinase (AMPK) activation, calcium influx, increased nitric oxide, body temperature and blood flow to the muscle (Pereira et al. 2017).

The main variables of physical exercise prescription, namely intensity, type, duration and progression, influence different body responses and adaptations (Pascatello et al. 2014). Intensity, duration, and type of exercise have been identified as important factors to determine the glucose uptake during and after the acute exercise session (Rohling et al. 2016; Pereira et al. 2017). In this way, research on the effects of the type of exercise plays a guiding role for prescription, since the effects can be antagonistic. Endurance or traditional resistance exercise is characterized by a high frequency of movements and a small resistance exerted for each muscular contraction, while strength or resistance exercise presents few repetitions and greater resistance against the movement and, in spite of different adaptations in the organism, strength, endurance, or both exercises (concurrent) have been identified as efficient in improving glucose uptake and response to insulin (Rohling et al. 2016). Data from the literature indicate that both endurance and strength exercises can be considered an effective non-drug strategy in the fight against insulin resistance, or to aid glycemic control in individuals with type 2 diabetes (Van dijk et al. 2011). In the present study, CT in two different orders promoted a reduction in glycemia at the end of the sessions.

Our data corroborate another interesting study which investigated the effect of 36 concurrent training sessions (force + endurance) on glycemia behavior in people with type 2 diabetes. Although the authors observed a significant hypoglycemic effect in 27 of the 36 sessions performed, the effect was not sustained for 48 hours, and no significant cumulative effect was observed (Bacchi et al. 2012).

In the present study, the order of exercises influenced glucose uptake, with the SE sequence being more efficient than ES. Regarding molecular aspects, resistance exercise causes increased activity of the mTORC1 (the mammalian target of rapamycin complex 1) signaling pathway, causing an increase in protein synthesis, while moderate high-volume endurance exercise performs its functions via AMPK (AMP-activated protein kinase) that acts as a key sensor of cellular energy (Ogasawara et al. 2014; Methenitis 2018). Based on these adaptations, studies in animal model, showed that the order of the concurrent exercise can present an influence, with greater phosphorylation of p70S6K (marker of mTORC1 activity), when resistance exercise is performed after endurance; and activation of AMPK when the endurance exercise is performed after resistance, with a concomitant reduction in the activity of the protein kinase B - mammalian target of rapamycin (AKT-mTOR) pathway (Ogasawara et al. 2014; Methenitis 2018).

Thus, considering the results found in the present study, it is important to emphasize that the original hypothesis was verified. Few studies have previously addressed the behavior of glycemia in different orders of exercise. The majority of studies consider chronic effects and not acute effects. The most commonly used exercises in research for acute glycemic control have an aerobic characteristic, such as running or swimming. Considering these reports, it is clear that both aerobic and resistance training contribute to the improvement in insulin sensitivity by restoring the action of important intracellular molecules in glucose uptake, since the effects of aerobic training performed after resistance exercise can cause a more pronounced drop in capillary blood glucose than in aerobic exercise alone. However, there are few studies reporting the molecular action and energetic pathways between different orders of execution in CT. Therefore, it is difficult to speculate the specific reason for glucose to present a more pronounced drop in the performance of resistance training followed by aerobic exercise. Further studies are needed in the area to better understand the glycemic behavior in relation to the order of execution in different populations.

The present study had some limitations, such as sampling by convenience criterion and covering only BMI. Thus, the selection of volunteers was restricted to a gym that received overweight and obese people. Blood glucose monitoring was not performed by the continuous monitoring method. Instead, the conventional device was used for glucose monitoring across the electrochemical method by capillary blood glucose.

5. Conclusions

In conclusion, both orders of execution of the concurrent training sessions had a significant effect on the reduction in glycemia concentrations. However, the SE order was more efficient in glucose uptake when compared to the ES order of execution, showing greater effectiveness in glycemic control, refuting the initial hypothesis. Further studies are needed to better understand the relationship between CT and glycemia, and to verify different variables such as age and attention to the molecular aspect.

Authors' Contributions: SILVA JUNIOR, O.T., CURIACOS, J.A. and DOS SANTOS, J.W.: conception and design, acquisition of data, analysis and interpretation of data, drafting the manuscript, final approval; NASCIMENTO, G.M., NISHIOKA, G.H.S. and BATISTA, A.P.: acquisition of data, analysis and interpretation of data, drafting the manuscript, final approval.

Conflicts of Interest: The authors declare no conflicts of interest.

Ethics Approval: Approved by Human Research Ethics Committee of the Catholic University Center Unisalesiano Lins. CAAE 88024018.8.0000.5379.

Acknowledgments: We would like to thank the Department of Physical Education, São Paulo State University (UNESP), and University Center Auxilium Unisalesiano for their support in carrying out this study.

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Received: 06 April 2020 | **Accepted:** 25 September 2020 | **Published:** 25 February 2021