The Effect of Acute Concurrent Exercise on Executive Function: An Event-Related Potential Study

Participants

Seven to eight younger adults aged 21 to 28 years from universities surrounding Taipei City, Taiwan, were recruited. All participants met seven inclusion criteria as follows: (1) right-handed dominant, (2) normal or corrected-to-normal vision, (3) no psychiatric or neurological disorders, (4) no regular exercise habits, (5) non-obese, (6) no cardiorespiratory diseases, and (7) no neuromuscular disorders.

Intervention

Participants in group CE were asked to warm up with a cycle ergometer for 5 minutes, with revolutions per minute (RPM) and wattage (W) set at 70 and 25, respectively. W was gradually increased to near-moderate HR during warm-up, and HR reached moderate intensity at the end. Participants then performed moderate AE for 12 minutes with a cycle ergometer, with the intensity set at 40–59% of HR reserve (HRR). After finishing AE, lactate was measured (mid-lactate). Participants then performed moderate RE for approximately 13 minutes, with training volume set at 1 set, 12 repetitions, 8 movements (consistent with baseline measurements) of 70% 10-RM with strength training machines, following the half training volume of a study published by (Hsieh et al., 2016). After finishing RE, participants completed a whole-body stretching routine for 5 minutes. The process in group AE was similar to group CE; however, AE changed to 25 minutes, and RE was canceled. Participants in group RC finished 35 minutes of magazine reading.

Electroencephalogram

Electroencephalogram (EEG) recorded utilized a 32-channel electrode cap (Quik-Cap Neo Net; Compumedics Neuroscan, Charlotte, NC) in conjunction with CURRY 8 Data Acquisition and Online Processing software (Compumedics Neuroscan, Charlotte, NC). Electrode positions were arranged in accordance with the extended International 10–10 System. Continuous online EEG data were initially re-referenced to the averaged signals from left and right mastoid electrodes (M1 and M2), with the AFz electrode serving as the ground reference. The electrooculogram (EOG) activity was concurrently monitored using additional electrodes positioned above and below the left-eye orbit and outer canthus of each eye. To maintain optimal recording conditions, the impedance of electrodes was diligently kept below 10 kΩ throughout the entire EEG recording period. This rigorous approach ensured the reliability and accuracy of the recorded neuro-electric signals.

Procedure

Participants were required to conduct two experiments. The first served as the baseline measurement, and the second as the research intervention. The two experiments needed to be separated by at least 7 days to avoid the possible acute influence of fitness measurements on physiological and psychological variables.

For the baseline measurement, participants first completed an informed consent form. Then, they took the Digit Span Forward and Backward test (Ryan & Lopez, 2001) and filled out demographic questionnaires, which included the Physical Activity Readiness Questionnaire (PAR-Q) (American College of Sports Medicine, 2022) and the International Physical Activity Questionnaire (IPAQ) (Hagströmer et al., 2006). The Digit Span Forward and Backward test was employed to describe other variables that might influence cognitive performance (Ryan & Lopez, 2001). The PAR-Q was used following ACSM guidelines to ensure participants had no potential risk factors for performing a single bout of exercise

(American College of Sports Medicine, 2022). The IPAQ was used to check that participants did not have exercise habits defined as total physical activity under 150 minutes per week, following ACSM guidelines (American College of Sports Medicine, 2022; Hagströmer et al., 2006). Secondly, BMI, cardiorespiratory fitness, and 10-repetition maximum (10-RM) were assessed. Cardiorespiratory fitness was estimated using the submaximal YMCA Ergometer Test with a cycle ergometer (Corival cpet, Lode, Netherlands) (American College of Sports Medicine, 2022; Beekley et al., 2004). 10-RM was measured following National Strength and Conditioning Association guidelines (National Strength and Conditioning Association, 2016) for chest press, rowing, lat pull down, shoulder press, arm curl, leg extension, leg press, and leg curl with strength training machines (Cybex, Germany). These measurements were examined to ensure the baselines of participants were similar. Finally, all participants drew lots and were randomly assigned to three groups: group CE, AE, and reading control (RC).

For the intervention, participants first conducted a pre-test of the executive function test and concurrently collected EEG activity. Secondly, participants were instructed to perform the intervention. Finally, all participants completed a post-test of the executive function test and concurrently collected EEG activity.

Task-switching test

Task-switching test comprised six blocks, each containing 64 trials. In the initial block, participants were tasked with determining whether the stimulus (digits 1–9, excluding digit 5) within the solid-line square was greater or less than the digit 5 (AAAA…). In the second block, participants identified whether the stimulus within the dotted-line square was even or odd (BBBB…). Blocks 3–6 were characterized by an equal number of stimuli from the first and second blocks, forming an alternating-runs paradigm (AABBAA…). Mean Reaction Time (RT) for correct responses and accuracy (ACC) for the following conditions were then calculated to facilitate statistical analysis: (1) homogeneous condition (AAAA or BBBB); (2) heterogeneous condition (AABBAA…); (3) non-switch (AA or BB in the heterogeneous condition); and (4) switch (AB or BA in the heterogeneous condition).

Stroop test

Stroop test comprised four blocks, each containing 108 trials. Within these trials, three types were distinguished: neutral, congruent, and incongruent trials. The neutral trial featured a square print in red, green, and blue colors. The congruent trial presented Chinese language prints in the same colors, accompanied by corresponding words [i.e., 紅 (RED), 綠 (GREEN), or 藍 (BLUE)]. In contrast, the incongruent trial displayed Chinese language prints in different colors and words [e.g., 紅 (RED) print in blue color]. Each block included an equal distribution of 36 neutral trials, 36 congruent trials, and 36 incongruent trials. Participants received explicit instructions to respond to the color of the stimulus with both speed and accuracy. Mean response time (RT), considering only correct trials, and accuracy for each Stroop condition underwent subsequent analysis.

Exercise Intensity Measurement

An objective index of exercise intensity was heart rate (HR), measured using HR monitors (H10; Polar Electro Oy, Kempele, Finland), which were employed to gauge the exercise intensity manipulation. Participants wore an HR monitor throughout the cardiorespiratory fitness test and the intervention. Four HR indices were identified: pre-test (assessed before and after the pre-test of CF), resting (assessed after sitting quietly in a comfortable chair for 5 minutes before the intervention), intervention (assessed at 2-minute intervals during the intervention), and post-test (assessed before and after the post-test of CF).

Reference

American College of Sports Medicine. (2022). *ACSM's Guidelines for Exercise Testing and Prescription* (G. Liguori, Ed. 11th ed.). Wolters Kluwer. https://shop.lww.com/ACSM-s-Guidelines-for-Exercise-Testing-and-Prescription/p/9781975150181

Beekley, M. D., Brechue, W. F., deHoyos, D. V., Garzarella, L., Werber-Zion, G., & Pollock, M. L. (2004). Cross-validation of the YMCA submaximal cycle ergometer test to predict VO2max. *Research Quarterly for Exercise and Sport*, *75*(3), 337–342. https://doi.org/10.1080/02701367.2004.10609165

Hagströmer, M., Oja, P., & Sjöström, M. (2006). The International Physical Activity Questionnaire (IPAQ): A study of concurrent and construct validity. *Public Health Nutrition*, *9*(6), 755–762. https://doi.org/10.1079/phn2005898

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 and Exercise*, *22*, 286–293. https://doi.org/10.1016/j.psychsport.2015.09.004

National Strength and Conditioning Association. (2016). *Essentials of Strength Training and Conditioning* (G. G. Haff & N. T. Triplett, Eds. 4ed ed.). Human Kinetics. https://www.nsca.com/store/product-detail/INV/9781718210868/9781718210868

Ryan, J. J., & Lopez, S. J. (2001). Wechsler Adult Intelligence Scale-III. In W. I. Dorfman & M. Hersen (Eds.), *Understanding Psychological Assessment* (pp. 19–42). Springer US. https://doi.org/10.1007/978-1-4615-1185-4_2