ORIGINAL ARTICLE

Enhancing CPR Training through Aerobic Exercise

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ABSTRAK

Latihan aerobik dikenali dengan pelbagai faedah kesihatan, seperti peningkatan kecergasan kardiovaskular dan penurunan berat badan. Menariknya, satu sesi latihan aerobik akut telah terbukti dalam meningkatkan pembelajaran dan fungsi kognitif. Walau bagaimanapun, hubungan antara latihan aerobik secara akut dan resusitasi kardiopulmonari praktikal (CPR) masih belum ditetapkan. Kajian ini bertujuan untuk mengkaji kesan latihan aerobik akut terhadap pembelajaran pengetahuan dan kemahiran CPR serta kesannya terhadap aras faktor neurotropik yang diperolehi dari otak (BDNF). Sejumlah 50 peserta (umur purata: 30.96 ± 4.33 tahun) telah dipilih secara rawak dan dibahagikan kepada kumpulan latihan atau kumpulan kawalan. Kumpulan latihan menjalankan larian pada sawat injak selama 30 minit pada intensiti sederhana, manakala kumpulan kawalan kekal berehat tanpa melakukan sebarang aktiviti fizikal. Pengetahuan dan penguasaan kemahiran CPR dinilai sebelum dan selepas intervensi. Hasil kajian menunjukkan perbezaan yang signifikan dalam semua parameter di antara kumpulan latihan dan kumpulan kawalan selepas intervensi, disertai dengan peningkatan yang ketara dalam aras faktor BDNF serum (P < 0.05). Penemuan ini menunjukkan bahawa senaman aerobik akut dapat meningkatkan pembelajaran CPR, mungkin melalui mekanisme neurobiologi yang dimediasi oleh BDNF. Penyelidikan ini memberikan gambaran berharga tentang kesan senaman terhadap kognitif, yang seterusnya mempunyai implikasi untuk program pembelajaran CPR bagi mengoptimumkan hasil pembelajaran CPR.

Kata kunci: Bantuan penyelamatan kardiorespiratori; fungsi kognitif; fungsi pembelajaran; senaman aerobik

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ABSTRACT

Aerobic exercise is known for its many health benefits, such as improved cardiovascular fitness and weight loss. Interestingly, acute aerobic exercise has been shown to improve learning and cognitive function. However, the relationship between acute aerobic exercise and learning practical cardiorespiratory resuscitation (CPR) has not yet been established. The aim of this study was to investigate the effect of acute moderate-intensity aerobic exercise on the learning of CPR knowledge and skills and the effects on the concentration of brain-derived neurotrophic factor (BDNF). A total of 50 participants (mean age: 30.96 $\pm$ 4.33 years) were randomly assigned to either the exercise or control group. The exercise group completed a 30-minute run on the treadmill at moderate intensity, while the control group rested without any physical activity. Knowledge and acquisition of CPR skills were assessed before and after the intervention. The results revealed a significant difference between the exercise group and the control group immediately post-intervention, accompanied by a notable increase in serum BDNF levels ($P < 0.05$). The findings suggest that acute aerobic exercise can improve CPR learning, possibly through BDNF-mediated neurobiological mechanisms. This research contributes valuable insight into the effects of exercise on cognition, which in turn has implications for CPR learning programmes to optimise the learning outcome of CPR.

Keywords: Aerobic exercise; cardiorespiratory resuscitation; learning function

INTRODUCTION

It is well-known that aerobic exercise has numerous health benefits, including improving cardiovascular fitness and reducing body weight. There are different types of exercise including aerobic, flexibility and resistance exercise. Aerobic exercise includes activities such as running, swimming, cycling and aerobic dance. It is characterised by continuous and rhythmic movements that increase heart rate and oxygen consumption (Koman et al. 2024). Flexibility exercises focus on improving the range of motion of muscles and joints through activities such as stretching and yoga (Garg et al. 2024). Resistance training aims to increase muscle strength and overall physical performance. It includes activities such as weightlifting and bodyweight exercises such as push-ups and squats (Copeland et al. 2019).

Acute aerobic exercise refers to a single session of aerobic exercise. This study focuses on moderate-intensity exercise, defined as activities that increase the heart rate to 40-59% of maximum heart rate (Riebe et al. 2017). In this study, moderate intensity acute aerobic exercise was chosen due to previous studies have shown that moderate-intensity exercise is an optimal intensity for improving cognitive function (reference). A systematic review study has also shown that a single bout of aerobic exercise can improve memory and learning (Blomstrand & Engvall 2021).

A cognitive–energy model suggests that exercise improves mental resources by increasing physiological arousal (Loras et al. 2020). It has been speculated that the relationship between exercise intensity and cognitive performance is not linear but rather follows an inverted U-curve, with too little or too much exercise leading to decreased cognitive performance (Chang et al. 2012; Lambourne et al. 2010). Apart from this, a study by Moriarty et al. (2019) concluded that acute aerobic exercise can improve cognitive function by increasing blood flow to the brain. The increased blood flow improves the supply of oxygen and nutrients to the brain, which improves cognitive performance. Moreover, acute aerobic exercise promotes the growth and survival of new brain cells by stimulating brain-derived neurotrophic factor (BDNF) (Hwang et al. 2016).

Acute aerobic exercise has been shown to increase BDNF levels and improve cognitive performance (Hwang et al. 2016; Rentería et al. 2019; Schmolesky et al. 2013). BDNF is a neurotrophin factor that essential for the development, and survival of neurons, the basic units of the nervous system. BDNF works by promoting the development of new neurons and synapses, the connections between neurons (Gliwińska et al. 2023). The brain can remodel itself in response to experience and learning through process called neuroplasticity, which supports cognitive processes such as memory and learning. Exercise has been shown to increase BDNF levels and improve cognitive performance as well as support general brain health (Koyya et al. 2024)

Several studies have demonstrated that acute aerobic exercise can enhance cognitive performance, including learning, memory, and motor skills (Loprinzi et al. 2021; Loprinzi et al. 2023; Perini et al. 2016). Additionally, acute aerobic exercise has been found to improve pre-frontal dependent cognitive performance and increase BDNF levels (Hwang et al. 2016). However, the relationship between acute aerobic exercise and BDNF levels is still unclear, as some studies have shown no changes in BDNF following exercise (Arrieta et al. 2020; Baird et al. 2018).

Cardiopulmonary resuscitation (CPR) is a life-saving technique that can be performed by anyone. The technique involves chest compressions and rescues breaths to maintain blood and oxygen flow to the brain and other vital organs until medical help arrives. In Malaysia, cardiac arrest is the leading cause of death for all major ethic groups (Department of Statistics Malaysia 2023). Although bystander CPR is a life-saving intervention for cardiac arrest, the rate of bystander CPR in Malaysia is still low (Yasin et al. 2021). This is all the more worrying as knowledge of CPR is also considered low among Malaysians (Karuthan et al. 2019). CPR can increase a person's chances of survival if performed early (Song et al. 2018). The low number of bystander CPR in Malaysia and the low knowledge of CPR among Malaysians make it essential for the public to learn CPR.

CPR learning involves various cognitive aspects, including learning, memory, and motor learning. Since acute aerobic exercise has been shown to improve memory and learning ability, it may be plausible that acute aerobic exercise could be beneficial to CPR learning. For this reason, our centre has introduced a 'Fit-CPR programme' in which a single training session (running for several kilometres) is combined with CPR learning. It usually involves large crowds (more than 100 participants). Before the run, they were taught the knowledge and skills of CPR. After completing the run, they were tested on their CPR knowledge and skills. The fit-CPR module itself was conducted in Malay and specifically formulated for the Malaysian population. According to a previous study, the fit-CPR approach showed significant improvement from baseline to CPR retention (Sanip et al. 2023). This CPR module was easy to remember because it is written in Malay language and is concise and time efficient.

Although there is growing evidence that acute aerobic exercise can improve memory and learning ability, to the our knowledge, there is no study investigating the effect of acute aerobic exercise specifically on CPR learning and its' mechanism. Therefore, the main objective of this study was to determine the effects of moderate intensity acute aerobic exercise on CPR learning which consisted of both CPR knowledge and skills. This study focused on acute aerobic exercise as it was relevant to the specific design of the "Fit-CPR programme" that included CPR learning and running as a key component. Given the potential role of BDNF as a mechanism underlying the positive effect of acute aerobic exercise on cognition, this study also investigated the effect of acute aerobic exercise on BDNF levels.

MATERIALS AND METHODS

Study Design and Subjects' Recruitment

This study was conducted at the Faculty of Medicine, Universiti Kebangsaan Malaysia (UKM) (Cheras, Malaysia) following approval from the Research Ethics Committee UKM (FF-2019-547). A total of 50 participants (25 females; 25 males) were recruited through advertisements. The sample size was calculated using PS calculator (Version 3.1.9.4, Germany). It was estimated based on previous study testing the effect of strength training on the quality of chest compression during CPR (Abelairas-gómez et al. 2017). A sample size of 22 participants per group was sufficient to achieve a mean improvement of 47.8 mm and standard deviation of 4.6 mm in chest compression. However, considering 10% of dropout rate, we had recruited 50 participants. Outcome measures were collected at time point 1 (T1) as baseline and time point 2 (T2) as post-intervention testing.

Procedures

On the first visit, the participants' eligibility was evaluated. Men and women between the ages of 18 and 40 were eligible to participate, provided they had no physical limitations or reasons for not exercising. The minimum level of education for subjects in this study was the Malaysian Certificate of Education (SPM), while the maximum level of education was a Bachelor's degree.

Participants were excluded from participation if they met one or more of the following criteria, i.e. (i) had previously completed CPR training one year ago; (ii) had a past or present history of cardiovascular disease, a psychiatric or neurological disorder, a chronic medical condition; and (iii) were currently taking medication that would prevent them to perform moderate intensity exercise, and/or were pregnant. All participants were asked to complete a Physical Activity Readiness Questionnaire (PAR-Q). It served as a screening tool to ensure the safety of the participants during the exercise conditions. Before participating in the study, anyone who answered "No" to any question on the PAR-Q was required to provide a medical clearance from their doctor (Shephard et al. 2014). Participant demographics and physical activity levels were collected using the International Physical Activity Questionnaire (IPAQ), which included information on days, house and intensity of sports/exercise per week. Only participants who had a low level of physical activity were included in this study. We recruited participants with low levels of physical activity for this study because we knew that fitness level may be one of the confounding factors for the effects of acute aerobic exercise on cognitive function (Li et al. 2019).

On the second visit, eligible subjects provided informed written consent before participating in this study. Subjects needed to sign the consent form with the attached study information, including their ID number. Available staff witnessed and signed the form. All subjects were required to fast for two hours and to refrain from consumption of caffeine for 12 hours before testing.

The participants were then equipped with polar heart rate monitors and lay down on the couch for five minutes to measure their resting heart rate. Blood was drawn from antecubital vein to measure the baseline of BDNF levels. They then completed a CPR pretest with an 11-item multiple-choice questionnaire in Malay language (Supplementary 1). The pretest was used to determine the baseline level of CPR knowledge. The same test was used to assess the increase in knowledge during the post-intervention procedure. The same questions were asked, but in a different order to counteract the advantages of order remembering. To test CPR skills abilities, participants were instructed to perform CPR steps on a mannequin. Assessment was done by the CPR instructor using the CPR skills checklist, which was also written in Malay language (Supplementary 2).

The pre-test assessment was followed by CPR training conducted by a licensed basic life support (BLS) instructor from the Emergency Department, Hospital Canselor Tuanku Muhriz (HCTM), Kuala Lumpur. During this training, the participants acquired knowledge and psychomotor skills related to hands-only CPR. CPR was practiced on standard mannequins and the correct depth of chest compressions was assessed based on the sound made by mannequin. After the training session, the participants were randomly divided into an exercise and non-exercise control group using simple randomisation. Group allocation was concealed from the CPR examiner. Participants in the exercise group walked on a treadmill for 30 minutes, including a 5-minutes warm-up and 5-minutes cool-down. The control group remained at rest and did not perform any physical activity. The speed of the treadmill was gradually increased while the heart rate and level of perceived exertion (RPE) were recorded every minute until they reached the target heart rate and a minimum rating of RPE is 13 on Borg's RPE. Exercise intensity was then monitored at five-minute intervals during the aerobic exercise intervention using Borg's RPE scale and target heart rate (Borg 1982). The speed was adjusted so that the intensity was within the range of a moderate intensity exercise.

In this study, a moderate exercise intensity was chosen as there was evidence that moderate intensity exercise improved cognitive performance (Ando et al. 2020; Chang et al. 2012; McMorris 2021). Although the research findings are mixed, researchers have generally concluded that there is a small positive effect. The purpose of this meta-analysis was to provide an updated comprehensive analysis of the extant literature on acute exercise and cognitive performance and to explore the effects of moderators that have implications for mechanisms of the effects. Searches of electronic databases and examinations of reference lists from relevant studies resulted in 79 studies meeting inclusion criteria. Consistent with past findings, analyses indicated that the overall effect was positive and small (g=0.097 n=1034 while high intensity exercise leads to dehydration and can impair cognitive performance (Cian et al. 2001; Tomporowski 2003). For this reason, water was also provided during the entire session and the exercise intensity remained moderate.

Subsequently, RPE and heart rate were accessed every 5 minutes for the remainder of the exercise duration, with the speed level adjusted to keep RPE between 13 and 15 and within the target heart rate range. When participants entered a 5-minute cool-down phase, the speed was gradually reduced to the original speed.

Finally, blood samples were taken from the participants after the intervention. They had to perform the CPR steps again and were assessed by the CPR instructor. Participants then completed the CPR knowledge questionnaire, which had the same content as the pre-test. The exercise and CPR training were carried out on the same day in a controlled laboratory environment. An overview of the experimental procedure was presented in Figure 1.

BDNF Measurement

Blood samples for the BDNF serum analysis were taken twice, before and after

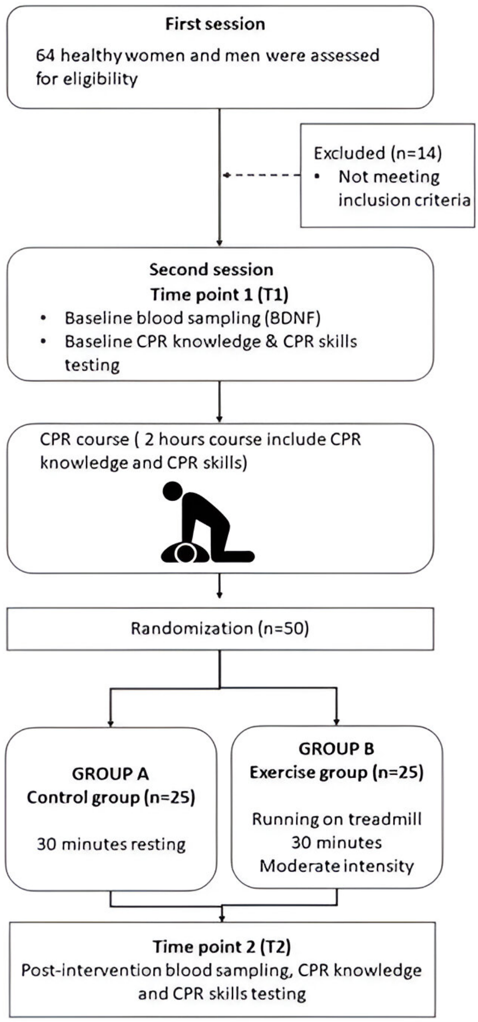

FIGURE 1: Overview of the experimental procedure

the intervention. The pre and post-exercise blood samples were taken at the same time, which was 8.00 am for pre-intervention and 11.00 am for post-intervention. Both pre and post-intervention, venous blood was drawn from the median antecubital vein or adjacent veins by a certified phlebotomist. Control subjects underwent the same procedure but were at rest during the intervention while subjects running on the treadmill. All blood samples were allowed to coagulate at room temperature before being centrifuged at 3000 rpm for 15 minutes at 4°C. Upon supernatant extraction, serum was immediately frozen at -80°C. For the quantification of serum BDNF concentrations, samples were analysed in duplicate using the Elabscience® Human BDNF ELISA Kit following the manufacturer's instructions.

Statistical Analysis

All statistical analysis was conducted using SPSS software, version 23 (SPSS, Chica-go, IL, USA). Normality distribution was determined using Shapiro-Wilk test. Descriptive statistics indicated using means with standard deviations (SD) for variables that followed a normal distribution, while the medians with inter-quartile range (IQR) were used for non-normal distributed date. Independent sample t-test and Mann-Whitney U tests were implemented to compare data between groups, depending on whether analysis was performed on parametric or non-parametric data, while Wilcoxon signed-rank test was implemented to compare data within group. Statistical significance was defined as a *P*-value less than 0.05.

RESULTS

The descriptive characteristics of the study population were shown in Table 1. The mean age for exercise and control group were 30.96 $\pm$ 4.33 and 31.28 $\pm$ 5.68, respectively. Both groups showed a majority of female participants, with 16 (64%) female and 9 (36%) male in the exercise group and 17 (68%) female and 8 (32%) male participants in the control group. This difference, however, was not statistically significant (P=0.765). The majority of the participants were degree holders and Malay ethnicity. The median body mass index (BMI) of the exercise group was 24.40 (3) and the median BMI of the control group was 24.60 (2). The median physical activity for the exercise group was 512 (38) MET-min/week while the median physical activity for the control group was 516 (64) MET-min/week. The statistical analysis showed that all baseline characteristics did not differ significantly between the two groups.

Prior to CPR training, the CPR knowledge, CPR skills and BDNF concentration of the exercise and control groups were assessed using the Mann-Whitney U test. As shown in Table 2, there were no significant differences between the groups in baseline measurements of CPR knowledge, CPR skills or BDNF (P<0.05). This suggested that both groups had similar CPR knowledge, CPR skills and BDNF levels prior to the intervention.

Post-intervention CPR Knowledge and CPR Skills Scores

The Mann-Whitney U test was used to compare the exercise and control groups in terms of post-intervention CPR knowledge

TABLE 1: Descriptive characteristics for exercise and control group

	Exercise group (n=25)	Control group (n=25)	p-value
Age, years (mean ± SD)	30.96 ± 4.33	31.28 ± 5.68	0.824[a]
Gender, n (%)	9 (36.0)	8 (32.0)	
Male	16 (64.0)	17 (68.0)	0.765[b]
Female			
Education level, n (%)	4 (16.0)	3 (12.0)	
Secondary Certificate	6 (24.0)	6 (24.0)	0.916[b]
Diploma	15 (60.0)	16 (64)	
Bachelor			
Ethnicity, n (%)	23 (92.0)	25 (100.0)	
Malay	2 (8.0)	0 (0.0)	0.149[b]
Non-Malay			
Body mass index (BMI)	24.40	24.60	
Median	3	2	0.793[c]
IQR			
IPAQ score (MET minutes/week)	512.00	516.00	
Median	38	64	0.321[c]
IQR			

SD: standard deviation; IQR: Inter-Quartile range; [a] Independent sample t-test; [b] Pearson's chi-square test; [c]Mann-Whitney U test

TABLE 2: Pre-test scores in CPR knowledge, CPR skills, and BDNF levels for exercise and control groups

	Groups	n	Median (IQR)	p-Value
CPR knowledge	Exercise	25	5.00 (2.00)	0.546
	Control	25	5.00 (3.00)	
CPR skills	Exercise	25	1.00(0)	0.085
	Control	25	1.00(0)	
BDNF (ng/ml)	Exercise	25	22.73 (41.60)	0.290
	Control	25	31.17 (48.67)	

Data were analysed using Mann-Whitney U test, and are presented as median (IQR). Note statistical significance *P<0.05.

and CPR skill scores. As shown in Table 3, there were significant differences between the exercise and control groups after the intervention in both CPR knowledge and CPR skills ($P < 0.05$). Both groups showed an improvement in CPR knowledge and CPR skills after learning, but, the exercise group performed better than the control group. CPR knowledge scores increased more in exercise group [from T1, 5.00 (2.00) to T2, 10.00 (2.00)], than in the control group [from T1, 5.00 (3.00) to T2, 9.00 (2.00)]. Similarly, CPR skills scores were higher after intervention in the exercise group [from T1, 1.00 (0) to T2, 9.00(1.00)], compared to the control group [from T1, 1.00 (0) to T2, 8.00 (2.00)].

Post-intervention BDNF levels

A Mann-Whitney U test was performed to compare the BDNF levels after the

TABLE 3: Post-test scores in CPR knowledge, CPR skills, and BDNF levels for exercise and control group

	Groups	n	Median (IQR)	p-Value
CPR knowledge	Exercise Control	25 25	10.00 (2.00) 9.00 (2.00)	*0.001
CPR skills	Exercise Control	25 25	9.00 (1.00) 8.00 (2.00)	*0.011
BDNF (ng/ml)	Exercise Control	25 25	32.13 (74.93) 21.72 (28.63)	*0.041

Data were analysed using Mann-Whitney U test, and are presented as median (IQR). Note statistical significance *P<0.05.

intervention between exercise group and control group. As presented in Table 3, there was a significant difference between the exercise and the control group in BDNF after intervention (T2), with $P < 0.05$. In exercise group, BDNF concentration increased [from T1, 22.73 (41.60) ng/ml to T2, 32.13 (74.93) ng/ml , $P < 0.05$]. While in control group, BDNF concentration was decreased [from T1, 31.17 (48.67) ng/ml to T2, 21.72 (28.63) ng/ml, $P < 0.05$].

DISCUSSION

This study examined the changes in CPR knowledge, CPR skills, and BDNF levels in response to a single bout of moderate intensity aerobic exercise in healthy individuals. Our findings revealed that acute moderate aerobic exercise improved cognitive function, as evidenced by the improvements in both CPR knowledge and CPR skills. Specifically, a single bout of moderate intensity aerobic exercise can improve the basic learning process of CPR, which requires cognitive skills such as learning, memory, and motor skills. This is reflected in higher improvement in both CPR knowledge and CPR skills scores in the exercise group compared to the control group (non-exercise group). In line with our findings, previous studies have reported that acute aerobic exercise has positive effects on both learning and memory processes (Perini et al. 2016; Wang et al. 2020). However, Hacker et al. (2020) reported no significant changes in memory in response to acute aerobic exercise. The discrepancy in changes in memory performance following acute aerobic exercise may be due to heterogeneity in the duration of exercise, which plays an important role in the relationship between exercise and cognition. Previous studies found that longer duration of exercise (>35 minutes) has a detrimental effect on memory function (Audiffren et al. 2009; Hacker et al. 2020; Lambourne et al. 2010). Continuous exercise leads to fatigue, which can result in decline in cognitive performance (Chang et al. 2015; Wang et al. 2013).

The present study also revealed some deviations from the previous literature. In this study, acute aerobic exercise was performed after the learning task, in contrast to most previous studies in which acute aerobic exercise was performed before or during learning (Labban & Etnier 2011; Schmidt-Kassow et al. 2014; Winter et al. 2007). Therefore, this study can investigate the effect of acute aerobic exercise during the early stages of memory consolidation. The findings of this study suggest that acute aerobic exercise, even when implemented post-learning, may contribute to the growing body of evidence suggesting that it can improve cognitive function.

The results of this study show a remarkable influence of acute aerobic training on the motor components of CPR learning. Participants in the exercise group performed better on CPR skills than the control group, suggesting a positive correlation between acute aerobic training and motor skill learning. These results are consistent with previous research emphasising the potential relationship between acute aerobic exercise and motor skill learning (Mang et al. 2014; Roig et al. 2012).

The mechanisms underlying the effects of acute aerobic exercise on CPR learning are not fully understood. Learning CPR requires a combination of cognitive and motor abilities. Several mechanisms potentially explain how acute aerobic exercise could improve CPR knowledge and skills through learning. Acute aerobic exercise causes changes in the brain, molecular, and behavioural levels (El-Sayes et al. 2019). At the brain level, acute aerobic exercise improves cerebral blood flow which could help neurons receive more oxygen and nutrients hence improving neuronal activity (Ludyga et al. 2022). This is also supported by functional neuroimaging techniques such as functional magnetic resonance imaging (fMRI) and electroencephalography (EEG). A recent systematic review study highlighted the findings of neuroimaging techniques following acute aerobic exercise. The study reported increased activation in various brain regions, particularly the frontal lobe, associated with cognitive improvements in response to exercise (Herold et al. 2020). The frontal lobe is an important brain region associated with cognitive skills, including memory (Firat 2019). Increased neural activation in this area suggests a potential mechanism by which acute aerobic exercise influences cognitive processing.

In the present study, the BDNF levels increased in the exercise group, while it decreased in the control group. The changes in BDNF levels seen in the control group could be due to the effect of morning fasting. Previous studies in humans have shown that serum BDNF levels increase after fasting (Abdolhossein et al. 2017). In this study, both groups were asked to fast before the first blood sample was taken. It is possible that subjects in the control group had lower BDNF levels after the intervention (rest) due to the BDNF levels had increased during fasting, and BDNF levels returned to pre-fasting levels after meals and intervention. In contrast, the increased in BDNF levels in the exercise group could be due to the aerobic exercise itself.

The increase in BDNF in this study could improve memory performance and is consistent with the study by Kuhne et al. (2021), which revealed an acute increase in BDNF levels induced by aerobic exercise in healthy young adults. Significant upregulation of BDNF following acute aerobic exercise is a possible mechanism underlying the observed improvements in CPR learning. Previous studies have shown that acute exercise increases peripheral BDNF in healthy adults, which may be related to better memory performance (Ferris et al. 2007; Griffin et al. 2011; Kuhne et al. 2021). BDNF is a neurotrophin that plays an important role in the growth, survival, and neuron plasticity. It enhances the growth and survival of neurons by binding to tropomyosin receptor kinase B (TrkB) receptors on neurons. Activation of TrkB receptors triggers a cascade of signaling events, hence promoting the growth and survival of neurons (Bathina & Das 2015; Li et al. 2023). BDNF also promotes synaptogenesis, which is a process of creating new connections between neurons (Leschik et al. 2022). At the molecular level, acute aerobic exercise increases BDNF levels, which play a role in learning and memory. It enables the brain to acquire new information and memories and adapt to new environments. Lastly, it reflected on behavioural changes, which may lead to improvements in motor and cognitive performance (El-Sayes et al. 2019; Miranda et al. 2019).

In addition to BDNF, several other neurotrophic factors could potentially contribute to the findings in this study. These include Insulin-Like Growth Factor 1 (IGF-1) and Vascular Endothelial Growth Factor (VEGF). IGF-1 has been shown to support neurogenesis and synaptic plasticity. It is known to increase in response to exercise and can improve cognitive function and learning abilities. VEGF is involved in angiogenesis and has neuroprotective effects. It supports the formation of new blood vessels in the brain, enhancing oxygen and nutrient supply, which can improve cognitive function and learning.

To the best of our knowledge, this is the first study investigating the relationship between acute aerobic exercise and CPR learning and the findings are novel in that they mark the first time that acute aerobic exercise could enhance CPR learning among healthy young adults' Malaysian population. This is also a novel study to show that a single bout of moderate intensity aerobic exercise increases peripheral BDNF in the Malaysian population and it might linked with the improvement in CPR learning.

Despite the positive results, it is important to recognise some limitations. One of the limitations of our study is the assessment of CPR skills, which was based on a checklist and evaluated by a CPR trainer. This method has the potential for human error. However, a qualified CPR trainer assessed participants' CPR skills, and the audible clicking sound of the manikin confirmed the correct depth of CPR chest compressions. Future research could utilise manikins equipped with instruments that can be more accurately test CPR performance to improve the accuracy of CPR skill assessment. This study design also provides insight into the immediate effects of acute aerobic exercise on CPR learning. However, the long-term effects and sustainability of improved CPR knowledge and skills remain unknown. Longitudinal studies with longer follow-up periods may be helpful to determine participants' long-term recall of the knowledge and skills learnt during CPR training. Third, this study did not investigate how acute aerobic training improves CPR learning. Future studies can investigate the mechanisms using imaging techniques such as functional MRI to measure brain activity before and after training. Finally, future studies could investigate the effect of acute aerobic exercise in different populations such as children and older adults.

CONCLUSION

In conclusion, this study has shown that moderate acute aerobic training integrated into the fit-CPR module improves CPR learning in terms of knowledge and skills. The BNDF values induced by the training can improve the learning of CPR. This is particularly important for laypersons who need to learn CPR in a short time. We found a significant correlation between moderate-intensity acute aerobic exercise and the short-term learning effect of CPR training. These results suggest that CPR training can be organised in a more entertaining way, such as the CPR Fun Run, which consists of physical activity and CPR training. However, for the future, it is necessary to conduct a similar study focusing on the retention of CPR knowledge and skills, which could improve the effectiveness of CPR training.

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SUPPLEMENTARY 1: CPR Knowledge

CPR knowledge was assessed using a questionnaire. Questionnaire were prepared and validated by a group of experts in the field of Emergency Medicine. The questionnaire were specifically prepared in Malay to suit the module of CPR teaching (Fit-CPR module) for our local population. There were two sections in the questionnaire:

A: Demographic data
B: Knowledge of CPR

In section A, demographic characteristics included age, gender and ethnicity. Additional questions were asked on the participants' highest completed education level.

In section B, the participants were tested on their knowledge of CPR. This section included questions such as "Where is the right location to perform chest compression?" and "What are the sequence to perform CPR?". In total, this section had 11 questions. This questionnaire used Likert score. For each question, a score of 1 was given to the correct answer, while incorrect and "do not know" responses were given 0 point. Thus, the total knowledge score could potentially range between 0 and 11 points. The Cronbach's   for the 11 items of CPR knowledge was 0.80.

SOALAN PENGETAHUAN CPR

NAMA :
SEBELUM BELAJAR/SELEPAS BELAJAR

1. Mangsa yang tidak bernafas setelah lemas di dalam kolam renang memerlukan bantuan resusitasi kardiopulmonari (CPR).
   A. Ya
   B. Tidak
   C. Tidak pasti

Anda berhadapan dengan situasi di mana secara tiba-tiba seseorang jatuh dan tidak sedarkan diri di hadapan anda.

Soalan 2 dan 3 berdasarkan situasi di atas
2. Tindakan pertama yang perlu anda lakukan adalah memastikan anda dan mangsa dalam persekitaran yang selamat.
   a. Ya
   b. Tidak
   c. Tidak pasti

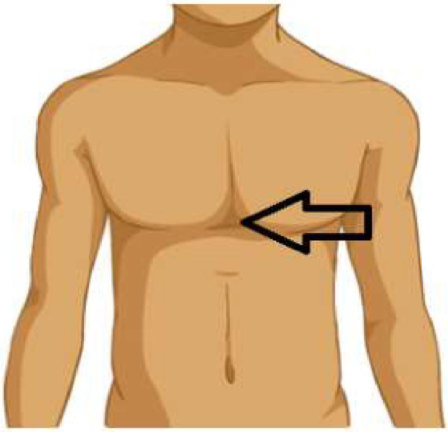
3. Sebelum meminta pertolongan, anda perlu memeriksa respon mangsa terlebih dahulu.
   a. Ya
   b. Tidak
   c. Tidak pasti

4. 999 adalah nombor talian kecemasan di Malaysia.
   a. Ya
   b. Tidak
   c. Tidak pasti

5. Tujuan anda menepuk bahu dan memanggil mangsa yang tidak sedarkan diri adalah untuk memeriksa respon mangsa.
   a. Ya
   b. Tidak
   c. Tidak pasti

6. Turutan langkah yang betul dalam memberikan bantuan CPR ialah menelefon talian kecemasan dan kemudian melakukan tekanan dada.
   a. Ya
   b. Tidak
   c. Tidak pasti

7. Anak panah di bawah menunjukkan lokasi yang betul bagi tekanan dada pada mangsa yang memerlukan CPR.



   a. Ya
   b. Tidak
   c. Tidak pasti

8. Kadar tekanan dada bagi setiap minit yang disarankan ialah sekurang-kurangnya 100 tekanan dalam masa satu minit.
   a. Ya
   b. Tidak
   c. Tidak pasti

9. Untuk menghasilkan CPR yang berkesan, tekanan pada bahagian dada perlu dilakukan sekurang-kurangnya sedalam 2 inci
   a. Ya
   b. Tidak
   c. Tidak pasti

10. CPR boleh diberhentikan sekiranya anda sudah terlalu penat untuk melakukan CPR.
   a. Ya
   b. Tidak
   c. Tidak pasti

11. CPR boleh diberhentikan sekiranya keadaan persekitaran menjadi tidak selamat.
   a. Ya
   b. Tidak
   c. Tidak pasti

SUPPLEMENTARY 2: CPR skills

CPR performance was assessed using an Objective Structured Clinical Examination (OSCE) checklist on basic CPR performance which has been used in the previous study (Amirudin et al. 2023). Examiners assessed the participants' performance in terms of the adequacy of administering the hands-only CPR sequence. The maximum score on the examiner-rated practical test was 10. High quality CPR involves a push-hard (100-120 compressions per minute), push-hard (at least 2-inch depth or a click sound on a mannequin), and allows full chest recoil with minimum interruption of chest compression. As hands-only CPR is recommended nowadays, ventilation was not performed and thus was not assessed in this study.

Reference:

Amirudin, S., H., I. M., Abd Samat Azlan, H., Jaafar, M. J., Meilya, S., & Saiboon, I. M. (2023). Fit-cardiopulmonary resuscitation approach in public mass cardiopulmonary resuscitation teaching. 44(5), 463-470. https://doi.org/10.15537/smj.2023.44.5.20220941

Senarai Semak Kemahiran CPR
PENILAIAN KEMAHIRAN CPR

Nama:
IC:
Kumpulan : Senaman / kawalan
Masa penilaian : Sebelum belajar / Selepas belajar

	Item penilaian	Markah peruntukan	Markah peserta
1	**Tengok** sekeliling. Pastikan persekitaran selamat	1	
2	**Tegur** mangsa. Tepuk bahu, tangan atau kaki	1	
3	**Teriak/telefon 999**, markah 1 diberikan sekiranya nombor telefon salah	2	
4	**Teliti.** Teliti dada mangsa selama 5-10 saat, untuk memastikan mangsa masih bernafas atau tidak	1	
5	**Tekan.** Kedudukan tangan yang betul (bahagian tengah dada di atas tulang sternum/dada)	1	
	a. **Tekan kuat** sekurang kurangnya 2 inci atau ada bunyi klik pada manikin	1	
	b. **Tekan cepat** (100 – 120 kali/minit) sekurang-kurangnya 30 tekanan di antara 15 hingga 18 saat.	1	
	c. Membenarkan **chest recoil** yang mencukupi.	1	
6	Terus menekan dada selama 2 minit dengan **gangguan yang minima** (tidak lebih dari 10 saat)	1	
	MARKAH KESELURUHAN	**/10**	