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Camilla May Nielson

Brigham Young University - Provo

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The Effect of Interval Training on Resting Blood Pressure

Camilla Nielson

A thesis submitted to the faculty of
Brigham Young University
in partial fulfillment of the requirements for the degree of
Master of Science

Barbara D. Lockhart, Chair
Ronald L. Hager
James D. George

Department of Exercise Sciences
Brigham Young University

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ABSTRACT

The Effect of Interval Training on Resting Blood Pressure

Camilla Nielson
Department of Exercise Sciences, BYU
Master of Science

Purpose: An experimental study to examine the effects of CardioWaves interval training (IT) and continuous training (CT) on resting blood pressure, resting heart rate, and mind-body wellness.

Methods: Fifty-two normotensive (blood pressure <120/80 mmHg), pre-hypertensive (120-139/80-89 mmHg), and hypertensive (>140/90 mmHg) participants were randomly assigned and equally divided between the IT and CT groups. Both groups participated in the assigned exercise protocol thirty minutes per day, four days per week for eight weeks. Resting blood pressure, resting heart rate, and mind-body wellness were measured pre- and post-intervention.

Results: A total of 47 participants (15 females and 32 males) were included in the analysis. The IT group had a non-significant trend of reduced systolic blood pressure (SBP) and increased diastolic blood pressure (DBP) while the CT group had a statistically significant decrease in awake SBP ($p=0.01$) and total SBP ($p=0.01$) and a non-significant decrease in DBP. With both groups combined, the female participants had a statistically significant decrease in awake SBP ($p=0.002$), asleep SBP ($p=0.01$), total SBP ($p=0.003$), awake DBP ($p=0.02$), and total DBP ($p=0.05$). The male participants had an increase in SBP and DBP with total DBP showing a statistically significant increase ($p=0.05$). Neither group had consistent change in resting heart rate. Both groups showed improved mind-body wellness.

Conclusion: IT and CT reduced resting blood pressure, with CT having a greater effect. Resting heart rate did not change in either group. Additionally, both IT and CT improved mind-body wellness.

Keywords: continuous training, resting heart rate, mind-body wellness

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My parents deserve thanks for being such wonderful examples of healthful living and encouraging me in my studies of health promotion. I hope to be an example for others as well as my own children in this way. Lastly, I am forever grateful to my husband, Mark, for his love, patience, and consistent support through my graduate degree. His listening ear and countless hours of help were matchless and I cannot imagine going through this experience without him.

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Introduction

According to the United States (U.S.) Department of Health and Human Services, the top four causes of death in the U.S. in 2011 were heart disease, malignant neoplasms (cancer), chronic lower-respiratory diseases, and cerebrovascular disease (stroke) (8). These conditions usually occur over a long period of time and may result in premature death. But there are risk factors that—if detected early and treated properly—may prevent disease from occurring. Two common risk factors for heart disease are hypertension (high blood pressure) (2) and high resting heart rate (15, 17, 19).

Lewington et al. state that reducing systolic blood pressure by 2 mmHg may lower stroke mortality by about 10% and ischemic heart disease mortality by about 7% (12). Additionally, Nauman et al. reported that over a 10-year span individuals whose resting heart rate levels increased from 70 beats per minute (bpm) to greater than 85 bpm had a 90% higher risk of death from ischemic heart disease, and a 50% higher risk of death from all causes, when compared to individuals whose resting heart-rate levels remained below 70 bpm (17). Fortunately, hypertension and high resting heart rate are modifiable through a healthy lifestyle, including regular exercise (9).

One traditionally recommended method for preventing or treating hypertension is continuous moderate-intensity training sustained for 30 minutes or more (2). When measured objectively, only about 10% of U.S. adults meet federal recommendations of at least 150 min/wk of moderate-intensity or 75 min/wk of vigorous-intensity aerobic exercise, despite the many benefits regular exercise provides (29).

Numerous studies have measured the effect of interval-training versus continuous-training on resting blood pressure (3, 6, 10, 15, 16, 18, 24, 25, 27, 28, 30-33) and resting heart

rate (6, 10, 15, 16, 18, 24, 31, 33). Some of these studies' interval-training protocols resulted in a mean decrease in systolic blood pressure of 6-11 mmHg and a mean decrease in diastolic blood pressure of 4-7 mmHg (3, 6, 10, 15, 25, 27, 28) as well as a mean decrease in resting heart rate of 3.4-9.8 bpm (10, 15, 16). Conversely, the continuous-training protocols resulted in a mean decrease in systolic blood pressure of 6-8 mmHg and a mean decrease in diastolic blood pressure of 4-5 mmHg (3, 6, 10, 18, 25, 27) and a mean decrease in resting heart rate of 6.0-9.8 bpm (10, 18). The interval-training protocol in each study varied, but most contained at least one minute or more of steady-state exercise (heart rate sustained at the same intensity) in each exercise interval (3, 6, 15, 16, 18, 24, 25, 27, 28, 30, 31, 33).

CardioWaves interval-training is an interval training protocol in which heart rate is continually elevated or lowered during the entire workout in a wavelike pattern (13). Each exercise interval has a desired upper heart-rate target and each recovery interval has a desired heart-rate personal-recovery range. Wearing a heart-rate monitor is preferred so heart rate can be measured throughout the exercise and recovery intervals.

To lower heart rate in the recovery intervals, both physical and mental relaxation are used (13). Recent efforts have been made to include both the physical body and the mind in defining overall health. This is known as mind-body medicine (5) or mind-body wellness (13). For example, "a 'well' person is satisfied in work, is spiritually fulfilled, enjoys leisure time, is physically fit, is socially involved, and has a positive emotional-mental outlook" (4). Interval-training studies have shown an improved quality of life, as measured by self-report questionnaires (15, 33), with one of the studies specifically showing an additional improvement in social function (15). All elements of wellness (emotional, mental, physical, social, and spiritual) affect one another; therefore, exercise influences all parts of one's being. The

CardioWaves interval-training method is designed to improve one's mind-body wellness through being mindful of what the body is doing during the exercise and recovery intervals (13).

Increased mindfulness may increase the ability to relax, increase positive feelings, and reduce anxiety (13).

Studies have reported the effects of interval training on resting blood pressure and resting heart rate, but fewer studies have also considered the effects on mind-body wellness. To date, no published studies have tested CardioWaves interval training. Thus, the main purpose of this study was to examine the effects of interval training on resting blood pressure, resting heart rate, and mind-body wellness—specifically, to determine if these will improve.

Methods

Research Design

This experimental study considered the effects of exercise training on resting blood pressure, resting heart rate, and mind-body wellness. The participants were randomized into two groups: an interval-training (IT) group and a continuous-training (CT) group.

Participants

A power analysis (with α of 0.05, β of 0.2, and standard deviation of 12 for blood pressure) was calculated to detect a change in blood pressure of 10 mmHg between the IT group and the CT group. The power-analysis indicated 23 participants per group would be needed to provide adequate statistical power. To accommodate a potential drop-out rate of 10%, a total of 26 participants per group were recruited.

Participants included males and females who currently had normotensive (<120/80 mmHg), pre-hypertensive (120-139/80-89 mmHg), and hypertensive (>140/90 mmHg) blood pressure levels and were not taking blood pressure altering medications. Participants were

excluded for the following: currently smoking, having a BMI greater than 40, or consuming alcohol and excessive amounts of caffeine (>400 mg/d) (1). Individuals were also excluded if they currently participated in intense regular physical activity, defined as a “high” current physical-fitness-activity level (300+ min/wk of moderate-intensity or 150+ min of vigorous-intensity aerobic exercise) (22).

Participant recruitment occurred on the university campus, at local hospitals and physician clinics, on social media, and through referrals. Medical clearance was required for participation in this study and included a record of each participant’s blood pressure, BMI, and current physical-fitness-activity level. Participants were also required to sign a consent form. Approval of the study protocol was obtained through the university Institutional Review Board prior to data collection.

Procedures

Fifty-two participants were randomly assigned to the IT group or CT group through a stratified random sample to ensure that baseline resting-blood-pressure levels were equally distributed between the groups.

All participants received instruction on their assigned exercise protocol. The IT group participated in the IT protocol for 30 minutes per day, four days per week for eight weeks. The protocol consisted of continuously elevating and lowering heart rate through the exercise and recovery intervals. Each exercise interval had a desired upper heart-rate target. Immediately after reaching the target, heart rate was actively lowered to the lowest pulse rate the participant could attain and within the recovery range (sitting pulse rate plus 20). As soon as the recovery pulse was reached, heart rate was again elevated for the next exercise interval. Depending on fitness level, the exercise intervals’ heart-rate targets varied in intensity, with the usual calculation of

220 minus age used as the maximum heart-rate limit. The IT participants started with the beginner workout (13) and gradually increased their intensity throughout the eight-week intervention.

The CT group followed the current ACSM exercise guidelines for those with hypertension (20) by participating in moderate-intensity (40-60% of VO_2 reserve (20) or HR reserve (26)) steady-state exercise for 30 minutes per day, four days per week for eight weeks. All participants wore a RS300X Polar heart-rate monitor (Polar Electro Oy, Professorintie 5, FI-90440 Kempele, Finland) during each exercise session to record each workout. Both the IT and CT groups were asked to not alter any lifestyle behavior other than physical activity during the eight-week intervention.

Resting blood pressure, resting heart rate, and body mass were measured pre- and post-intervention. To avoid the acute lowering effect of blood pressure post-exercise (32), each participant abstained from exercise 24 hours (h) prior to placement of an Accutracker II ambulatory blood pressure device (ABPD) (SunTech Medical, Inc., Morrisville, North Carolina). The ABPD was worn for 24 h and took blood-pressure and heart-rate measurements three times per h (about every 20 min) from 6:00 AM until 11:00 PM (awake time period) and once per h from 11:00 PM until 6:00 AM the following day (asleep time period). Throughout the 24 h, if an error occurred, the ABPD repeated the measurement.

Mind-body wellness was measured pre- and post-intervention via the following self-reported validated online questionnaires: Brief Inventory of Perceived Stress (Stress) (11), The Functional Assessment of Chronic-Illness Therapy—Spiritual Well-Being Scale (Spiritual Well-being) (Cronbach's α = .81-.88) (21), and Worth Index (r = .86, p < .001; test retest reliability r = .74, p < .001) (14). These questionnaires were chosen to measure the participants' stress, spiritual

well-being, and perception of self-worth as these are components of mind-body wellness. A decrease in total points on the Stress survey indicates a decrease in overall stress while an increase in points on the Spiritual Well-being survey means an increase in spiritual well-being. The Worth Index survey has four subscales: 1) basic human worth, 2) personal security, 3) performance, and 4) appearance. An increase in total points means an improvement in one's perception of his/her individual worth—the individual perceives self-worth to be inherent rather than dependent on outside influences. These questionnaires were administered using Qualtrics online survey software (Qualtrics, Provo, Utah), included a total of 58 questions, and required 5-15 minutes to complete. Participants answered additional demographic, lifestyle, and satisfaction questions for descriptive purposes.

Every two weeks throughout the intervention, a research assistant met with the participant to electronically download the workout data from the heart-rate monitor. The research assistant reviewed the participant's workouts to verify if the participant was performing the assigned exercise protocol correctly and instructed the participant on any necessary changes.

The participants received a FT1 Polar heart-rate monitor as compensation for completing the study and to provide motivation to comply with the exercise protocol.

Statistical Analysis

Statistical Analysis Software (SAS), version 9.3 (Cary, North Carolina) was used for data analysis. The ABPD resting blood pressure and heart-rate data, and the mind-body wellness surveys were analyzed using analysis of covariance. The ABPD data was also analyzed using regression analysis. Participant demographics were analyzed using basic statistics and chi-square analysis. Statistical significance was set at $p < 0.05$.

Results

The majority of the participants were Caucasian (97%), married (88%), and working part-time or full-time (73%). Table 1 shows additional participant demographics. The participants' body mass, and consequently BMI, did not change significantly from the beginning to the end of the study. At the beginning of the study, the participants' baseline resting blood pressure and heart rate were not significantly different from one another (see Table 2). About half of the participants had resting blood pressure in pre-hypertensive or hypertensive ranges and the other half of the participants were in normotensive ranges (see Table 3).

The participants were asked to complete a total of 32 workouts over the eight week study. All participants completed an average of 27 ± 6.33 workouts, with 64% of both the IT group and the CT group completing more than 27 workouts. Five participants dropped out of the study—one participant from the IT group and four participants from the CT group. Therefore, a total of 47 participants (15 females and 32 males) were included in the analysis.

To better control for confounding variables, the participants were asked to not change any lifestyle habits except the assigned exercise protocol. At the beginning and end of the study, the participants were asked general questions about their current lifestyle habits. There was not a significant difference in the answers to these questions except for the participants' exercise habits, which infers the participants complied with the requirements of the study.

Resting Blood Pressure and Resting Heart Rate

The ABPD data output gave an average measurement for resting systolic blood pressure (SBP), diastolic blood pressure (DBP), and heart rate (HR) for the awake, asleep, and total period the ABPD was worn. The covariates age, gender, BMI, and workout compliance (number of completed workouts) were used in the analysis to see if any of the variables had an impact on

resting blood pressure or HR levels. After the initial analysis, group (IT or CT) was also included as a covariate to determine any within and between group differences.

Table 4 shows the change in resting blood pressure by group. The CT group had a statistically significant decrease in awake SBP ($p=0.01$) and total SBP ($p=0.01$). Gender was a covariate that was statistically significant for all blood pressure measures, except asleep DBP ($p=0.09$). Table 5 shows the change in resting blood pressure by gender. With both groups combined, the female participants had a statistically significant decrease in awake SBP ($p=0.002$), asleep SBP ($p=0.01$), total SBP ($p=0.003$), awake DBP ($p=0.02$), and total DBP ($p=0.05$). The male participants had an increasing trend of blood pressure with total DBP having a statistically significant increase ($p=0.05$).

Table 6 shows the change in resting HR. Neither group had a consistent trend in change or statistical significance for all HR measurements.

Mind-Body Wellness Surveys

A total of 10 post-intervention surveys were not completed—five from the participants who dropped out and five from participants that had missing post-intervention survey data. Therefore, a total of 42 pre- and post-intervention survey results were included in the analysis.

Table 7 shows the change in the results of the mind-body wellness surveys. Both groups had positive improvement for all surveys. The IT group had a statistically significant reduction in stress ($p=0.002$) and the CT group had a statistically significant increase in spiritual well-being ($p=0.005$). The IT group had statistically significant improvement with their perceptions of their personal security ($p=0.03$) as related to their individual self-worth. Additionally, the CT group had statistically significant improvement with their perceptions of their performance ($p=0.003$) and perceptions of their appearance ($p=0.01$).

Discussion

This study examined the effects of IT and CT on resting blood pressure, resting HR, and mind-body wellness. The data resulted in a trend of reduced SBP for both IT and CT, but CT lowered SBP significantly more than IT. No consistent change in HR was found in either group, but mind-body wellness improved for both IT and CT. These results further add to the literature of other interval training protocols compared to CT.

Research comparing various interval-training protocols with CT has found conflicting blood pressure results. Many have found interval training and CT equally effective at decreasing blood pressure (mean SBP/DBP decrease of 6/4 and median SBP/DBP decrease of 2/4 mmHg) (3, 6, 10, 25, 27) or both exercise protocols showing no change in blood pressure (16, 24, 30, 31, 33). Nybo et al., however, found CT lowered blood pressure more than interval training with a SBP/DBP mean decrease of 8/5 mmHg (18). This current study's results are similar in that CT lowered blood pressure more than IT, but with a SBP/DBP decrease of about 4/2 mmHg. Having a larger number of participants with blood pressure in pre-hypertensive or hypertensive ranges could possibly show a larger reduction in resting blood-pressure levels with CT or IT. The literature shows that when normotensive and hypertensive participants follow the same exercise program, blood-pressure reduction is greatest in the hypertensive participants (20).

With both groups combined, the female participants had a significant reduction in blood pressure while the male participants' blood pressure increased. Many interval training studies have included both female and male participants, but did not report the gender difference in the blood pressure results (6, 15, 16, 24, 25, 27, 28, 30, 33). Nybo et al. (18) and Whyte et al. (32) included only male participants in their interval training studies and saw a 8/5 mmHg reduction and 2/7 mmHg reduction in blood pressure, respectively. On the other hand, Ciolac et al.

included only female participants and found only a 2/2 mmHg reduction in blood pressure (3). This present study's findings of the female participants reducing blood pressure more than the male participants adds to the inconsistencies in the literature, which suggests a need for further investigation into gender differences with IT and CT.

Resting HR levels did not change in either the IT or CT groups. Other studies results were similar, indicating no change in resting HR (24, 31, 33). However, some research found interval training to be more effective than CT (mean decrease of 3.4 bpm) (15, 16) while others found CT more effective than interval training (mean decrease of 6.0 bpm) (18). All participants in this study had baseline resting HR levels that were normal. If the participants had higher baseline resting heart-rate levels, training effects for lowering HR may have been noted.

Both groups' mind-body wellness survey results showed positive improvement. The CT group had a statistically significant increase in spiritual well-being while the IT group had a statistically significant reduction in stress. A unique component of IT is lowering the heart rate to the lowest attainable point during the recovery interval. This is meditative in nature because of the need for the mind to clear itself from any stress to lower the heart rate (13). One study found interval training improved quality of life more than CT (33) whereas another found both interval training and CT equally improved quality of life (15), which is consistent with this study. Further research is needed to clarify the effect of IT and CT on stress, spiritual well-being, and one's perceptions of self-worth.

Strengths and Limitations

There were notable strengths regarding this study, including the unique design. The study was a randomized controlled experimental study, which allows for possible inference to a similar population of that used in the study. The recovery interval of IT and the moderate-intensity of

CT made it possible for almost anyone to participate independent of their current fitness level or age. ABPDs were used to measure resting blood-pressure levels, which gave a complete accounting of blood-pressure fluctuations over a long period of time, from which a more representative blood-pressure mean was calculated. This was advantageous because one-time clinical assessment is subject to variation due to situation-specific influences on blood pressure (7). The ability to monitor blood pressure over 24 h accounted for possible outside influences that could have artificially altered blood-pressure outcomes.

There were also limitations of this study. Because the questionnaires used in this study were self-reported, there was limited control over the accuracy of individual's responses. Also, the participants completed their exercise protocol under free-living conditions; therefore the researchers had very little—if any—control over other confounding factors that may have influenced the study outcome. One hope for this study was to recruit mostly participants with baseline pre-hypertensive blood-pressure levels to increase potential for determining a blood-pressure lowering effect for the different training protocols. The medical clearance form was used to verify baseline blood-pressure levels and other inclusion criteria required to accept each participant into the study. Because this baseline blood-pressure measurement was taken by a medical professional at one point in time (either with a manual or automatic blood-pressure cuff) some of the participants' resting pre-ABPD measurements did not match up with their reported baseline levels, meaning there were more participants with lower true baseline blood-pressure levels than was hoped for. This finding is in accordance with Pickering et al. who state ABPD measurements are typically lower than clinical blood-pressure measurements (23). For future studies, using ABPD measurement as part of the screening process of potential participants will ensure participants' baseline blood pressure is within pre-hypertensive or hypertensive ranges.

Conclusion

In conclusion, this study revealed that IT and CT exercise programs reduced resting blood pressure, with CT having a greater effect. Additionally, both IT and CT improved mind-body wellness. Further research is warranted to investigate resting heart-rate effects, gender differences, and mind-body wellness differences between IT and CT.

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Table 1: Participant Demographics

Variables	All participants (n=52)	Males (n=36)	Females (n=16)
Age (y)	38.94±10.51	37.06±9.51	43.19±11.70
Body mass (kg)	84.69±16.26	89.77±14.66	73.56±14.20
BMI (kg/m ²)	27.28±4.41	27.22±4.01	27.43±5.36

Results are described as mean±standard deviation

Table 2: Baseline Resting Blood Pressure (mmHg) and Resting Heart Rate (bpm)

Variables	IT group	CT group	F	p
Awake SBP	120.96±1.86	119.50±1.94	0.30	0.59
Asleep SBP	108.04±2.70	103.50±2.76	1.38	0.25
Total SBP	119.19±1.82	117.92±1.89	0.24	0.63
Awake DBP	74.19±1.28	73.13±1.33	0.34	0.57
Asleep DBP	62.60±1.66	61.67±1.69	0.15	0.70
Total DBP	72.50±1.34	71.88±1.40	0.10	0.75
Awake HR	70.54±2.06	69.96±2.15	0.04	0.85
Asleep HR	61.56±2.11	59.25±2.15	0.59	0.45
Total HR	69.46±2.03	68.71±2.11	0.07	0.80

Results are described as mean±standard error

Results are analyzed from pre SBP/DBP measurements from ambulatory blood pressure devices (ABPDs)

No significant difference ($p < 0.05$)

Table 3: Distribution of Participants According to Baseline Resting Blood Pressure

	IT group		CT group	
	(n=25)		(n=22)	
	Males (n=17)	Females (n=8)	Males (n=15)	Females (n=7)
Hypertensive BP	0	0	1	0
Pre-hypertensive BP	10	3	6	3
Normotensive BP	7	5	8	4

Results are analyzed from pre total SBP/total DBP measurements from ambulatory blood pressure devices (ABPDs)

Hypertensive BP=blood pressure >140/90 mmHg

Pre-hypertensive BP=blood pressure 120-139/80-89 mmHg

Normotensive BP=blood pressure <120/80 mmHg

Table 4: Change in Resting Blood Pressure (mmHg) by Group

Variables	IT group	CT group
Awake SBP	-0.31±1.59 (p=0.85)	-4.37±1.64 (p=0.01)*
Asleep SBP	-2.22±2.19 (p=0.32)	-2.12±2.15 (p=0.33)
Total SBP	-0.28±1.61 (p=0.86)	-4.24±1.66 (p=0.01)*
Awake DBP	0.44±1.10 (p=0.69)	-2.07±1.18 (p=0.09)
Asleep DBP	0.85±1.73 (p=0.63)	-0.44±1.71 (p=0.80)
Total DBP	0.78±1.17 (p=0.51)	-1.86±1.25 (p=0.14)

Results are described as mean±standard error

Results are analyzed from pre and post SBP/DBP measurements from ambulatory blood pressure devices (ABPDs)

*Significant at $p < 0.05$

Table 5: Change in Resting Blood Pressure (mmHg) by Gender

Variables	Males	Females
Awake SBP	2.00±1.36 (p=0.15)	-6.68±2.06 (p=0.002)*
Asleep SBP	3.08±1.74 (p=0.09)	-7.41±2.80 (p=0.01)*
Total SBP	1.99±1.37 (p=0.15)	-6.51±2.07 (p=0.003)*
Awake DBP	1.75±0.95 (p=0.07)	-3.38±1.42 (p=0.02)*
Asleep DBP	2.53±1.40 (p=0.08)	-2.12±2.20 (p=0.34)
Total DBP	2.02±1.01 (p=0.05)*	-3.10±1.51 (p=0.05)*

Results are described as mean±standard error

Results are analyzed from pre and post SBP/DBP measurements from ambulatory blood pressure devices (ABPDs)

*Significant at $p < 0.05$

Table 6: Change in Resting Heart Rate (bpm) by Group

Variables	IT group	CT group
Awake HR	1.54±1.13 (p=0.18)	-0.02±1.20 (p=0.98)
Asleep HR	-0.31±1.16 (p=0.79)	0.58±1.16 (p=0.62)
Total HR	1.03±1.09 (p=0.35)	0.05±1.16 (p=0.96)

Results are described as mean±standard error

Results are analyzed from pre and post SBP/DBP measurements from ambulatory blood pressure devices (ABPDs)

No significant change (p<0.05)

Table 7: Change in Mind-Body Wellness Surveys by Group

Variables	IT group	CT group
Stress	-2.19±0.65 (p=0.002)*	-0.99±0.68 (p=0.15)
Spiritual well-being	2.52±1.37 (p=0.07)	4.23±1.44 (p=0.005)*
Worth Index:		
Basic human worth	1.30±0.90 (p=0.16)	0.42±0.94 (p=0.66)
Personal security	1.21±0.55 (p=0.03)*	0.32±0.57 (p=0.57)
Performance	1.03±0.61 (p=0.10)	2.01±0.64 (p=0.003)*
Appearance	0.93±0.83 (p=0.27)	2.23±0.87 (p=0.01)*

Results are described as mean±standard error

*Significant at $p < 0.05$