Int. J. Sport Psychol., 2021; 52: 149-162
doi: 10.7352/IJSP.2021.52.149

Selective effects of 8 weeks of high-intensity circuit training on inhibitory control in adult women

YIN LUO*, YUMEI LOU**, YA DOU*, AND YUNTAO LI*

(*) *Faculty of Physical Education, Ningbo University, Ningbo, China*
(**) *Ningbo University Li Huili Hospital, Ningbo, China*

The purpose of the current study was to examine the effects of 8 weeks of high-intensity circuit training (HICT) on inhibitory control in adult women. To this end, sixty-seven sedentary women were randomly assigned to either a HICT group (n = 31; mean$_{age}$ = 42.7 ± 8.6 years) or a waitlist control group (n = 36; mean$_{age}$ = 40.2 ± 10.8 years). The HICT consisted of 11 body-weight movements, with the training density determined by work-to-recovery ratio ranging from 1:3 to 3:1. Inhibitory control was assessed by a modified flanker task before and after the intervention. The results indicated an interaction favoring the HICT. Specifically, shorter mean reaction times in incongruent trials were observed following eight weeks of HICT (p = .047, Cohen's d = 0.38), whereas there was no difference between the pretest and posttest outcomes in the waitlist group. Further analysis of change scores from pretest to posttest on incongruent mean RT (incongruent RT) also revealed a significant group difference (p = .023, Cohen's d = 0.56), with the HICT group having a larger incongruent RT relative to the waitlist control group, and the direction of change was opposite between groups (HICT: -60.3 ± 161.9 ms, waitlist: 18.1 ± 113.4 ms). Overall, the current findings suggest that 8 weeks of HICT may have selective benefits for inhibitory control performance in adult women.

KEY WORDS: sedentarism; physical activity; HIIT; executive function; circuit training.

Introduction

The 2018 Physical Activity Guidelines for Americans suggests a weekly requirement of 150 minutes of moderate-to-vigorous-intensity physical activity to foster brain health in adults, particularly cognitive aspects that are prefrontal-dependent, such as cognitive control (Hillman, Erickson, & Kramer,

---

Correspondence to: Yuntao Li, Faculty of Physical Education, Ningbo University, No. 818, Fenghua Road, Ningbo, China. (E-mail: lyt9@qq.com)

2008), a top-down, multifaceted cognitive process involved in goal-oriented behaviors (Diamond, 2013). Despite the well-known facilitative effects of physical activity on cognitive control in adulthood, a large number of people in contemporary society continue to be sedentary due to several barriers, especially '*lack of time*' (Centers for Disease Control and Prevention, 2012).

Recently, there has been increasing data supporting the cognitive benefits of high-intensity interval training (HIIT) (Cooper, Dring, & Nevill, 2016). HIIT refers to exercise characterized by short bouts of vigorous-intensity exercise interspersed by short periods of recovery (Eddolls, McNarry, Stratton, Winn, & Mackintosh, 2017). It has been suggested that HIIT may be an alternative to typical continuous aerobic exercise or resistance exercise as a means of promoting various health outcomes, such as aerobic capacity (Lee, Hsu, & Cheng, 2018), lipid metabolism (Lee, Kuo, & Cheng, 2018), vascular function (Brien et al., in press), and balance (Jiménez-García et al., 2019). Although HIIT may be associated with higher risk of injury (Rynecki, Siracuse, Ippolito, & Beebe, 2019), cardiovascular insults (e.g., myocardial infarction and hypertension-induced vasoconstriction; Calverley et al., in press), or unpleasant affect (Olney et al., 2018), its health-related benefits can be manifested once implemented appropriately. Moreover, the time-efficient nature of HIIT has made it an alternative option for overcoming "*lack of time*" – one of the most cited barriers to engaging in exercise (Centers for Disease Control and Prevention, 2012). Moreover, the role of HIIT in cognitive control could be important for adults, especially adult women, given that evidence has suggested that over one-third of adult women aged 25-54 years old are physically inactive (Townsend, Wickramasinghe, Williams, Bhatnagar, & Rayner, 2015) and are less adherent to exercise compared to adult men (Armstrong et al., 2018). In addition, adult women may have worse brain function relative to their age-matched male counterparts (Li & Singh, 2014). These findings, collectively, highlight a need to further investigate the effects of HIIT on brain health in adult women, as evidence has indicated that HIIT is effective in improving fitness (Coletta et al., 2019) and decreasing adiposity without compromising adherence to the intervention in sedentary women (Batrakoulis et al., in press; Grossman, Arigo, & Bachman, 2018).

Specifically, in a group of 45 middle-aged women, Connelly et al. (2017) implemented a 12-week (3 sessions per week) HIIT protocol consisting of 5 x 5-minute cycling bouts that comprised 2.5 minutes of low-intensity cycling (~30% of maximum effort), 1.5 minutes of moderate-intensity cycling (~50–60% of maximum effort), and 1 minute of high-intensity cycling (>90% maximum effort). Their results showed enhanced working memory, one subcomponent of cognitive control relating to the ability to hold information in mind for a short period of time and mentally work with it (Diamond, 2013), following the 12-week intervention. It is worthwhile to expand the positive influence of HIIT to other subcomponents of cognitive control, such as inhibitory control. Inhibitory control is the ability to selectively focus on task-relevant information while resisting giving attention to a prepotent but undesirable response (Diamond, 2013). Inhibitory control is highly modifiable by exercise via structural and functional changes in brain networks (e.g., prefrontal cortex, anterior cingulate cortex) associated with this cognitive domain across the lifespan (Hillman et al., 2008; Khan & Hillman, 2014). Moreover, inhibitory control is the cornerstone of other higher-order cognitions (e.g., cognitive flexibility, planning, problem-solving) (Diamond, 2013) and is related to different aspects of behavior/performance (e.g., self-regulation, addiction, reading, vocational performance) (Diamond, 2013).

Thus, the aim of the current study was to examine the effects of HIIT on inhibitory control in adult women who were sedentary. In addition to be implemented on a treadmill or cycle ergometer, HIIT can also be implemented in a variety of settings with complex vigorous exercises. As such, the current study utilized a high-intensity circuit training (HICT) recommended by the American College of Sports Medicine (ACSM) (Klika & Jordan, 2013), which is one form of HIIT consisting of functional, multi-joint, and body-weight movements. HICT can be easily implemented in a variety of settings (e.g., home, office, gym) with minimal requirements on the training facilities (Klika, & Jordan, 2013). These advantages favor the ecological validity and practical relevance of HICT for practitioners and the public who wish to implement physical exercise interventions in real-world settings without barriers. Given that preliminary data have indicated a positive effect of acute bouts of HICT on cognition in adult women (Gmiat et al., 2017), it would be informative to investigate long-term HICT-induced cognitive benefits. It was hypothesized that HICT could facilitate inhibitory control performance in adult women.

Methods

Study design

The purpose of the current randomized-controlled study was to examine the effects of an eight-week community-based HICT on adult women's inhibitory control performance. The participants were randomly assigned into either a HICT group or a waitlist control group. A trained staff member accomplished the randomization by lottery following baseline assessments. Group assignment was blinded to the staff involved in data collection to ensure that all participants were equally encouraged during data collection. The staff involved in the analyses were also blinded to group assignment by associating a 1 or 2 with each woman's ID.

Participants

Seventy sedentary women were recruited from communities close to each other in Ningbo City, China via flyers distributed around communities. Specifically, 34 women ($Mean_{age}$ = 42.7 ± 8.6 years) were assigned to an eight-week HICT group, whereas 36 women ($Mean_{age}$ = 40.2 ± 10.8 years) were assigned to a wait-list control group. Participants in the current study were limited to those who reported that they (1) had <60 minutes of physical activity per week, (2) were premenopausal, (3) were nonsmokers, (4) were not pregnant, (5) were free from any of the medical conditions listed on the Physical Activity Readiness Questionnaire (PARQ), (6) were free from cardiovascular, cerebrovascular or neurological disorders, and (7) had normal or corrected-to-normal vision. All participants provided written informed consent in the format approved by the local institutional review board.

Measurements

Baseline Demographic Measures. Age, education (assessed with the following scale: 1, elementary school, 2, middle school, 3, high school, 4, bachelor's degree, and 5, master's degree or higher), and socioeconomic status (SES; measured on a 5-point scale, with '5' representing the highest status) were assessed by self-report. Height and weight were measured by experimenters via a height and weight scale. Body mass index (BMI) was calculated as an individual's weight divided by their height in meters squared.

Flanker Task. We utilized an Ericksen flanker task as a measure of inhibitory control given that this paradigm has been widely used in the physical activity-cognition literature (Hillman et al., 2008). Participants completed a modified version of the Eriksen flanker task (Eriksen & Eriksen, 1974) to assess inhibitory control (see **Figure 1** for diagram of procedure). All stimuli were presented focally on a computer screen for 200 ms at a distance of approximately 1 meter using Neuroscan Stim2 software (Compumedics NeuroScan, Charlotte, NC). Participants were instructed to respond with a thumb press on a response pad (Neuroscan STIM system) to the direction of the centrally presented arrows amid either congruent (e.g., <<<<<) or incongruent (e.g., <<><<) flanking nontargets (identical arrows). Task instructions and encouragement prior to and following each task block emphasized response accuracy (i.e., "It is important that you respond as accurately as possible…"), with secondary instructions encouraging maintaining response speed to respond within the allotted response window (i.e., "but we also want you to respond quickly so please make sure you respond before the next set of arrows appears on the screen"). Prior to testing, participants were given 20 practice trials to control for potential practice effects. They had to meet the criteria of 75% accuracy (i.e., a minimum of 15 correct responses) before starting the actual testing. Two blocks of 20 trials were presented randomly with equally probable congruency (i.e., 50% congruent trials versus 50% incongruent trials) and directionality (50% of targets facing right and the other 50% facing left) with an intertrial interval of 1500 ms. Trials with response time <150 ms or >1000 ms were discarded. Performance outcomes were the accuracy rate (AR; the percentage of correct-response trials relative to all trials) and the mean reaction time (mean RT) of correct-response trials.

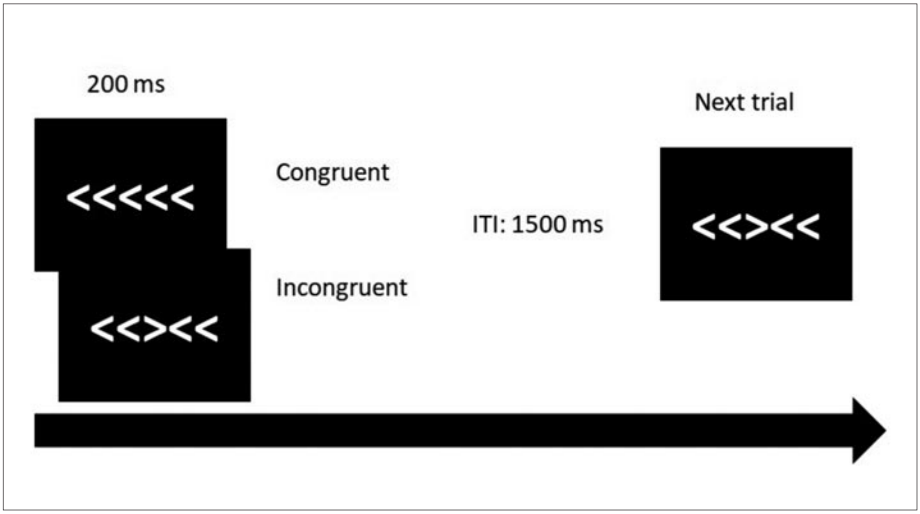

Fig. 1. - Diagram of flanker task procedure.

INTERVENTIONS

Table 1 summarizes details of the HICT program. The eight-week HICT program occurred in a sports center in 6 communities between September 2019 and November 2019. Participants in the HICT group were divided into subgroups of 4 or 5 people. Each subgroup attended 5 sessions per week with a duration of 32 minutes per session. The goal of the program was to have participants attend a total of 40 sessions, and those who could not complete 40 sessions over the 8-week period were given make-up sessions. The program was led by a trained and certified physical education teacher. It consisted of movements from the 7-minute workout recommended by the ACSM, including the following 11 movements: jumping jacks, crunches, high-knees, squats, planks, side planks, lunges, push-ups, push-ups with rotation, step-ups, and wall-sits. The training density of the exercise bouts was determined by adjusting

TABLE I
Summary of training variables in the HICT program.

Variable	
Movements	jumping jacks, crunches, high-knees, squats, planks, side planks, lunges, push-ups, push-ups with rotation, step-ups, and wall-sits
Frequency	5 sessions per week
Intensity	76.4% of individual HR_{max}
Work-to-recovery ratio	Week 1: 10 sec to 30 sec Week 2: 20 sec to 20 sec Week 3-8: 30 sec to 10 sec

the work-to-recovery ratio (WRR). Thus, exercises were performed for 10 seconds and followed by a 30-second recovery during the first week, then increased to a 20-second to 20-second WRR in the second week and maintained at a 30-second to 10-second WRR during weeks 3-8. Participants were instructed to wear sporty clothes and avoid consuming caffeine before training sessions. Each session began with a 10-minute warm-up (i.e., neck and shoulder warm-ups, chest warm-ups, waist warm-ups, bilateral quadriceps warm-ups, bilateral biceps femoris warm-ups), followed by 7 minutes of HICT and then 10 minutes of stretching. In each session, participants' heart rates (HRs) were recorded during recovery following each movement using a fingertip pulse oximeter to ensure they exercised at a moderate to vigorous intensity. Mean HRs across all movements were 135.2 ± 10.9 bpm (corresponding to 76.4% of age-predicted HR_{max}; age-predicted HR_{max} was determined by the formula 205.8 – (0.685 x Age); Robergs & Landwehr, 2002). This intensity is closed to a vigorous intensity (i.e., >77% of HR_{max}) according to the classification of the ACSM guideline for healthy, untrained individuals (Garber et al., 2011). Participants were asked to continue their routine of daily activities when they did not attend the intervention. Alternatively, participants in the waitlist control group received no intervention and were instructed to maintain their routine of daily activities. They received access to the same HICT intervention after the study period.

Statistical Analysis

Data on two participants in the HICT group were discarded because the participants dropped out of the intervention for personal reasons, and data on one participant was further discarded due to <50% overall response accuracy in the flanker task (Kao, Westfall, Soneson, Gurd, & Hillman, 2017; Kao, Drollette, Ritondale, Khan, & Hillman, 2018). Therefore, the data analyses were based on 31 participants in the HICT group and 36 participants in the waitlist control group. Data analyses were performed using SPSS 23.0 software (IBM, Inc.) with an alpha of .05 set as the significance level. The normality of the data was confirmed using the Shapiro–Wilk test. For baseline demographic measures (i.e., age, education level, SES, BMI), independent *t*-tests were performed to ensure homogeneity between groups before the intervention. For flanker task performance, a 2 (Group: HICT, waitlist) × 2 (Time: pretest, posttest) × 2 (Condition: congruent, incongruent) repeated measures analysis of variance (RM ANOVA) was used for AR and mean RT. Greenhouse–Geisser corrections were used if the assumption of sphericity was violated. Post-hoc comparisons were performed using *Bonferroni*-corrected *t*-tests. Cohen's *d* effect sizes were reported to complement significant group/time/congruency differences wherever necessary. Further, we also calculated minimal detective difference of effect sizes *d* as sensitivity analysis using G*Power 3.1.9.4 to inform if the effect of HICT reported herein was practically significant and with sufficient power. With power of 0.80 and alpha of 0.05, sensitivity analyses showed that our sample size was sufficient to detect medium to large effects in terms of between-group (d = 0.69) and within-group comparisons (d of 0.52 for HICT and 0.48 for waitlist control group).

Results

Demographic, Fitness, and Baseline Cognitive Measures

Independent *t*-tests indicated no group differences in all of the baseline demographic measures, *t*'s = -0.50-1.92, *p*'s >.059 (Table 2).

TABLE II
Summary table of baseline demographic measures.

Variable	HICT group (n = 31)	Control (n = 36)	Group difference
Age (years)	42.7 (8.6)	40.2 (10.8)	$p = .292$
Education (scale)	3.4 (1.0)	3.0 (0.9)	$p = .059$
SES (scale)	1.8 (1.2)	1.6 (0.7)	$p = .483$
BMI (kg/m^2)	24.0 (3.0)	23.6 (3.7)	$p = .634$

Note. SES = socioeconomic status. BMI = body mass index.

FLANKER TASK PERFORMANCE

For details on flanker task performance, please see Table 3 for summary. For AR, the RM ANOVA revealed a main effect of *Congruency*, $F(1,65) = 27.8$, $p < .001$, $\eta^2_{p} = .30$, with the congruent trials (91.2 ± 23.2%) having higher ARs than the incongruent trials (85.5 ± 11.5%), suggesting that participants responded less accurately during the incongruent trials relative to congruent trials. There was no other main effect or interaction (*p*'s >.21).

For illustration of the mean RT for the HICT and control groups, please refer to Figure 2. The analysis of mean RT showed a main effect of *Congruency*, $F(1,65) = 51.7$, $p < .001$, $\eta^2_{p} = .44$, with the congruent trials (671.2 ± 184.7 ms) having shorter mean RTs relative to the incongruent trials (724.0 ± 206.7 ms), suggesting that participants responded more slowly during incongruent trials relative to congruent trials. This main effect was superseded by a *Group* x *Time* x *Congruency* interaction, $F(1,65) = 4.0$, $p = .049$, $\eta^2_{p} = .06$. Decomposition of this three-way interaction (with Bonferroni-corrected alpha level of .025) revealed a significant simple *Group* x *Time* interaction for the incongru-

TABLE III
Summary of flanker task performance as a function of intervention.

Outcomes	Group	Pre	Post
Congruent AR (%)	Exercise	93.6 (11.1)	90.8 (10.7)
	Waitlist	89.8 (14.2)	91.1 (10.2)
Incongruent AR (%)	Exercise	84.5 (12.2)	85.5 (10.3)
	Waitlist	85.5 (11.4)	86.5 (12.1)
Congruent RT (ms)	Exercise	704.4 (189.5)	682.9 (180.5)
	Waitlist	648.2 (178.8)	655.5 (190.0)
Incongruent RT (ms)	Exercise	787.7 (251.2)	727.4 (193.7)*
	Waitlist	686.1 (179.4)	704.2 (195.3)

Note. *significantly different from pretest.

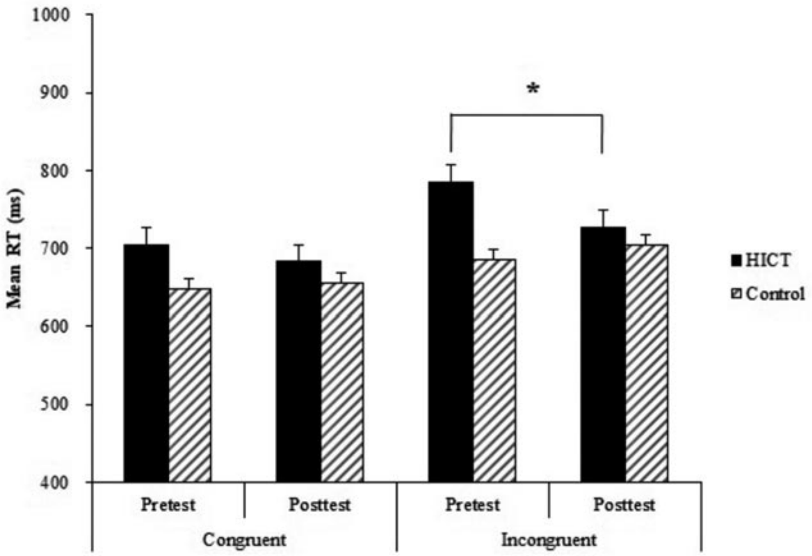

Fig. 2. - Illustration of the mean RTs for the HICT and control groups. Data are presented as the mean ± 1SE. *p < .05.

ent trials, $F(1,65) = 5.4$, $p = .023$, $\eta^2_{p} = .08$, but not for the congruent trials, $F(1,65) = 0.2$, $p = .625$, $\eta^2_{p} = <.01$. *Post-hoc* analyses showed that, whereas there was no group difference at either the pretest (HICT: 787.7 ± 251.2 ms, Waitlist: 686.1 ± 179.4 ms, $t(65) = 1.93$, $p = .059$) or posttest (HICT: 727.4 ± 193.7 ms, Waitlist: 704.2 ± 195.3 ms, $t(65) = 0.49$, $p = .628$), incongruent RTs were faster after HICT ($t(30) = -2.08$, $p = .047$, Cohen's $d = 0.38$) but not after the control intervention ($t(35) = 0.96$, $p = .345$). To better characterize the magnitude of change in the HICT and waitlist control group, we performed additional independent *t*-tests on change scores for incongruent meant RT from pretest to posttest (incongruent RT) in both groups, and the data revealed significant group difference, $t(1,65) = 2.32$, $p = .023$, Cohen's d = 0.56), with larger incongruent RT in the HICT group relative to the waitlist control group, and the direction of change was opposite between roups (HICT: -60.3 ± 161.9 ms vs. waitlist: 18.1 ± 113.4 ms).

Discussion

The current investigation aimed to study the effects of 8 weeks of community-based HICT on inhibitory control in sedentary women. Our findings revealed that 8 weeks of HICT had selective benefits for inhibitory control. That is, HICT facilitated only response speed in incongruent trials but not congruent trials. A comparison of incongruent RT between HICT and waitlist control group further indicated that incongruent RT was larger in the HICT group, and the direction of change was opposite between groups (i.e., decreased RT in HICT group but increased RT in the waitlist control group). To the best of our knowledge, the current study is the first to assess the effects of a long-term HICT on inhibitory control in adult women in a community-based setting, which increases the ecological validity of HICT as a mean to counteract sedentarism and favor brain health.

The novelty of the current investigation is the positive effect of a community-based HICT intervention on adult women's inhibitory control performance. Previously, Connelly et al. (2017) found enhanced working memory, assessed by an n-back task, after 12 weeks of high-intensity interval cycling in a group of middle-aged women. The current study not only corroborates the Connelly et al. study but also expands our understanding of the benefits of HIIT for other subcomponents of cognitive control in adult women. While it remains debatable whether habitual exercise generally or selectively facilitates brain function, the selective benefit of HICT found in this study is in alignment with previous studies that examined the effects of long-term exercise on inhibitory control (Chang, Tsai, Chen, & Hung, 2013; Hillman et al., 2014) and partly supported by two reviews on the association of fitness/exercise and brain function (Hillman et al., 2008; Colcombe & Kramer, 2003). That is, the current literature suggests that exercise has a selective or disproportionally larger benefit on task components requiring larger cognitive demands (Colcombe & Kramer, 2003; Chang et al., 2013; Hillman et al., 2008; Hillman et al., 2014). The current findings support the selective benefit of regular exercise and move one step further by showing the cognitive modulation of chronic HICT on brain function. This positive adaptation in inhibitory control is relevant to adult women given that: (a) inhibitory control is the cornerstone of other higher-order cognitions (e.g., cognitive flexibility, planning, problem-solving) (Diamond, 2013) and is related to different aspects of behavior/performance (e.g., self-regulation, addiction, reading, vocational performance) (Diamond, 2013), and (b) adult women may have worse brain function relative to their age-matched male counterparts (Li & Singh, 2014). Moreover, given that HICT could be easily implemented, it requires minimal training equipment and has multidomain health benefits. From a practical perspective, HICT could be a more feasible workout for individuals who may not be able to access specialized exercise equipment (e.g., treadmill, ergometer) given that it could be completed without any equipment as a complete body-weight exercise session. Therefore, HICT could reasonably be completed either in a home or clinical environment with little space or equipment needed.

There are several mechanisms that may account for the facilitation of inhibitory control following the HICT program. For example, the beneficial effects of HIIT on inhibitory control may be accounted for by changes in cortical activity. Studies by Kao and colleagues have found decreased cortical activation (Kao et al., 2017), along with faster neural processing and improved flanker task performance (Kao et al., 2017; Kao et al., 2018), following acute bouts of HIIT. The observed decrease in cortical activation and faster neural processing speed may indicate more efficient cognitive processing. On the other hand, evidence has indicated that improved inhibitory control following acute bouts of HIIT was correlated with high levels of cerebral oxygenation in the prefrontal cortex (Lambrick et al., 2015) and increased secretion of brain-derived neurotrophic factor (BDNF) in the hippocampus (Freitas et al., 2018), a vital regulator of neuronal function, plasticity, and long-term potentiation (Lipsky & Marini, 2007; Zhou et al., 2011). Moreover, chronic HIIT may facilitate brain and cognition via decrease in inflammation-related cytokines (Freitas et al., 2018), increased expression of BDNF (Freitas et al., 2018), and increased uptake of glucose (Robinson et al., 2018). These preliminary findings, collectively, indicate neurobiological mechanisms that may drive the HIIT-induced effects on brain and cognition. More research is needed to better understand the link between neurobiological adaptations and changes in inhibitory control following HIIT.

Our data contradicted the findings of Coetsee and Terblanche (2017), who implemented a 16-week HIIT on a treadmill for a total of 48 sessions. Their results indicated no improvement in inhibitory control as assessed by a Stroop test after training. Such discrepancies could be partly accounted for by differences in gender distribution, discrepancies in the cognitive tasks, and/or differences in the HIIT protocol. For example, our participants were all women, whereas participants in the Coetsee & Terblanche study included both men and women. It has been shown that studies with both men and women had larger effect sizes than those studies with either men or women (Chang, Laban, Gapin, & Etnier, 2012). Regarding cognitive task selection, we used a modified flanker task, which measures inhibitory control only at the perceptual/attention level, whereas the Coetsee and Terblanche study employed a Stroop test, which measures inhibitory control at the cognitive level. It is plausible that HICT may have selective effects on the flanker task but not on the Stroop test in middle-aged adults, as another study found a null effect of HICT on Stroop test performance in this population (Gmiat et al., 2017). Last, the current study employed interventions consisting of functional, multi-joint movements via both aerobic and muscle-strengthening exercises, whereas the Coetsee and Terblanche study employed treadmill running. It is plausible that the joint benefits on cardiovascular endurance and muscular fitness lead to larger cognitive benefits compared to running or cycling as both health dimensions are associated with executive function in adults (Hsieh et al., 2016; Kao et al., 2019). Future research is recommended to take these confounding factors into account while examining the effects of HIIT on adults' inhibitory control.

There were several limitations to this study that should be acknowledged. First, the current study did not employ an active control group. Although debatable, there are issues associated with comparing an inactive, noncontact control group to an exercise group. However, as participants in the waitlist control group were asked to maintain their typical daily routines, this group may best represent individuals' typical behavior/routine. More specifically, the inactive, noncontact control group offers an opportunity to compare an intervention against typical behavior/routine, which is not possible with an active control group. In this manner, an intervention that induced a change in inhibitory control over a period of time was compared with a group experiencing typical routines.

Second, a related issue may be the lack of an aerobic-based intervention. That is, one may argue that improved flanker task performance reported herein might be a result of exercise, rather than a result of specific aspects of the HICT intervention. The lack of fitness assessments also precluded us from understanding whether changes in fitness dimensions inherent in HICT (i.e., cardiovascular, muscular, etc.) led to improvements in cognition. It is recommended that future research implement HICT and cardiovascular-based interventions, as well as multiple fitness assessments to obtain a more comprehensive view of the specific aspects of physical activity that result in improvement in cognition.

Third, it is noteworthy that the flanker task only measures inhibitory control at the perceptual/attention level (Diamond, 2013), which precludes our understanding of the effects of HICT on other subdomains of inhibitory control, including cognitive inhibition as assessed by a Stroop test and motor inhibition as measured by a Go/no-go task or a Stop-signal test (Diamond, 2013). Future research is recommended to expand the current findings by investigating the effect of HICT on other subdomains of inhibitory control.

Fourth, given that the HICT was implemented in a community-based setting, it was harder for trainers to have strict control over training variables (e.g., compliance to training protocol, exposure to social interactions, etc.). However, we argue that the social interaction aspect of intervention was minimal given that all movements were individually based without interaction with others. Regardless, future studies should consider these factors when implementing HICT in a community-based setting.

Fifth, the current study utilized $\%HR_{max}$ to quantify individual exercise intensity. It has been challenged that $\%HR_{max}$ is not as valid as %lactate threshold or %anaerobic threshold. That being said, $\%HR_{max}$ is widely utilized in the exercise-cognition literature and has been recommended by the ACSM for characterizing exercise intensity for untrained individuals, either healthy or clinical, due to its convenience and easy-to-implement nature (ACSM, 2010).

Sixth, the current finding should be interpreted with caution given that our sample size was only sufficient to detect medium to large between- and within-group differences based on the sensitivity analysis. That is, the between- and within-group differences reported herein, although with meaningful effect sizes, may be lack of practical significance and underpowered. However, we argue that the current findings still provide relevant information supporting an ecologically valid physical exercise intervention to foster inhibitory control in sedentary adult women. Future research is recommended to replicate our findings with a larger sample size and provide stronger support of the effects of HICT on inhibitory control.

In conclusion, the current investigation suggests that 8 weeks of community-based HICT has selective benefits for inhibitory control performance in a group of sedentary adult women. Although HIIT may be associated with higher risk of injury or unpleasant affect during exercise, its health-related benefits can be manifested once implemented appropriately. Given a prevailing trend of sedentary lifestyles resulting in deteriorated cognition among adult women, the role of HICT as an exercise choice for counteracting sedentarism and fostering brain health should be considered. Future studies are recommended to include both cognitive and psychological measures (e.g., affect) to enhance the practical relevance of HICT.

Funding source:

This study was financially supported by the K. C. Wong Magna Fund from Ningbo University.

Acknowledgements

We thank the participants who participated in the study.

REFERENCES

American College of Sports Medicine (ACSM) (2010). *ACSM's guidelines for exercise testing and prescription* (8th ed.). New York: Loppincott Williams & Wilkins.

Armstrong, S., Wong, C. A., Perrin, E., Page, S., Sibley, L., & Skinner, A. (2018). Association of physical activity with income, race/ethnicity, and sex among adolescents and young adults in the United States: findings from the National Health and Nutrition Examination Survey, 2007-2016. *JAMA Pediatrics, 172*, 732-740.

Batrakoulis, A., Loules, G., Georgakouli, K., Tsimeas, P., Draganidis, D., Chatzinikolaou, A., ... & Theodorakis, Y. (in press). High-intensity interval neuromuscular training promotes exercise behavioral regulation, adherence and weight loss in inactive obese women. *European Journal of Sport Science*. doi: 10.1080/17461391.2019

Calverley, T. A., Ogoh, S., Marley, C. J., Steggall, M., Marchi, N., Brassard, P., ... & Wisløff, U. (in press). HIITing the brain with exercise: mechanisms, consequences and practical recommendations. *Journal of Physiology*.

Center for Disease Control and Prevention. (2012). *Prevalence of Insufficient Physical Activity*. World Health Organization. Geneva, Switzerland.

Chang YK, Labban JD, Gapin JI, & Etnier JL. (2012). The effects of acute exercise on cognitive performance: a meta-analysis. *Brain Research, 1453*, 87-101.

Chang, Y. K., Tsai, Y. J., Chen, T. T., & Hung, T. M. (2013). The impacts of coordinative exercise on executive function in kindergarten children: an ERP study. *Experimental Brain Research, 225*, 187-196.

Coetsee, C., & Terblanche, E. (2017). The effect of three different exercise training modalities on cognitive and physical function in a healthy older population. *European Review of Aging and Physical Activity, 14*: 13.

Colcombe, S., & Kramer, A. F. (2003). Fitness effects on the cognitive function of older adults: a meta-analytic study. *Psychological Science, 14*, 125-130.

Coletta, A. M., Brewster, A. M., Chen, M., Li, Y., Bevers, T. B., Basen-Engquist, K., & Gilchrist, S. C. (2019). High-intensity interval training is feasible in women at high risk for breast cancer. *Medicine & Science in Sports & Exercise, 51*, 2193-2200.

Connolly, L. J., Bailey, S. J., Krustrup, P., Fulford, J., Smietanka, C., & Jones, A. M. (2017). Effects of self-paced interval and continuous training on health markers in women. *European Journal of Applied Physiology, 117*, 2281-2293.

Cooper, S. B., Dring, K. J., & Nevill, M. E. (2016). High-intensity intermittent exercise: effect on young people's cardiometabolic health and cognition. *Current Sports Medicine Reports, 15*, 245-251.

Diamond A. (2013). Executive functions. *Annual Review in Psychology, 64*, 135-168.

Eddolls, W. T., McNarry, M. A., Stratton, G., Winn, C. O., & Mackintosh, K. A. (2017). High-intensity interval training interventions in children and adolescents: a systematic review. *Sports Medicine, 47*, 2363-2374.

Eriksen, B. A., & Eriksen, C. W. (1974). Effects of noise letters upon the identification of a target letter in a nonsearch task. *Perception & Psychophysics, 16*,143-149.

Freitas, D. A., Rocha-Vieira, E., Soares, B. A., Nonato, L. F., Fonseca, S. R., Martins, J. B., ... & Meeusen, R. (2018). High intensity interval training modulates hippocampal oxidative stress, BDNF and inflammatory mediators in rats. *Physiology & Behavior, 184*, 6-11.

Gmiat, A., Micielska, K., Kozłowska, M., Flis, D. J., Smaruj, M., Kujach, S., ... & Ziemann, E. (2017). The impact of a single bout of high intensity circuit training on myokines' concentrations and cognitive functions in women of different age. *Physiology & Behavior, 179*, 290-297.

Grossman, J. A., Arigo, D., & Bachman, J. L. (2018). Meaningful weight loss in obese post-menopausal women: a pilot study of high-intensity interval training and wearable technology. *Menopause, 25*, 465-470.
Hillman, C. H., Erickson, K. I., & Kramer, A. F. (2008). Be smart, exercise your heart: exercise effects on brain and cognition. *Nature Reviews Neuroscience, 9*: 58.
Hillman, C. H., Pontifex, M. B., Castelli, D. M., Khan, N. A., Raine, L. B., Scudder, M. R., ... & Kamijo, K. (2014). Effects of the FITKids randomized controlled trial on executive control and brain function. *Pediatrics, 134*, e1063-e1071.
Hsieh, S. S., Chang, Y. K., Hung, T. M., & Fang, C. L. (2016). The effects of acute resistance exercise on young and older males' working memory. *Psychology of Sport Exercise, 22*, 286-93.
Kao SC, Cadenas Sanchez C, Shigeta TT, et al. A systematic review of physical activity and cardiorespiratory fitness on P3b. Psychophysiology. 2019. doi: 10.1111/psyp.13425
Kao, S. C., Drollette, E. S., Ritondale, J. P., Khan, N., & Hillman, C. H. (2018). The acute effects of high-intensity interval training and moderate-intensity continuous exercise on declarative memory and inhibitory control. *Psychology of Sport and Exercise, 38*, 90-99.
Kao, S. C., Westfall, D. R., Soneson, J., Gurd, B., & Hillman, C. H. (2017). Comparison of the acute effects of high intensity interval training and continuous aerobic walking on inhibitory control. *Psychophysiology, 54*, 1335-1345.
Khan, N. A., & Hillman, C. H. (2014). The relation of childhood physical activity and aerobic fitness to brain function and cognition: a review. *Pediatric Exercise Science, 26*, 138-146.
Klika, B., & Jordan, C. (2013). High-intensity circuit training using body weight: maximum results with minimal investment. *ACSM's Health & Fitness Journal, 17*, 8-13.
Kuczmarski, R. J., Kuczmarski, M. F., & Roche, A. F. (2002). 2000 CDC Growth charts: background for clinical application. *Topics in Clinical Nutrition, 17*, 15-26.
Lambrick, D., Stoner, L., Grigg, R., & Faulkner, J. (2016). Effects of continuous and intermittent exercise on executive function in children aged 8-10 years. *Psychophysiology, 53*, 1335-1342.
Li, R., & Singh, M. (2014). Sex differences in cognitive impairment and Alzheimer's disease. *Frontiers in Neuroendocrinology, 35*, 385-403.
Lipsky, R. H., & Marini, A. M. (2007). Brain derived neurotrophic factor in neuronal survival and behavior related plasticity. *Annals of the New York Academy of Sciences, 1122*, 130-143.
Olney, N., Wertz, T., LaPorta, Z., Mora, A., Serbas, J., & Astorino, T. A. (2018). Comparison of acute physiological and psychological responses between moderate-intensity continuous exercise and three regimes of high-intensity interval training. *Journal of Strength & Conditioning Research, 32*, 2130-2138.
Robinson, M. M., Lowe, V. J., & Nair, K. S. (2018). Increased brain glucose uptake after 12 weeks of aerobic high-intensity interval training in young and older adults. *Journal of Clinical Endocrinology & Metabolism, 103*(1), 221-227.
Townsend, N., Wickramasinghe, K., Williams, J., Bhatnagar, P., & Rayner, M. (2015). *Physical Activity Statistics.* British Heart Foundation, London.
Zhou, L. J., Yang, T., Wei, X., Liu, Y., Xin, W. J., Chen, Y., ... & Liu, X. G. (2011). Brain-derived neurotrophic factor contributes to spinal long-term potentiation and mechanical hypersensitivity by activation of spinal microglia in rat. *Brain, Behavior, and Immunity, 25*, 322-334.

Manuscript submitted …… . Accepted for publication …… .