Effects of Low and Moderate Acute Resistance Exercise on Executive Function in Community- Living Older Adults

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Abstract

The aim of the study was to examine the influence of acute bouts of low and moderate resistance exercise on the executive function of community-living older adults. Forty older adults (20 men and 20 women; age range: 60-75 years) were randomly assigned to an exercise or control group. The exercise group completed two 45-min resistance exercise bouts at 40% and 70% of their individual 10-repetition maximum on different days, whereas the control group watched an exercise-related video. To assess immediate and delayed effects of exercise on executive function, tests assessing working memory, response inhibition, and cognitive flexibility were performed before (pre-test), and 15 and 180 mins after the exercise. Exercise improved executive function, but no change was observed in the control group. The exercise-induced gains were i) larger after moderate than low intensity exercise, ii) similar for women and men, and iii) larger at 15 than 180 min after exercise. These results indicate that exercise improves, at least transiently, executive function in healthy older adults.

Key words: Executive function, resistance exercise, working memory, inhibition control, older adults

Aging is associated with reductions in the performance of most physiological systems including the brain (Colcombe et al., 2004), the latter reflected by decrements in executive function (Craik & Salthouse, 2011). Executive function is an umbrella term that encompasses the set of higher-order cognitive functions involved in goal directed behavior that are essential for daily life and regulate human cognition such as working memory, inhibition control, and shifting (Kirova, Bays, & Lagalwar, 2015). These functions are typically associated with the frontal (Alvarez & Emory, 2006) and prefrontal cortex, thalamus, basal ganglia (F. A. Middleton & Strick, 2002) and parietal portions of the brain(Colcombe et al., 2004).

It is thus important to develop interventions to attenuate the age-related cognitive decline that will also enhance the well-being and autonomy of the older person, and reduce the number of individuals suffering from mild cognitive impairment, or even dementia (Alvarez & Emory, 2006; Kelly et al., 2014; Simon, Cordás, & Bottino, 2015).

To date, pharmacological interventions have not been effective in slowing down cognitive aging and the progression to dementia (Barnes et al., 2009; Kelly et al., 2014). However, there is evidence that cognitive training (Barnes et al., 2009), psychotherapeutic interventions (Simon et al., 2015) and physical activity and exercise (Kelly et al., 2014) are effective to sustain cognitive function and improve the quality of life of the older adult.

There is a growing interest in exercise as a means to delay the decline and/or improve cognitive function of older adults (Barella, Etnier, & Chang, 2010; Kelly et al., 2014; Monteiro-Junior et al., 2016; Peiffer, Darby, Fullenkamp, & Morgan, 2015). Long-term resistance training has been shown to improve executive functions such as tasks assessing, selective attention (Cassilhas et al., 2007; Liu-Ambrose et al., 2010; Nagamatsu, Handy, Hsu, Voss, & Liu-Ambrose, 2012), conflict resolution (Liu-Ambrose et al., 2010; Nagamatsu et al., 2012), set shifting (Cassilhas et al., 2007; Liu-Ambrose et al., 2010), working memory (Cassilhas et al., 2007; Liu-Ambrose et al., 2010) and inhibition processes (Liu-Ambrose, Nagamatsu, Voss, Khan, & Handy, 2012) in older adults. Little is known, however, about the acute effects of a single bout of resistance exercise on executive function, but several studies do suggest that short-term resistance training does improve various cognitive tasks, especially those involving top-down executive performance (Hsieh, Chang, Hung, & Fang, 2016; Monteiro-Junior et al., 2016; Soga, Shishido, & Nagatomi, 2015; Tsai et al., 2014). However, most of the studies on the effect of short-term resistance training included either middle-aged (Chang, Chu, Chen, & Wang, 2011; Yu-Kai Chang & Jennifer L. Etnier, 2009; Chang, Ku, Tomporowski, Chen, & Huang, 2012; Chang, Tsai, Huang, Wang, & Chu, 2014), or young adults (Brush, Olson, Ehmann, Osovsky, & Alderman, 2016; Pontifex, Hillman, Fernhall, Thompson, & Valentini, 2009a; Tsai et al., 2014). Studies in healthy older adults (Emery, Honn, Frid, Lebowitz, & Diaz, 2001) or addressing special types of executive function components such as attention control and working memory are few (Hsieh, Chang, Fang, & Hung, 2016; Hsieh, Chang, Hung, et al., 2016). There is thus a need to examine whether even an acute bout of resistance exercise can improve cognitive function in the older person.

It has been reported that there is a U-shape relationship between executive performance and resistance training intensity, where too low and too high exercise intensities do reduce, rather than improve executive function (Brush et al., 2016; Chang et al., 2011; Yu-Kai Chang & Jennifer L Etnier, 2009). McMorris (2009) proposed that as exercise increases in intensity, adrenaline and noradrenaline are released from the adrenal medulla. Moderate increases could influence pre-frontal lobe attentional systems (Masulam, 1990) that is modulated by the release of cortisol by limiting the synthesis of corticotrophin releasing hormone (CRH) and adrenocorticotrophin hormone (ACTH). As exercise increases in intensity or duration, cortisol production is unable to inhibit CRH and ACTH and arousal levels increase to the point that cognitive performance is compromised.

Based on this U-shape relationship, we hypothesized that executive function performance is improved more by acute bouts of moderate than low intensity resistance exercise (Brush et al., 2016; Chang et al., 2011; Yu-Kai Chang & Jennifer L Etnier, 2009).

Another factor that is not often considered is that cognitive improvements after an exercise bout are most pronounced shortly after exercise and gradually decrease thereafter (Chang, Labban, Gapin, & Etnier, 2012). Indeed, it has been reported that exercise-induced improvementsi n executive function were most pronounced 11 min after exercise cessation (Chang, Labban, et al., 2012), and could have disappeared as soon as 20 min after exercise cessation (Brush et al., 2016; Chang, Labban, et al., 2012). The rapid disappearance of cognitive function improvements is due to diminishing arousal after exercise (Ji et al., 2017), that may be related to several factors, such as return of cerebral blood flow (Lyons, Lopez, Yang, & Schatzberg, 2000; Tsai et al., 2014), and neurotropic factors and neuromodulators (such as norepinephrine and dopamine) (Cahill & Alkire, 2003) to baseline levels within 120 min after exercise.

Cognitive function differs between men and women (Borella, Meneghetti, Ronconi, & De Beni, 2014); generally, women show advantages in verbal fluency, perceptual speed, accuracy and fine motor skills, while men outperform women in spatial, working memory and mathematical abilities. For the older adults, neuroanatomic studies with magnetic resonance imaging (MRI) indicate that the progressive decrease in brain volume affects frontotemporal brain regions associated with attention, inhibition, and memory in men more than in women and functional imaging methods suggest sex differences in blood flow, pattern of glucose metabolism, and receptor activity(Gur & Gur, 2002). In addition, various studies have shown that exercise-induced improvements in cognitive function may be sex-specific, with larger benefits in women than in men in executive performance and prevention of cognitive impairment (Baker et al., 2010; L. Middleton, Kirkland, & Rockwood, 2008), possibly due to differences in endocrine responses to exercise (Kraemer et al., 1998). However, this variable has not been considered, as far as we know, in older adults.

In the present study, we therefore examined 1) the effects of a single bout of low or moderate exercise intensity on cognitive function in the older person, 2) whether the effects differ between older men and women and 3) to what extent any benefits are maintained 3 hours after completion of the exercise. As some recent studies suggest that fitness level is positively associated with exercise-induced improvements in cognitive function (Chang, Chi, et al., 2014) we also took into account the fitness level of our participants as a co-variate. We hypothesised that 1) a bout of moderate intensity would be more effective than a low-intensity bout to improve executive function in the older person that 2) would differ for different tasks in women than men, but 3) in both men and women the benefits of an exercise bout would slowly diminish over time.

Methods

Participants

Power analysis using a mixed RMANOVA based on inhibition control (Stroop Test) effect sizes from a previous study on the effects of an acute bout of resistance exercise on cognitive performance in middle-aged adults (Yu-Kai Chang & Jennifer L. Etnier, 2009) showed that for an effect size of 0.31 at a 2-tailed significance level (α) of 0.05 and a power (1-β) of 0.80 was 33. To account for a 20% drop out we recruited 40 older men and women (60 to 75 years old) through presentations in the local community. We choose people older than 60 years as cognitive function decline starts in the sixth decade of life, with no or little drop in cognitive ability before the age 60 (Plassman et al., 1995; Rönnlund, Nyberg, Bäckman, & Nilsson, 2005). They were randomly assigned to the acute resistance exercise group (EG: n=20) or the control group (CG: n=20). None of the participants performed a regular exercise program for at least 2 years.

The inclusion criteria were: 1) age >60 years as cognitive function decline begins almost from the sixth decade of elderly life (Plassman et al., 1995; Rönnlund et al., 2005); 2) right-handed, as cognitive ability can be influenced by handedness (Gunstad, Spitznagel, Luyster, Cohen, & Paul, 2007); 3) a level of education required to complete the questionnaire; 4) a score of more than 26 on the Persian version of the mini-mental state examination (MMSE) (Ansari, Naghdi, Hasson, Valizadeh, & Jalaie, 2010); 5) an adequate score on the physical activity readiness questionnaire (PAR-Q) to ensure their safety when performing a single bout of exercise (all questions answered 'NO' (Cardinal, Esters, & Cardinal, 1996), and 6) the physician's approval for participation in the exercise program. Participants were excluded if they had 1) a history of depression, anxiety or other psychiatric disorders; 2) history of balance impairments or frequent dizziness; 3) any neurological, respiratory, vascular or metabolic diseases; 4) serious visual or auditory problems; 5) use of tranquilizers or any specific drug that influences mental state or cognitive functioning, and 6) regular engagement in resistance training programs or receiving a recent physiotherapy program during the study period.

Demographic characteristics

The age, sex and education level of the participants were determined through self-reporting. Height and mass were measured using a measuring tape (5 M/16FT measuring tape) in cm and an electronic digital Seca® scale (Seca 700 scale, Seca gmbh, Hamburg, Germany) to the nearest 0.1 kg in the laboratory, respectively. Height and body mass were used to calculate the body mass index (BMI) (kg/m^2). For the height and mass measurements, the participants wore light clothing and were barefoot. The physical activity level of the participants was assessed as metabolic equivalents (METs) using the Persian version of the International Physical Activity Questionnaire (IPAQ) (Moghaddam, Nakhaee, Sheibani, Garrusi, & Amirkafi, 2012).

The fitness level of the participants was measured with a maximal exercise test on a motor-driven treadmill and a modified Balke protocol (Balke & Ware, 1959), as previously described (Sui et al., 2007). The resting heart rate and blood pressure were assessed using a Polar RS400 heart rate monitor (Polar Electro Oy, Kuopio, Finland) and digital upper arm device (BM 16, Beurer, Ulm, Germany), respectively.

Executive function tasks

Working Memory: Working memory was evaluated by the modified Sternberg task (Firth et al., 2016). During this test, a memory set of three numbers (e.g., 521) was presented for 200 ms on a black background followed by a 3000-ms delay. This was randomly followed by either in-set probe (e.g. 1, 2 or 5) or out-of-set probe (7, 3 or 6) for 500 ms. A total of 160 memory sets, separated into four blocks of 40 trials, separated by 1 minute rest, were presented. The total duration of this test was approximately 12 min. The participants were asked to respond as quickly as possible, and the time taken was the reaction time (RT). The accuracy of assessing the new probe as an in-set, or out-set probe was recorded as response accuracy (RA).

Inhibition control: Inhibition control was evaluated by the flanker task (Eriksen & Eriksen, 1974). The flanker task involved two types of trials: congruent (same five letters e.g., DDDDD or FFFFF) and incongruent (five letters in which the middle letter was different e.g., DDFDD or FFDFF). Each trial was presented for 1000 ms on a black background with an inter-trial interval of 2000 ms. The participants were asked to respond as quickly as possible (response time; RT) and say whether it was congruent or incongruent, to assess the response accuracy (RA). A total of 96 trials, separated into two blocks of 48 trials, with 1 minute rest between blocks, were presented. The total duration of the test was approximately 8 min. RT, RA, and inhibition index, defined as the reaction time difference between incongruent and congruent trials were assessed as dependent variables.

Shifting*:* Shifting was evaluated by the more-odd task (Chen, Yan, Yin, Pan, & Chang, 2014), which consisted of a series of numeric digits from either 1 to 4, or 6 to 9. The more-odd task consisted of three types of blocks. The A block involved 16 non-switch trials printed on a black background, where the participant was required to as quickly and accurately as possible indicate whether the presented digit was greater than or less than 5, by pressing the "F" or the "L" button with their left or right index finger, respectively. The B block also involved 16 non-switch trials that were printed on a green background, and where the participants were required to say "odd" or "even", depending on the parity of the number. The shifting block (block S) consisted of 32 switch trials (included both block A and B), where the participants regularly alternated between blocks A and B at every 2-trial interval. All digits were presented focally for 2000 ms with an inter-trial interval of 2000 ms. The total test duration was approximately 12 min. The participants were required to complete 2 switching blocks and 4 non-switching blocks (2 blocks of each condition) with 1-min rest intervals between the blocks in the following order; ABSSBA. RT, RA, and switch cost, defined as the difference between average RTs of the switch trials in the shifting block (block S) and the average RTs of the non-switch trials in the control blocks (block A and B), were assessed as the dependent variables.

Physiological measures

Exercise Intensity Control: The 10-repetition maximum (10-RM) lift was determined for each of the eight exercises (see below) based on a testing protocol developed by (Baechle &

Earle, 2008) The 10-RM represents the heaviest weight an individual can successfully lift 10 times for a given exercise. Eight exercises were included: chest presses, shoulder presses, high pull-downs, rowing, alternating biceps curls, leg extensions, leg curls, and leg presses. In this session, participants were familiarized with the exercises. The exercise intensity was verified by the heart rate (HR) and rating of perceived exertion (RPE), two commonly used indicators for exercise intensity in cognition studies (Chang, Ku, et al., 2012; Chang, Tsai, et al., 2014; Hsieh, Chang, Fang, et al., 2016; Hsieh, Chang, Hung, et al., 2016). HR was monitored with a Polar RS400 heart rate monitor (Polar Electro Oy, Kuopio, Finland), a short-range radio telemetry device. RPE, a category-interval rating scale that ranges from 6 (no exertion at all) to 20 (maximal exertion), was used to provide a subjective rating of perception of effort after each exercise. The reported HR was the average HR during the exercise or video watching period and was 85-90 and 95-100 bpm for the light and moderate exercise intensity, respectively. The RPE, based on the Borg Scale, ranged from 7 - 10 and 11-14 for low and moderate intensity exercise, respectively.

Cardiovascular fitness test: The YMCA Submaximal Cycle Ergometer Test consisted of a series of 2–4 consecutive 3-min cycling stages appropriate for adults with Class A risk stratification (Fletcher et al., 2001). The initial workload was 25 W and the participants pedalled at 50 RPM on an electronic bicycle ergometer. The heart rate (HR) was at the second and third min of the first stage of cycling. After the initial 3-min stage, workload of the second stage was based on the participant's HR response recorded at the third min of the first stage of exercise. Workload of the third stage was based on the participant's HR response of the second stage. These two heart rate values, along with the YMCA equations, the body mass, and age-predicted maximal heart rate (220-age), were used to estimate VO_2peak (Medicine, 2013).

Procedure

Participants were invited to come to the laboratory individually for five separate sessions, with an interval of at least 48 h between them. Session 4 and 5 were separated by 1 week. During the first session, the participant was presented with a brief description of the experiment, signed a written informed consent, and then completed the following four questionnaires: PARQ, demographic, MMSE, and IPAQ questionnaires. Then the resting-HR and blood pressure were assessed after sitting quietly for 15 minutes in a dimly lit room. Following confirmation that the participant could safely participate in the study, the participant was randomly assigned to either the resistance exercise or the control group.

During the second session, the exercise intensity was set as described above under the heading 'Exercise Intensity Control'.

In the third session, participants were familiarized with the executive function tasks (modified Sternberg task, flanker task, and more-odd task) by completing two blocks of practice trials for each task, with visual and auditory feedbacks. The third session finished with a YMCA submaximal cycle ergometer test (American College of Sports Medicine, 2013) to determine peak oxygen uptake (VO_2peak).

In session four, the participants completed the executive function tasks– presented in a counterbalanced order across participants. This was done while sitting quietly in a dimly lit room for 15 min. After pre-test data collection, the participant performed the activities depending on the assigned treatment conditions.

Participants in the EG performed a resistance exercise protocol (Brush et al., 2016; Hsieh, Chang, Hung, et al., 2016; Pontifex et al., 2009a). The exercise machine and free weights were used in both concentric and eccentric phases. Each participant of the EG first warmed up with light aerobic activity and general stretching exercise for five to ten minutes and then performed three sets of 10 repetitions at 70% of 10-RM of each of the eight exercises. The rest intervals between sets and exercises were 30 and 90 seconds, respectively. All exercises were performed under supervision of one of the researchers. The order of the exercises was the same for all participants and in both the fourth and fifth session. The order of the exercises was as follows: high pull-downs, rowing, chest presses, shoulder presses, alternating biceps curls, leg extensions, leg presses, and leg curls.

CG participants watched an instructional video on how exercise can influence mental health for approximately the same duration as the exercise sessions (~45 min).

After completion of the assigned treatment conditions by the participants, they sat quietly in a dimly lit room for 15 min before completing the executive function tasks: the 15-min post-exercise test (post- test phase). Following completion of the 15-min test, participants were allowed to leave the laboratory and return at 180 min after the completion of exercise or video watching to complete another executive function task as a 180-min post-exercise test. During the intervening period, participants were requested to continue their normal daily activities, avoid any additional physical activity, and to refrain from consuming any food and drinks, including coffee, tea, or alcohol, that might alter mood or cognition and stimulate or inhibit the cardiovascular system.

The fifth session was similar to that of the fourth session for both groups, but the exercise intensity was 40% of 10-RM for EG participants whereas CG participants watched an instructional video.

Data analyses

SPSS statistical software (version 18.0, SPSS Inc., Chicago, IL, USA) was used for all statistical analyses. The Shapiro-Wilk test was used to assess normality. A 2 (groups: control and exercise groups) ×3 (times: pre-test, 15 min after exercise, and 180 min after exercise) ×2 (exercise intensities: low intensity, and moderate intensity) × 2 (sex: male, and female) repeated measure MANCOVA were used to test the main and interaction effects of RA and RT for the tasks of interest (that is the modified Sternberg, more-odd, and flanker tasks as well as switch cost (Shift) and inhibition index for more-odd and flanker tasks, respectively). Statistical significance was set at $p<0.05$. Additional follow-up comparisons were conducted using Bonferroni-corrected t-tests for multiple comparisons. Partial eta squared (η2p) values with 0.01–0.059, 0.06–0.139, and >0.14 represented small, moderate, and large effects, respectively (Cohen, 1973). To obtain a better understanding of the range of training gains, Cohen's *d* (1988) – expressing the effect size of the comparisons – was calculated (values with 0.01–0.2, 0.21- 0.50, 0.51- 0.80 and >0.81 representing small, medium, large and very large effects, respectively (Cohen, 1988).

Results

Participant characteristics

There were no significant differences in age, height, body mass, BMI, years of education, VO_2peak, physical activity and systolic and diastolic blood pressure between the control and exercise group (Table 1).

Insert Table 1 here

Physiological measures

The effect of exercise intensity ($F(1,36)=83.9$, $p = 0.001$, η2p = 0.70) on HR in the groups ($F(1,36)=594.9$, $p = 0.001$, η2p = 0.94) and sexes ($F(1,36)=5.5$, $p = 0.02$, η2p = 0.13) indicated a higher average HR for 70% than 40% 10-RM exercise intensity, and a higher HR for exercise than the control group, and a higher HR in women than men (Table 2).

Similarly, the RPE was higher during the 70% than 40% 10-RM exercise and this is turn was higher than in the controls. The RPE did not differ between men and women (Table 2).

These results showed that the different resistance exercise intensity manipulation were effective to induce desirable physiological responses and increase arousal.

Insert Table 2 here

Executive function performance

Working memory

A mixed ANOVA revealed a significant main effect of group for RAs of in-set probe and out-set probe ($F_{(1, 36)}$ =5.3; p=0.03; η2p =0.13 and $F_{(1, 36)}$ =10.9; p=0.002; η2p =0.23, respectively), indicating a higher RA for the exercise than the control group. The main effect of group was also significant for RTs of in-set probe ($F_{(1, 36)}$ =5.3; p=0.03; η2p =0.13) in favour of the exercise group (see Table 3 and 4).

A significant effect of time and a group×time interaction were found across the four variables of interest: RTs of in-set probe ($F_{(2, 72)}$ =15.7; p=0.001; η2p =0.30 and $F_{(1, 36)}$ =12.1; p=0.001; η2p =0.25; respectively), RTs of out-set probe ($F_{(2, 72)}$ =13.7; p=0.001; η2p =0.28 and $F_{(1, 36)}$ =13.1; p=0.001; η2p =0.27; respectively), RAs of in-set probe ($F_{(2, 72)}$ =3.7; p=0.03; η2p =0.09 and $F_{(1, 36)}$ =10.3; p=0.001; η2p =0.22; respectively), and RAs of out-set probe ($F_{(2, 72)}$ =9.1; p=0.001; η2p =0.20 and $F_{(1, 36)}$ =3.7; p=0.03; η2p =0.09; respectively). Bonferroni post-hoc tests revealed shorter RTs of in-set probe and out-set probe, and higher RAs of in-set probe and out-set probe for the exercise groups from baseline to 15-min.

A significant effect of exercise intensity was found across the four variables: RTs of in-set probe ($F_{(1, 36)}$ =6.7; p=0.01; η2p =0.16), and out-set probe ($F_{(1, 36)}$ =16.6; p=0.001; η2p =0.31), indicating a shorter RT for 70% than 40% 10-RM exercise intensity and RAs of in-set probe ($F_{(1, 36)}$ =4.2; p=0.04; η2p =0.09) and out-set probe ($F_{(1, 36)}$ =13.2; p=0.001; η2p =0.27) in favour of 70% 10-RM exercise intensity relative to 40% 10-RM exercise intensity. The main effect of sex and other interactions were not significant (p>0.05).

Cognitive flexibility

There was a group effect for RAs of switch trials and non –switch trials ($F_{(1, 36)}$ =4.4; p=0.04; η2p =0.11, and $F_{(1, 36)}$ =4.7; p=0.04; η2p =0.11; respectively), indicating a higher RA in the exercise than in the control group. The group effect on RT of switch trials and non –switch trials ($F_{(1, 36)}$ =8.2; p=0.01; η2p =0.19 and $F_{(1, 36)}$ =4.1; p=0.05; η2p =0.10; respectively), indicated a shorter RT for the exercise than the control group (see Table 3 and 4).

There were time effects and a group× time interactions for RT of switch trials ($F_{(2, 72)}$ =14.8; p=0.001; η2p =0.29 and $F_{(1, 36)}$ =21.3; p=0.001; η2p =0.37; respectively), RT of non–switch trials ($F_{(2, 72)}$ =13.3; p=0.001; η2p =0.27 and $F_{(1, 36)}$ =11.7; p=0.001; η2p =0.25; respectively), RA of switch trials ($F_{(2, 72)}$ =6.3; p=0.003; η2p =0.15 and $F_{(1, 36)}$ =15.0; p=0.001; η2p =0.29; respectively), and RA of non–switch trials ($F_{(2, 72)}$ =9.8; p=0.01; η2p =0.21 and $F_{(1, 36)}$ =15.3; p=0.001; η2p =0.30; respectively). Bonferroni post-hoc revealed a shorter RT of switch trials and non–switch trials and greater RAs of switch trials and non–switch trials for the exercise groups from baseline to 15-min. A time effect and a group×time interaction ($F_{(2, 72)}$ =6.7; p=0.002; η2p =0.17 and $F_{(1, 36)}$ =12.3; p=0.001; η2p =0.26; respectively) were found for the switch costs, wherein pairwise comparisons revealed a shorter time of switching for the exercise groups from baseline to 15-min.

An effect of exercise intensity was found for RTs of switch ($F_{(1, 36)}$ =5.5; p=0.01; η2p =0.14) and non–switch trials ($F_{(1, 36)}$ =4.9; p=0.03; η2p =0.13), indicating a shorter RT for 70% than 40% 10-RM exercise intensity. The RA of non–switch trials ($F_{(1, 36)}$ =6.5; p=0.01; η2p =0.15), was higher for 70% than 40% 10-RM exercise intensity.

Inhibitory control

A mixed ANOVA revealed a significant main effect of group for RAs of congruent and incongruent trials ($F_{(1, 36)}$ =10.5; p=0.001; η2p =0.23 and $F_{(1, 36)}$ =4.4; p=0.04; η2p =0.11;

respectively), indicating a higher RA for the exercise than the control group, and RT of incongruent trials ($F_{(1, 36)}$ =4.2; p=0.04; η2p =0.11), indicating a shorter RT for exercise than the control group (see Table 3 and 4).

An effects of time and a group×time interactions were found for RT of congruent trials ($F_{(2, 72)}$ =28.8; p=0.001; η2p =0.44 and $F_{(1, 36)}$ =37.8; p=0.001; η2p =0.51; respectively), RT of incongruent trials ($F_{(2, 72)}$ =23.8; p=0.001; η2p =0.40 and $F_{(1, 36)}$ =18.7; p=0.001; η2p =0.34; respectively), RA of congruent trials ($F_{(2, 72)}$ =12.4; p=0.001; η2p =0.26 and $F_{(1, 36)}$ =18.9; p=0.001; η2p =0.34; respectively) and RA of incongruent trials ($F_{(1, 36)}$ =4.8; p=0.04; η2p =0.12 and $F_{(1, 36)}$ =12.8; p=0.001; η2p =0.26; respectively). Bonferroni post-hoc tests revealed shorter RTs of congruent trials and incongruent trials and greater RAs of congruent trials and incongruent trials for the exercise groups from baseline to 15-min.

The RTs of congruent and incongruent trials ($F_{(1, 36)}$ =5.7; p=0.02; η2p =0.14 and $F_{(1, 36)}$ =7.6; p=0.01; η2p =0.17; respectively) were shorter for the 70% than the 40% 10-RM exercise intensity. The RA of incongruent trials ($F_{(1, 36)}$ =5.5; p=0.03; η2p =0.13) was better in the 70% than the 40% 10-RM exercise intensity.

Insert Table 3 and 4 here

Comparisons of the gains from pre- to post- test within each group revealed a large (above .80) effect size from baseline to 15-min, independent of intensity, for all the cognitive tasks, compared to control (Figure 1, 2 and 3). Exercise groups from baseline to 15-min had also larger effect sizes than from baseline to 180 min. Qualitatively, the effect sizes from baseline to 15 min were larger for the moderate intensity group than the low intensity one (Figure 1, 2 and 3).

Insert Figure 1 and 2 and 3 here

Discussion

An age-related decrement in cognitive function can significantly disrupt the quality of life of the older person. Therefore, the aim of the present study was to assess whether a single bout of low or moderate acute resistance exercise can improve executive functions in adults over 60 years of age. The main observations of our work are that both moderate and low intensity resistance exercise have beneficial effects on executive functions, such as improvement in working memory, cognitive flexibility and inhibition control tasks. These benefits were similar in older men and women, and stronger after a moderate than a low-intensity exercise bout. These improvements were most pronounced briefly after exercise and gradually diminished after exercise.

The beneficial effects of a single bout of resistance exercise we found in older adults are in line with many previous studies that reported similar benefits on executive function components of young adults (Berse et al., 2015; Hsieh, Chang, Hung, et al., 2016; Tsai et al., 2014), adolescents (Alves et al., 2012), and middle- aged people (Yu-Kai Chang & Jennifer L. Etnier, 2009; Chang, Tsai, et al., 2014).

The present results also suggest that moderate-intensity resistance exercise leads to more benefits to executive functions than low-intensity exercise, something also seen by others (Yu-Kai Chang & Jennifer L Etnier, 2009; Kamijo et al., 2004). Those results could be explained by a cognitive-energetic model that postulates that acute exercise facilitates cognitive performance via optimal arousal levels (Audiffren, 2009), where the moderate-intensity exercise puts a higher demand on cognitive and central processing than low-intensity exercise. In our study resistance exercise interventions induced an increase in HRs that may be related to exercise-induced increases in arousal and lead to improved processing speeds in exclusive functions components. Indeed, (Arent, Landers, Matt, & Etnier, 2005) reported that the benefit of exercise for cognitive function shows a U-shape, which may also explain the absence of a beneficial effect in young adults on cognitive function when exercising at 80% of 1-RM ((Pontifex et al., 2009a). The present results contrast, however, with observations by (Brush et al., 2016) who reported no difference between the effect of different intensities of acute resistance exercise (low, moderate, and high-intensity) on executive function of participants aged 18 to 30 years. Differences in the research methodology and participant's age between that and our study may explain the different results.

Here we show that the benefits of a single resistance exercise bout for executive function are similar for older men and women. Other studies in young adults, however, reported a smaller benefit of exercise in women (Baker et al., 2010; Laurin, Verreault, Lindsay, MacPherson, & Rockwood, 2001; L. Middleton et al., 2008). Part of the discrepancy may be attributable to a lower fitness of the women who participated in the study than the participating men in those studies, while here men and women had similar fitness levels.

We found that the improvement in cognitive function were more pronounced 15 min than 180 min after completion of exercise. This is in line with a meta-analysis that showed that best results for cognitive enhancement are seen 11-30 min after cessation of exercise (Chang, Labban, et al., 2012; Pontifex, Hillman, Fernhall, Thompson, & Valentini, 2009b). Also (Brush et al., 2016) found the best results for a Stroop task 15 min after resistance exercise. It thus seems that the benefits of exercise slowly fade away and suggest that to maintain improved cognitive function regular exercise is required. The rapid disappearance of cognitive function improvements following an acute exercise session may be due to diminishing arousal (Ji et al., 2017). The diminishing arousal may be a consequence of return of cerebral blood flow, norepinephrine and dopamine (Lyons et al., 2000; Tsai et al., 2014), corticosteroids (especially cortisol) (Henckens, van Wingen, Joëls, & Fernández, 2012), growth factors (especially IGF-1 and brain-derived neurotropic factor (BDNF)) (Cahill & Alkire, 2003; Sonntag, Ramsey, &

Carter, 2005), and neural processing (Tsai & Wang, 2015) to baseline levels within 120 min after cessation of exercise. Those mechanisms should be examined in future studies to understand their role in exercise-induced improvements in cognitive function in the older adult.

We acknowledge that the acute benefits of exercise for executive function may well differ from the benefits of chronic exercise, that are associated, among others, with neuro/synaptogenesis and angiogenesis (Li, O'Connor, O'Dwyer, & Orr, 2017). However, the acute effects, such as increased blood flow and neurotrophic factors, will be a first step in realising these chronic adaptations to exercise, by stimulating angiogenesis and neurogenesis, respectively and only regular exercise can cause the acute effects of exercise to induce the chronic adaptations.

One potential limitation is that the data are somewhat influenced by a learning effect over the repeated sessions. However, this bias is negligible as the control group underwent all the same procedures as the exercise group, except for the exercise itself. After the 15 min post-exercise evaluation, participants were allowed to leave the lab, so other environmental factors may have affected the executive function evaluations at 180 minutes after exercise cessation and cause a reduction that otherwise might not have been seen. However, they were performing their normal daily life routine, and rather than being a weakness or limitation it is a strength of the study allowing a better translation of the results to daily life. In addition, keeping the participants in the lab for 3 hours may cause other unwanted causes (for example, stress or fatigue) that may affect the outcomes. To limit any effects of the circadian rhythm on executive function (Schmidt, Collette, Cajochen, & Peigneux, 2007), tests were performed at the same time of day (in the morning at 9:30 am and evening at 6:00 pm to 8:00 pm). Finally, the outcome of this study may be affected by the small sample size, but given the significance and size of the effects, we believe that a larger sample size would not have significantly altered the outcome of the study.

Future studies should use complementary neuroimaging techniques (e.g., EEG / ERP, fMRI and fNIRS) and biochemical markers (such as growth hormone, IGF1, BDNF, dopamine and cortisol) to better understand what factors underlie the improvements in cognitive function after a single resistance exercise bout. Future studies may also consider the circadian rhythm and evaluate at what time of day exercise elicits the largest benefits, and maybe study older adults with chronic diseases, particularly those with reduced executive function such as dementia and Alzheimer's disease.

Conclusion

The present study shows that a single bout of low- and moderate-intensity resistance exercise improves executive function in >60-year-old men and women. These effects were more pronounced after moderate- than low-intensity exercise and were particularly evident early (15 min) after cessation of exercise, gradually decreasing thereafter. This suggests that to maintain the exercise-induced benefits on cognitive function, the exercise should be repeated regularly. Given that older adults are often concerned about maintaining their cognitive function, these findings can be used to encourage older individuals to participate in resistance exercise programs.

Compliance with Ethical Standards

Financial Disclosure: This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Conflict of Interest: The authors report no conflicts of interest. The authors alone are responsible for the content and writing of the paper.

Ethical Approval: All authors complied with the APA ethical standards in the treatment of participants.

Informed Consent: All participants were informed of the study procedures and signed an informed consent and participants were free to withdraw from the study at any time.

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Table 1. Participant characteristics (mean±SD) by sex for exercise and control groups

Measures	*Exercise group*		*Control group*		*p-value*
	Male	Female	Male	Female	
Anthropometric variables					
Sample size (n)	12	12	12	12	
Age (years)	63.7±2.6	63.9±2.9	63.1±2.1	63.6±2.2	0.5
Education (years)	7.7±3.4	10.7±4.3	8.2±3.6	11.7±3.3	0.5
Health measures					
BMI (kg/m^2)	25.8±2.6	26.3±2.4	25.6±2.8	25.5±2.8	0.5
MMSE (points)	28.8±1.03	28.3±0.9	29.0±1.1	28.1±1.0	0.6
Resting HR (bpm)	67.2±6.3	64.4±7.97	65.3±10.0	68.9±9.9	0.8
Resting SB (mmHg)	86.4±8.1	84.5±7.5	81.8±8.9	83.9±5.7	0.3
Resting DBP (mmHg)	135±11	135±11	134±12	136±10	0.9
IPAQ (METs)	1894±1624	2215±1232	2179±1441	1741±1105	0.8
VO2 peak (mL/kg/min)	23.5±3.6	20.1±3.2	23.01±3.5	21.9±4.6	0.18

Abbreviations: *BMI: body mass index; MMSE: mini-mental state examination; HR: heart rate, SBP: systolic blood pressure; DBP: diastolic blood pressure; IPAQ: International Physical Activity Questionnaire; MET: Metabolic Equivalent*

Table 2. Exercise intensity manipulation check (mean ± SD) during the low and moderate intensity exercise

Variables	Moderate intensity (70% 10-RM)				Low intensity (40% 10-RM)			
	Exercise group		Control group		Exercise group		Control group	
	Man	woman	man	woman	man	woman	man	Woman
HR (bpm)	97.6±6.8	99.7±3.6	61.6±4.7	65.0±4.9	86.2±7.1	90.4±2.5	60.2±2.5	62.5±2.8
RPE (points)	12.5±0.7	13.1±0.9	6.5±0.5	6.2±0.4	8.9±1.1	9.2±1.2	6.2±0.4	6.3±0.5

Abbreviations: HR: heart rate, RPE: rating of perceived exertion

Table 3. Executive function tests (M ±SD) by exercise intensity, time, group and gender.

Variables	time	Moderate intensity (70% 10-RM)				Lowe intensity (40% 10-RM)			
		Exercise group		Control group		Exercise group		Control group	
		male	female	Male	female	male	female	male	female
Working memory (Modified Sternberg task)									
Accuracy response (%)									
in-set probe	baseline	91.8±1.1	91.5±0.8	91.5±1.0	91.4±0.8	91.8±1.1	91.5±0.8	91.5±1.0	91.4±0.8
	15-min	93.3±0.9	93.1±1.2	91.5±1.0	91.1±0.9	92.4±0.8	92.6±1.3	91.0±0.7	91.3±0.7
	180-min	92.0±0.8	91.8±0.6	91.5±0.8	91.5±0.9	91.8±0.6	91.8±0.8	91.3±0.7	91.6±0.7
out-of-set probe	baseline	90.7±0.7	90.8±0.6	91.0±0.8	91.0±1.2	90.9±0.8	90.9±0.7	91.1±0.8	91.0±0.9
	15-min	92.8±0.8	92.5±1.1	91.1±0.9	91.2±0.8	92.0±0.7	92.0±0.8	91.0±1.0	91.1±0.7
	180-min	91.4±0.7	91.1±1.1	91.2±0.6	91.1±0.9	91.3±0.8	91.0±0.9	90.8±0.8	91.1±0.9
Reaction time (ms)									
in-set probe	baseline	652±74	655±76	680±52	673.5±42	643±77	664.6±84	680±53	678±48
	15-min	606±64	610±60	683±48	670.3±34	618±69	634.5±76	679±57	668±37
	180-min	620±59	631±67	680±51	672.2±34	627±68	654.3±61	679±51	669±36
out-of-set probe	baseline	688±76	694±40	698±48	685.1±86	686±73	692.7±39	698±47	685±86
	15-min	656±47	649±33	697±53	687.8±80	666±56	669.4±35	702±49	685±77
	180-min	673±62	675±35	693±51	682.8±74	671.7±62	685.4±42	698±49	679±81
Cognitive flexibility (More-odd task)									
Accuracy response (%)									
non -switch trials	baseline	91.8±1.0	91.7±1.6	91.7±1.3	92.2±1.3	91.9±1.1	91.8±1.6	91.6±1.3	92.0±1.3
	15-min	94.1±1.4	94.1±1.0	91.9±1.0	91.4±1.0	92.6±0.8	92.6±1.3	91.6±0.7	91.9±1.0
	180-min	92.5±1.6	92.5±1.8	91.8±1.1	91.6±1.0	91.9±1.2	91.6±1.7	91.9±1.0	92.0±1.2
switch trials	Baseline	89.3±2.5	88.9±2.3	90.2±1.7	88.6±2.1	89.2±1.4	89.6±1.0	89.6±1.3	89.5±0.8
	15-min	91.8±0.9	92.2±1.4	89.0±2.3	89.6±1.5	90.5±1.5	90.9±1.2	89.1±2.6	88.7±2.5
	180-min	89.9±1.0	90.1±1.1	89.5±1.1	89.4±1.9	89.4±1.9	89.9±1.5	90.2±0.9	89.6±1.0
Reaction time (ms)									
non-switch trials	baseline	703±52	695±34	710±38	709±39	705±60	694±33	701.±42	711±39
	15-min	667±41	705±34	658±31	701±37	680±45	712±32	670±27	712±23
	180-min	678±59	711±28	678±41	703±31	688±68	700±38	687±30	712±31
switch trials	baseline	1061±123	1105±98	1084±133	1096±131	1065±111	1060±96	1106±118	1092±92
	15-min	951±105	930±75	1107±93	1080±84	967±96	951±85	1145±75	1097±67
	180-min	1023±80	1007±91	1079±80	1045±91	1037±105	1019±94	1094±92	1075±104
switch cost (ms)	Baseline	358±166	356±107	374±129	387±125	361±159	366±99	404±120	380±86
	15-min	284±134	273±93	402±88	379±69	287±139	287±95	434±82	357±58
	180-min	345±120	329±99	369±67	343±74	348±144	331±98	394±95	363±95
Inhibition control(Flanker task)									
Accuracy response (%)									
congruent	baseline	91.9±0.9	92.0±0.9	91.7±1.1	91.7±1.1	91.7±0.9	91.8±0.6	91.6±1.1	91.5±1.2
	15-min	93.2±1.0	93.3±0.9	91.5±0.9	91.4±0.9	92.8±1.0	92.9±0.7	91.3±0.7	91.8±1.1
	180-min	91.9±1.2	92.0±0.8	91.6±0.8	91.7±1.8	91.7±0.7	92.0±0.7	91.7±1.2	91.8±1.1
incongruent	Baseline	91.4±1.2	91.3±1.1	91.2±1.3	91.7±1.3	91.0±1.3	91.2±1.0	90.8±1.2	91.0±0.9
	15-min	92.7±0.9	92.6±0.7	90.8±1.1	91.3±1.3	92.2±1.3	92.0±1.2	90.4±0.7	91.2±1.03
	180-min	91.3±0.7	91.4±0.8	91.3±1.3	91.1±1.0	91.2±0.9	91.1±1.0	91.4±1.3	91.1±1.0
Reaction time (ms)									
congruent	Baseline	619±35	619±59	622±47	618±34	622±40	626±57	623±45	617±37
	15-min	573±35	580±58	615±50	618±32	583±30	584±54	629±34	624±24
	180-min	618±45	616±52	617±53	611±39	621±35	616±54	621±41	618±34
incongruent	baseline	673±58	675±48	677±63	684±63	686±65	679±51	692±70	691±45
	15-min	608±42	610±34	677±47	670±57	646±51	621±43	696±64	693±42
	180-min	652±77	660±45	694±43	677±40	679±68	680±50	694±66	685±46
inhibition index	Baseline	62±55	53±89.9	59±50	68±69	57±52	56±69	55±54	59±64
	15-min	56±38	44±46.6	56±63	65±69	42±48	48±61	50±55	57±70
	180-min	59±71	64±83.7	67±58	62±61	56±73	56±71	59±54	54±63

Table 4. Repeated Measure ANOVA results (F (sig)) for executive function tests of interest.

	Group effect	Time effect	group *time	Sex effect	time* sex	sex*group	time* sex*group	Exercise intensity effect	intensity*sex	intensity*group	intensity * sex* group	time * intensity	time * intensity * sex	time * intensity * group	time * intensity * sex * group
Working memory (Modified Sternberg task)															
Accuracy (%)															
in-set probe	**13.9 (0.001)**	**6.8 (0.03)**	**15.7 (0.001)**	0.1 (0.7)	0.4 (0.7)	0.1 (0.7)	0.2 (0.8)	**4.1 (0.04)**	2.4 (0.13)	1.4 (0.2)	0.2 (0.7)	2.6 (0.08)	1.3 (0.3)	1.6 (0.2)	0.1 (0.9)
out-of-set probe	**6.3 (0.02)**	**16.5 (0.001)**	**15.2 (0.001)**	0.1 (0.8)	0.1 (0.9)	0.2 (0.6)	0.4 (0.7)	**5.9 (0.02)**	0.2 (0.7)	0.05 (0.8)	0.4 (0.5)	**3.9 (0.03)**	0.4 (0.7)	1.6 (0.2)	0.6 (0.5)
Reaction time (ms)															
in-set probe	**5.3 (0.03)**	**15.8 (0.001)**	**12.1 (0.001)**	0.03 (0.9)	0.5 (0.6)	0.3 (0.6)	0.2 (0.8)	**6.7 (0.01)**	3.9 (0.05)	**9.1 (0.005)**	1.9 (0.17)	0.3 (0.7)	0.1 (0.9)	**4.9 (0.01)**	0.1 (0.9)
out-of-set probe	0.7 (0.4)	**12.5 (0.001)**	**14.6 (0.001)**	0.06 (0.8)	0.2 (0.8)	0.3 (0.6)	0.4 (0.7)	**8.0 (0.008)**	0.2 (0.7)	**5.6 (0.02)**	**8.1 (0.007)**	**5.2 (0.008)**	0.5 (0.6)	**4.8 (0.01)**	2.1 (0.1)
Cognitive flexibility (More-odd task)															
Accuracy (%)															
non -switch trials	**4.7 (0.04)**	**9.8 (0.001)**	**15.3 (0.001)**	0.1 (0.9)	0.4 (0.7)	0.1 (0.8)	0.5 (0.6)	**6.5 (0.01)**	0.2 (0.7)	**9.4 (0.004)**	0.8 (0.4)	**5.3 (0.01)**	0.7 (0.5)	**10.2 (0.001)**	0.7 (0.5)
switch trials	**4.4 (0.04)**	**6.3 (0.003)**	**15.0 (0.001)**	0.01 (0.9)	1.0 (0.4)	0.6 (0.4)	0.2 (0.8)	0.7 (0.4)	0.2 (0.7)	1.2 (0.3)	0.2 (0.7)	**5.0 (0.01)**	2.8 (0.07)	1.3 (0.3)	0.8 (0.4)
Reaction time (ms)															
non-switch trials	**4.1 (0.05)**	**13.3 (0.001)**	**11.7 (0.001)**	0.05 (0.8)	0.6 (0.5)	0.12 (0.7)	0.4 (0.7)	**4.9 (0.03)**	1.4 (0.2)	1.9 (0.2)	2.7 (0.11)	**5.21 (0.01)**	0.52 (0.6)	0.5 (0.6)	0.5 (0.6)
switch trials	**8.2 (0.01)**	**14.8 (0.001)**	**21.3 (0.001)**	0.5 (0.5)	1.3 (0.3)	0.06 (0.8)	0.6 (0.6)	**5.5 (0.01)**	0.5 (0.5)	0.1 (0.8)	0.4 (0.5)	**5.4 (0.01)**	0.8 (0.5)	0.14 (0.8)	1.3 (0.3)
switch cost (ms)	3.2 (0.08)	**6.7 (0.002)**	**12.3 (0.001)**	0.3 (0.6)	1.2 (0.3)	0.12 (0.7)	0.5 (0.6)	2.2 (0.15)	1.3 (0.3)	0.4 (0.5)	2.1 (0.1)	0.2 (0.8)	0.4 (0.7)	0.4 (0.7)	0.7 (0.5)
Inhabitation control (Flanker task)															
Accuracy (%)															
Congruent trials	**10.5 (0.001)**	**12.4 (0.001)**	**18.9 (0.001)**	0.3 (0.6)	0.8 (0.8)	0.02 (0.9)	0.2 (0.8)	0.7 (0.4)	0.2 (0.7)	0.8 (0.4)	0.1 (0.8)	0.8 (0.4)	0.4 (0.7)	0.6 (0.5)	0.5 (0.6)
incongruent trials	**4.4 (0.04)**	**4.8 (0.04)**	**12.8 (0.001)**	0.3 (0.6)	0.8 (0.5)	0.2 (0.6)	1.3 (0.3)	**5.5 (0.03)**	0.06 (0.8)	0.1 (0.7)	0.02 (0.9)	2.4 (0.1)	0.3 (0.8)	1.9 (0.2)	1.1 (0.3)
Reaction time (ms)															
Congruent trials	1.3 (0.3)	**28.8 (0.001)**	**37.8 (0.001)**	0.2 (0.7)	0.5 (0.6)	0.1 (0.7)	0.2 (0.8)	**5.7 (0.02)**	0.4 (0.5)	0.06 (0.8)	0.05 (0.8)	1.2 (0.3)	0.5 (0.6)	0.5 (0.6)	0.4 (0.7)
Incongruent trials	**4.2 (0.04)**	**23.8 (0.001)**	**18.7 (0.001)**	0.12 (0.7)	0.7 (0.4)	0.06 (0.8)	1.1 (0.3)	**7.6 (0.01)**	0.3 (0.6)	0.3 (0.6)	2.0 (0.1)	**3.4 (0.04)**	0.7 (0.5)	0.8 (0.4)	0.9 (0.4)
inhibition index	0.2 (0.7)	2.5 (0.08)	0.3 (0.8)	0.01 (0.9)	0.6 (0.6)	0.01 (0.9)	1.8 (0.2)	0.4 (0.5)	0.03 (0.8)	0.01 (0.9)	0.5 (0.5)	0.4 (0.7)	1.9 (0.2)	0.8 (0.4)	0.1 (0.8)

Figure legends

Figure 1. Effect size d for working memory variables from baseline to 15-min and from baseline to180-min contrasts for control and exercise groups after moderate and low intensity exercise

Figure 2. Effect size d for inhibition control variables from baseline to 15-min and from baseline to180-min contrasts for control and exercise groups after moderate and low intensity exercise

Figure 3. Effect size d for cognitive flexibility variables from baseline to 15-min and from baseline to180-min contrasts for control and exercise groups after moderate and low intensity exercise

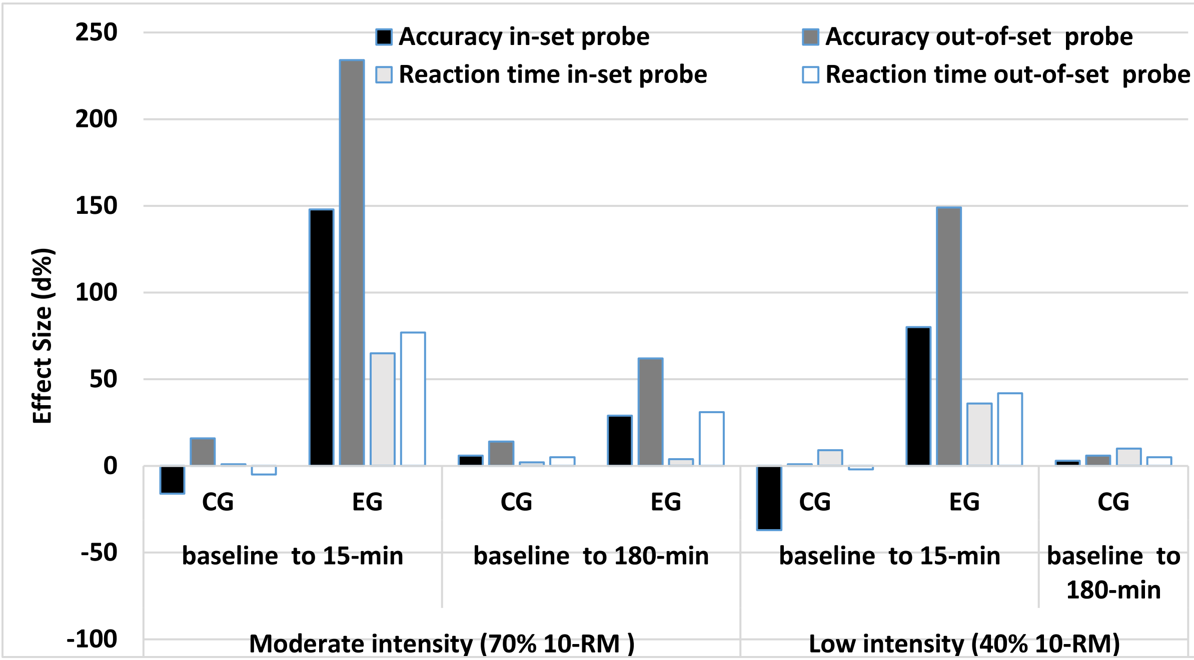
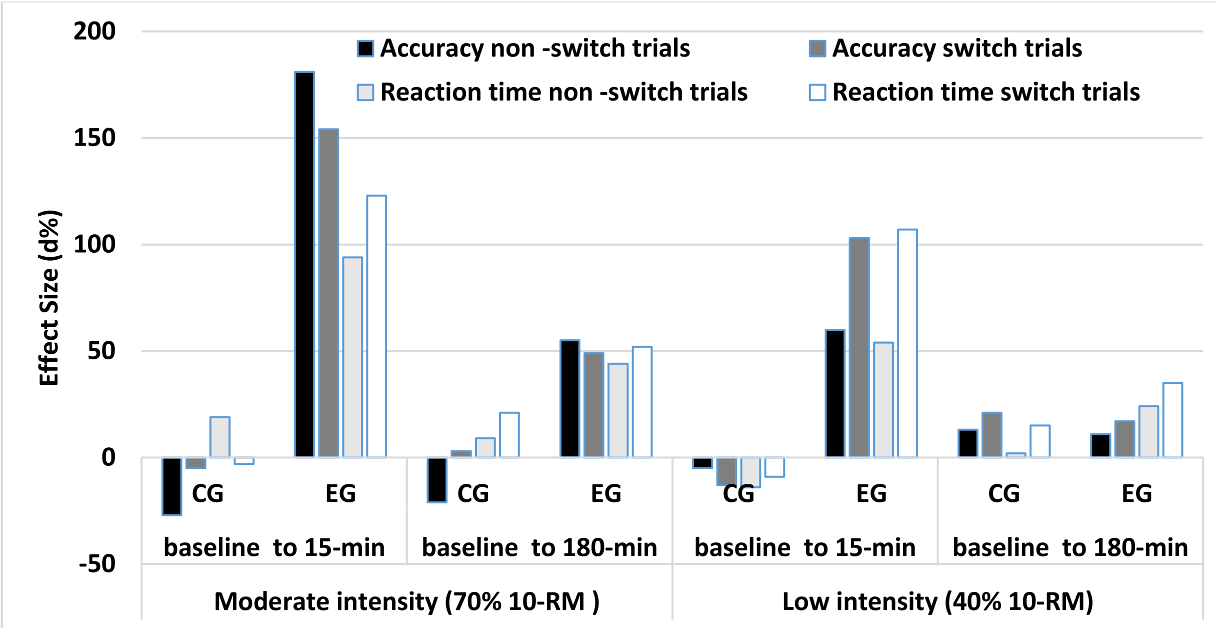

Accuracy in-set probe
Accuracy out-of-set probe
Reaction time in-set probe
Reaction time out-of-set probe
Effect Size (d%)
250
200
150
100
50
0
-50
-100
CG
EG
CG
EG
CG
EG
CG
baseline to 15-min
baseline to 180-min
baseline to 15-min
baseline to 180-min
Moderate intensity (70% 10-RM)
Low intensity (40% 10-RM)

Figure 1.



200
150
100
50
0
-50
Effect Size (d%)
Accuracy non -switch trials
Accuracy switch trials
Reaction time non -switch trials
Reaction time switch trials
CG
EG
CG
EG
CG
EG
CG
EG
baseline to 15-min
baseline to 180-min
baseline to 15-min
baseline to 180-min
Moderate intensity (70% 10-RM)
Low intensity (40% 10-RM)

Figure 2.

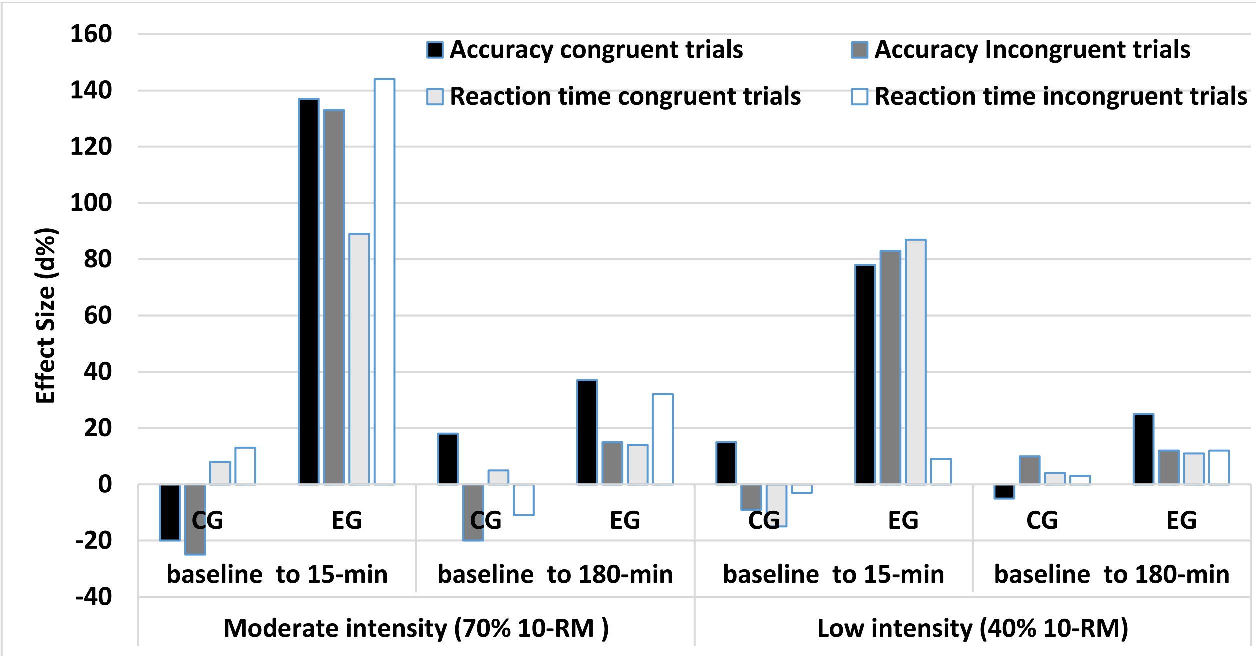

160
140
120
100
80
60
40
20
0
-20
-40
Effect Size (d%)
Accuracy congruent trials
Accuracy Incongruent trials
Reaction time congruent trials
Reaction time incongruent trials
CG
EG
CG
EG
CG
EG
CG
EG
baseline to 15-min
baseline to 180-min
baseline to 15-min
baseline to 180-min
Moderate intensity (70% 10-RM)
Low intensity (40% 10-RM)

Figure 3.