

Aerobic Interval Exercise Training Induces Greater Reduction in Cardiac Workload in the Recovery Period in Rats

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Abstract

Background: Aerobic interval exercise training has greater benefits on cardiovascular function as compared with aerobic continuous exercise training.

Objective: The present study aimed at analyzing the effects of both exercise modalities on acute and subacute hemodynamic responses of healthy rats.

Methods: Thirty male rats were randomly assigned into three groups as follows: continuous exercise (CE, $n = 10$); interval exercise (IE, $n = 10$); and control (C, $n = 10$). Both IE and CE groups performed a 30-minute exercise session. The IE group session consisted of three successive 4-minute periods at 60% of maximal velocity (Max Vel), with 4-minute recovery intervals at 40% of Max Vel. The CE group ran continuously at 50% of Max Vel. Heart rate (HR), blood pressure (BP), and rate pressure product (RPP) were measured before, during and after the exercise session.

Results: The CE and IE groups showed an increase in systolic BP and RPP during exercise as compared with the baseline values. After the end of exercise, the CE group showed a lower response of systolic BP and RPP as compared with the baseline values, while the IE group showed lower systolic BP and mean BP values. However, only the IE group had a lower response of HR and RPP during recovery.

Conclusion: In healthy rats, one interval exercise session, as compared with continuous exercise, induced similar hemodynamic responses during exercise. However, during recovery, the interval exercise caused greater reductions in cardiac workload than the continuous exercise. (*Arq Bras Cardiol.* 2014; 102(1):47-53)

Keywords: Blood pressure; Exercise acute effects; Intermittent exercise.

Introduction

Aerobic interval or intermittent training, originally used by athletes, consists of alternated bouts of high- and low-intensity exercises¹⁻⁴. There is a body of evidence suggesting that the magnitude of the benefits originating from physical exercise increases proportionally with the intensity of each exercise session that constitutes the exercise training program⁵. The effects observed on the cardiorespiratory and muscular function have led researchers to consider the practice of interval exercise in the field of cardiovascular diseases¹. Gibala et al⁶ have shown that interval exercise training is more efficient in inducing rapid adaptations in skeletal muscles and exercise performance as compared with continuous training. At a markedly smaller training volume, interval exercise promotes benefits in the exercise capacity and expression of antioxidant enzymes similar to those observed in traditional

conservative trainings of continuous exercise⁶. Molmen-Hansen et al⁷ have recently demonstrated that intermittent exercise sessions could reduce blood pressure (BP) and improve myocardial function of hypertensive patients. In addition, several previous studies had reported that interval training at a relatively higher intensity could be used in both clinical practice and experiments, and that such exercise modality had greater beneficial effects on the heart^{8,9}. Those characteristics suggest that intermittent training can be more appropriate to individuals with metabolic syndrome, dyslipidemia and other cardiovascular risk factors¹⁰⁻¹². However, little is known about the acute and subacute differences obtained with that exercise modality as compared to traditional continuous training. The acute effect refers to the physiological response observed when exercise is performed [increase in heart rate (HR) and systolic BP]. However, the subacute effects occur immediately after finishing the training, and involve chronic physiological adaptations that develop over the training period¹³. Thus, such effects of interval and continuous exercise trainings should be further studied, considering that continuous and interval exercise trainings could promote different hemodynamic responses regarding kinetics and magnitude, especially important for cardiovascular impairment. The present study aimed at assessing the acute and subacute hemodynamic responses of both exercise modalities in rats.

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Methods

Animals

All procedures performed were approved by the Committee on Ethics and Research of the Fundação Oswaldo Cruz (protocol 31/10-3 LW21-10), according to the Helsinki Declaration. There was no conflict of interest related to this study.

During the experimental period, the animals were submitted to 12-hour light/dark cycles under controlled temperature ($22 \pm 1^\circ\text{C}$), and kept in boxes (three to four animals per box). The animals received water and food preparation *ad libitum*.

Male Wistar rats (weight range, 300 and 350 g; minimum age, 180 days) were randomly distributed into three groups as follows: continuous exercise (CE, $n = 10$); interval exercise (IE, $n = 10$); and control (C, $n = 10$).

Exercise protocol

The whole protocol comprised six consecutive days. All animals were adapted to exercise treadmill (HT 2.0, Hectron Fitness Equipment, Rio de Janeiro, Brazil) over three consecutive days (10 minutes at 10 m/min). On the fourth day, maximal exercise test was performed to determine maximal velocity (Max Vel). The test consisted of initial velocity of 5 m/min with 1.5-m/min velocity increase every 2 minutes up to exhaustion, when the animal remained on the shock grid despite the sound stimulus. On the fifth day, the rats underwent the cannulation procedure described in the following session. Finally, on the sixth day, the animals underwent either exercise or control session. Both IE and CE groups underwent a 30-minute exercise training, including 3 minutes of warm-up and 3 minutes of deceleration at 30% of Max Vel. The CE group session consisted of continuous running at 50% of the Max Vel, while the IE group performed three successive 4-minute periods at 60% of Max Vel, with 4-minute intervals of recovery at 40% of Max Vel. Such intensities were used to equalize the exercise session volume between the groups, allowing their comparison. By maintaining mean intensity at 50% of Max Vel in both groups, the only difference would be the way of applying intensity, that is, with intervals or not. Thus, the possible differences found between the two groups could not be attributed to different exercise loads.

Surgical procedure and hemodynamic measures

All animals were anesthetized with pentobarbital (50 mg/kg ip) for polyethylene cannula (PE-50 with saline-heparin solution) implantation in the left carotid artery to directly measure BP and HR. The cannula was then exteriorized on the animal's back, allowing 24-hour analysis for all three groups. Thus, the analysis was performed while the animals were conscious and could move freely during the experiment.

To measure BP and HR, the cannula was connected to a pressure transducer (TSD104A, BIOPAC Systems Inc, Goleta, CA, USA) and a signal amplifier (DA100C, BIOPAC Systems Inc, Goleta, CA, USA). The measures were acquired at a sample rate of 200 samples/second by use of the

MP150 system (BIOPAC Systems Inc, Goleta, CA, USA) and recorded using a specific software (AcqKnowledge 3.7.3 for Windows, BIOPAC Systems Inc, Goleta, CA, USA). The signals were recorded at rest (10 minutes), during exercise (every 8 minutes excluding warm-up and deceleration), and up to 90 minutes after ending the exercise (1 minute every 5 minutes). The signals were analyzed beat-to-beat to quantify changes in BP and HR. Rate pressure product (RPP), considered an estimation of myocardial workload, was calculated by multiplying HR by systolic BP.

Statistical analysis

Differences between the groups were analyzed by using two-way ANOVA for repeated measures, followed by Bonferroni post-test. The significance level of 5% was adopted. All results were expressed as mean \pm standard deviation. The statistical analyses were performed with the GraphPad Prism software (Version 5 for Windows, GraphPad Software, Inc, La Jolla, CA, USA).

Results

The groups had no statistical difference regarding body weight (CE: 377.5 ± 16 ; IE: 374.4 ± 18 ; C: 378.3 ± 15 g) and hemodynamic measures at rest. In the maximal exercise test, no statistical difference was observed between the groups regarding Max Vel (CE: 20.5 ± 3 ; IE: 19.6 ± 2 ; C: 19.2 ± 1 m/min) and duration (CE: 1319.9 ± 200 ; IE: 1204.5 ± 179 ; C: 1209.4 ± 105 sec).

The acute and subacute effects on BP, HR and RPP in the different exercise modalities are shown in Figures 1 and 2, respectively.

Regarding the acute effect of exercise, the CE group had a statistically higher response after 8, 16 and 24 minutes of exercise for systolic BP, HR and RPP as compared with the baseline values (Table 1). In addition, the CE group had a statistically lower diastolic BP after 8, 16 and 24 minutes of exercise as compared with rest values (Table 1). The IE group also had a statistically higher response after 8, 16 and 24 minutes of exercise for systolic BP and RPP as compared with rest values, while diastolic BP was statistically reduced only after 8 minutes of exercise (Table 1).

Regarding the subacute effect of exercise in the CE group, statically lower values were observed as follows: of systolic BP, at minutes 115 (121.2 ± 5.9 mmHg, $p = 0.04$) and 120 (120.3 ± 7.5 mmHg, $p = 0.03$); of RPP, at minutes 55 (44875.5 ± 4925.4 mmHg.bpm, $p < 0.05$), 75 (45153.5 ± 4937.8 mmHg, $p < 0.05$) and 115 (43098.2 ± 4318.7 mmHg.bpm, $p < 0.01$) as compared to rest values. In the IE group, systolic BP was statistically reduced at minutes 50 (120.2 ± 12.2 mmHg, $p = 0.03$), 55 (118.2 ± 13.9 mmHg, $p = 0.02$) and 60 (118.0 ± 15.5 mmHg, $p = 0.03$), while mean BP was statistically reduced at minutes 55 (100.1 ± 8.3 mmHg, $p = 0.03$) and 60 (101.0 ± 7.8 mmHg, $p = 0.04$) as compared to rest values. In addition, HR and RPP were statistically reduced at minutes 55 and 45, respectively, until the end of the analysis (120 minutes).

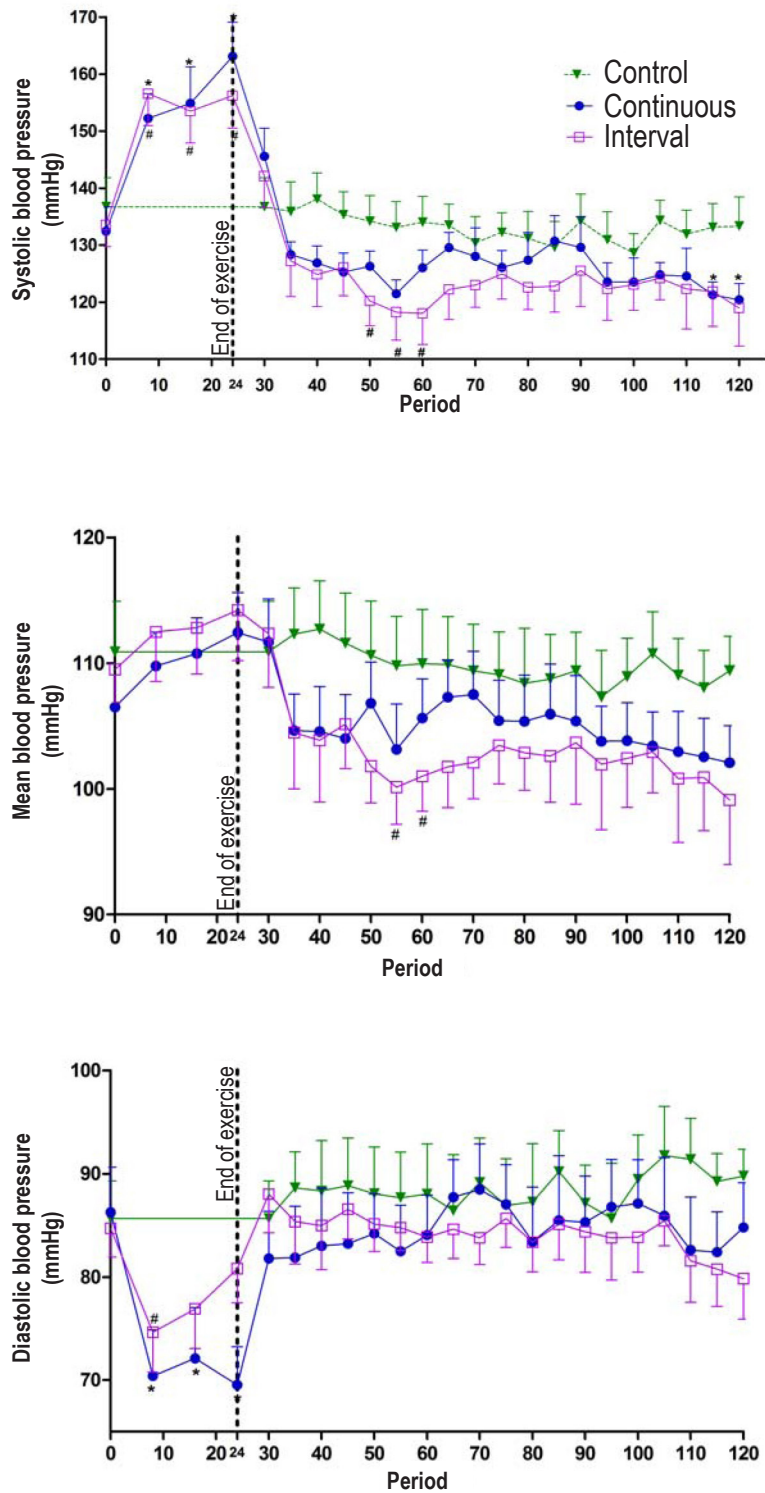


Figure 1 - Systolic, mean and diastolic blood pressure during and after exercise training. * $p < 0.05$ vs. rest in the continuous group; # $p < 0.05$ vs. rest in the interval group.

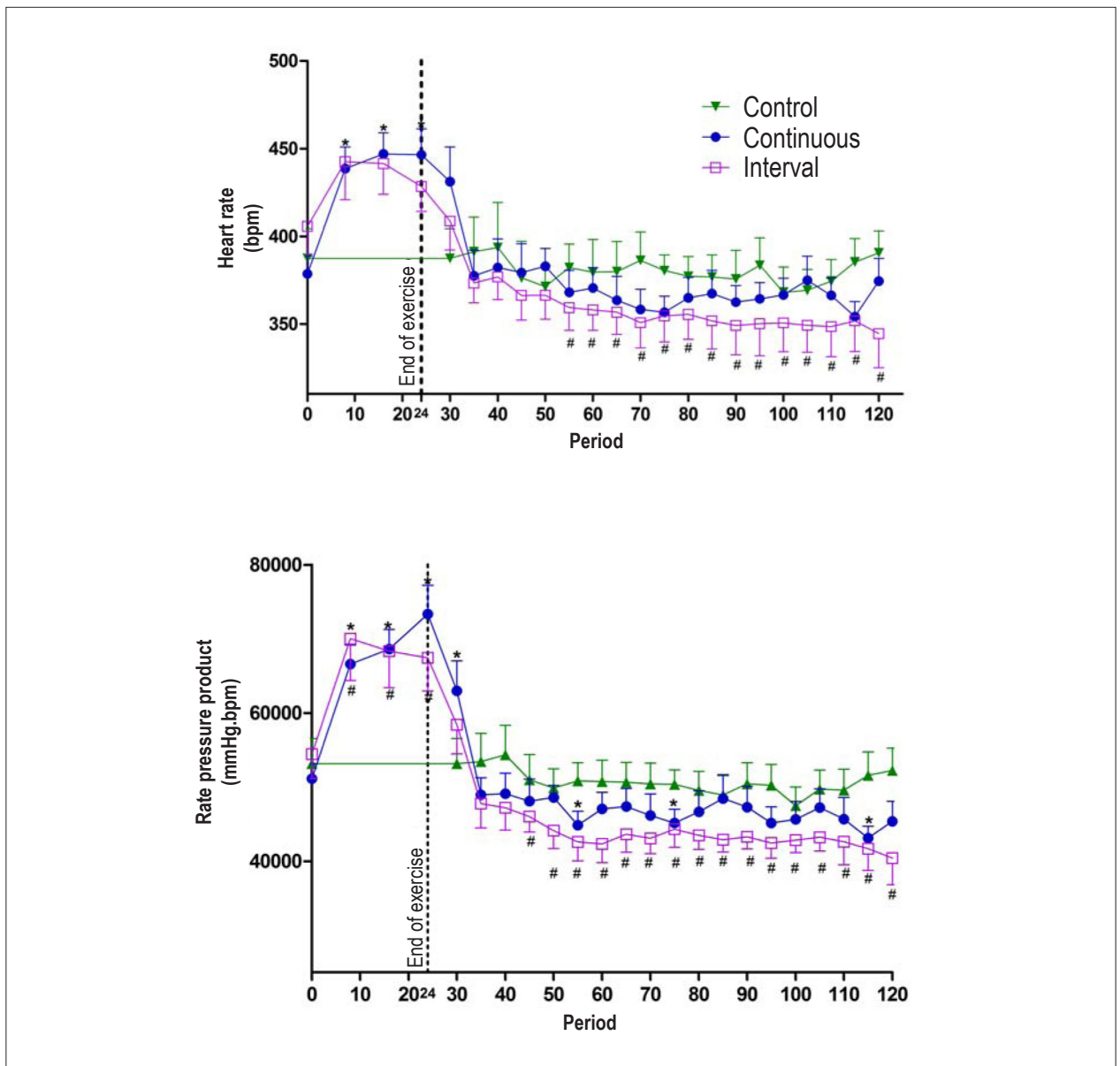


Figure 2 - Heart rate and rate pressure product during and after exercise training. * $p < 0.05$ vs. rest in the continuous group; # $p < 0.05$ vs. rest in the interval group.

Finally, the C group showed no statistic difference in any hemodynamic parameter neither during, nor after the control session, as compared to the initial measure.

Discussion

The major finding of this study was as follows: similarity of the increase in the hemodynamic parameters obtained during the interval exercise session and greater reduction in HR and RPP in the recovery period as compared with those of the continuous exercise session. There is a body of evidence suggesting that the magnitude of the benefits originating from physical exercise increases proportionally with the intensity of each exercise session that constitutes the exercise training

program⁵. Thus, the principle of the interval exercise is to spend more time in higher intensity zones as compared with continuous exercise, without causing exhaustion due to alternation of lower-intensity recovery periods³. Several previous studies have reported that intermittent exercise induces greater increase in VO_{2peak} ¹⁴, in muscular adaptations⁶, HDL-cholesterol¹⁴ and greater reduction in baseline BP⁷, in healthy individuals and patients, such as those with hypertension and heart failure. In fact, the prescription of interval exercise has exponentially increased over a relatively short period of time, especially in cardiac rehabilitation^{8,14}. However, that exercise modality, consisting of higher-intensity periods, could promote an increase in myocardial workload, therefore increasing concern with exercise safety.

Table 1 - Hemodynamic responses obtained at baseline and during physical exercise (8, 16 and 24 minutes) for the continuous, interval and control groups

		SBP	MBP	DBP	HR	RPP
Baseline	CE (n = 10)	132.4 ± 11.3	106.4 ± 7.2	86.2 ± 12.3	378.6 ± 28.3	51136.8 ± 5306.3
	IE (n = 10)	133.5 ± 10.8	109.4 ± 7.3	84.7 ± 8.2	405.6 ± 44.7	54444.0 ± 9282.6
	C (n = 10)	136.7 ± 15.9	110.9 ± 12.0	85.6 ± 10.8	387.4 ± 50.4	53161.5 ± 10232.5
8 min		SBP	MBP	DBP	HR	RPP
	CE (n = 10)	152.2 [#] ± 11.4	109.7 ± 7.6	70.4* ± 12.6	438.5 [#] ± 34.7	66593.9 [#] ± 6773.5
	IE (n = 10)	156.5 [#] ± 15.8	112.4 ± 11.1	74.6* ± 11.5	442.5 ± 61.2	70002.4* ± 15835.7
	C (n = 10)	NA	NA	NA	NA	NA
16 min		SBP	MBP	DBP	HR	RPP
	CE (n = 10)	154.8 [#] ± 17.0	110.7 ± 8.0	72.1* ± 13.8	446.9 [#] ± 33.8	68607.2 [#] ± 7001.4
	IE (n = 10)	153.4 [#] ± 15.8	112.8 ± 10.4	76.9 ± 11.5	441.4 ± 49.2	68342.1* ± 13838.3
	C (n = 10)	NA	NA	NA	NA	NA
24 min		SBP	MBP	DBP	HR	RPP
	CE (n = 10)	163 [#] ± 15.9	112.4 ± 8.9	69.5* ± 10.4	446.4 [#] ± 41.7	73343.9 [#] ± 10333.4
	IE (n = 10)	156.2 [#] ± 16.1	114.1 ± 11.3	80.8 ± 9.9	428.3 ± 40.1	67420.6* ± 12530.3
	C (n = 10)	NA	NA	NA	NA	NA

Results shown as mean ± standard deviation; CE: continuous exercise; IE: interval exercise; C: control; SBP: systolic blood pressure (mm Hg); MBP: mean blood pressure (mm Hg); DBP: diastolic blood pressure (mm Hg); HR: heart rate (bpm); RPP: rate pressure product (bpm.mm Hg); NA: not assessed; *p < 0.05 vs intragroup baseline; [#]p < 0.01 vs intragroup baseline.

According to our results, the interval exercise promoted no additional increase in cardiac workload as compared with continuous exercise, since both modalities induced similar increases in systolic BP and RPP. Similar results have been found by Gayda et al⁹, when comparing central hemodynamic changes, measured by use of cardiac bioimpedance, during intermittent and continuous exercise in 13 patients with heart failure. Compared with continuous exercise, interval exercise promoted a similar increase in mean cardiac output (9.26 ± 1.93 vs 10.06 ± 3.14 L/min) and mean systolic volume (96 ± 22 vs 93 ± 21 mL).

In our study, significant reductions have also been evidenced in HR and RPP after the intermittent session. That new finding could be justified by a possible improvement in the sympathovagal balance after the interval exercise session, which might represent a cardioprotective effect. That result has been corroborated by Labrunee et al¹⁵ performing 24-hour Holter on three consecutive days in 12 patients with heart failure: after the interval exercise session; after moderate continuous exercise; and after a control period with no physical activity. Interestingly, a greater reduction in HR and an improvement in HR variability indices were found after the interval exercise session as compared with the continuous exercise session. The authors have also reported that the numbers of premature ventricular contractions and non-sustained ventricular tachycardia episodes were clearly and significantly lower after interval exercise as compared with continuous exercise or no exercise.

It is also worth noting that systolic BP was reduced in the recovery period in the IE group (50, 55 and 60 minutes) and CE (115 and 120 minutes). At the end of the period assessed, for both exercise modalities, systolic BP was not yet stable. It seems that, if the recovery period were longer, systolic BP might even show lower values. A few studies have demonstrated post-exercise hypotension (PEH) in normotensive individuals^{16,17}, while others have shown PEH in hypertensive individuals¹⁸⁻²⁰ and spontaneously hypertensive rats²¹⁻²⁴.

A larger number of studies, in addition to more extensive ones, are required to establish the real safety and efficacy of interval exercise, mainly in patients with heart disease. It is worth noting that our study was performed in an experimental model, and the application of its results in clinical practice should be extremely cautious. New experimental studies are necessary to serve as comparison base with our results. Assessments on cardiac workload, including HR and BP monitoring, during and after physical exercise practice, can increase the safety of exercise prescription, especially when involving individuals at cardiovascular risk.

Conclusion

Aerobic interval exercise sessions of a relatively higher intensity suggest a higher reduction in HR and RPP immediately after finishing exercise as compared with continuous exercise of moderate intensity in healthy rats.

Author contributions

Conception and design of the research: Masson GS, Lessa MA. Acquisition of data: Masson GS. Analysis and interpretation of the data: Borges JP, Masson GS, Lessa MA. Statistical analysis: Borges JP, Masson GS, Lessa MA. Obtaining funding: Tibiriçá E, Lessa MA. Writing of the manuscript: Borges JP, Tibiriçá E, Lessa MA. Critical revision of the manuscript for intellectual content: Borges JP, Tibiriçá E, Lessa MA.

Potential Conflict of Interest

No potential conflict of interest relevant to this article was reported.

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Study Association

This study is not associated with any post-graduation program.

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