The effect of exercise on vascular function in adolescents

Dr Sascha Kranen discusses how both chronic and acute exercise can improve vascular function in an adolescent population.

Introduction

Cardiovascular diseases (CVD) are the leading cause of non-communicable deaths worldwide. According to the British Heart Foundation, ~28% of all deaths recorded in the UK in 2017 were attributable to CVD. However, the overall burden of CVD is not only reflected in the number of deaths but also in the diminished quality of life and both direct and indirect costs of medical treatment. As a precursor to overt CVD, atherosclerosis is a progressive disease that originates in youth with atherosclerotic lesions already apparent in the first decades of life (Stary, 1989). Therefore, childhood and adolescence are the ideal time to implement preventative measures.

The initial stage in the pathophysiology of atherosclerosis is endothelial dysfunction and vascular endothelial function has been identified as 'novel' risk factor for CVD. Vascular function can be assessed non-invasively using flow-mediated dilation (FMD). This technique is popular and frequently used mainly due to its ease and non-invasive nature. Typically, FMD is assessed in the brachial artery using high-resolution ultrasound (see Figure 1). Baseline arterial diameter is measured followed by a 5 min ischaemic stimulus, caused by inflation of a pneumatic cuff distal to the brachial artery, and the measurement of peak post-occlusion diameter thereafter. FMD is then calculated as the difference between baseline and peak arterial diameter and expressed as percentage of the baseline diameter with higher values representing better vascular function (Thijssen *et al.*, 2019).

Previous research has shown that exercise improves vascular function (Thijssen *et al.*, 2010). However, children and adolescents fail to meet the recommended daily physical activity (PA) levels and numerous studies have stated that previous efforts to increase PA levels in youth have been unsuccessful. The development of effective strategies including smaller volumes of exercise to boost cardiovascular health is an important approach in this context. High-intensity interval exercise (HIIE) may be a valuable tool for CVD health promotion as it has been shown to be both effective and enjoyable in youth. Therefore, this article provides insight into chronic and acute HIIE and their respective effect on vascular function in adolescents.

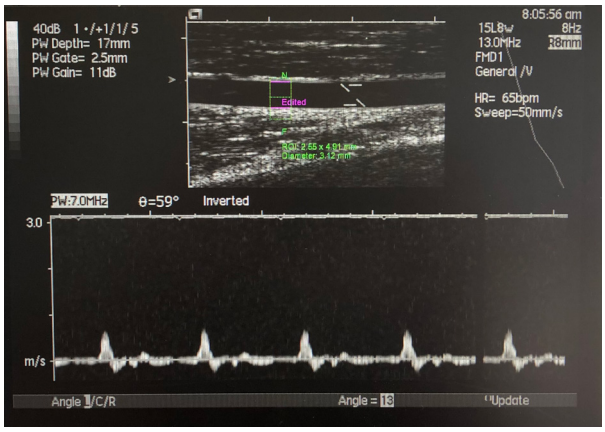

Figure 1. Ultrasound image of the brachial artery and continuous Doppler velocity.

Chronic exercise

Systematic reviews and meta-analyses have shown that high-intensity interval training (HIIT) represents an effective method to improve cardiometabolic health in adolescents. However, the literature is sparse with research on the effect of HIIT on vascular function in healthy adolescents. Following on from the study by Bond *et al.* (2015a) showing that two weeks of HIIT improved novel CVD risk factors in the absence of changes in traditional risk in adolescents, we aimed to investigate the effect of four weeks of HIIT followed by two weeks of detraining on vascular function and traditional CVD risk factors in adolescent boys (Kranen *et al.*, 2023). For this, nineteen male adolescents (13 ± 1 y) were recruited and randomly allocated to either a training (TRAIN, n = 10) or control (CON, n = 9) group. Participants in TRAIN completed four weeks of HIIT running with three sessions per week (Monday, Wednesday, Friday) in their school's sports hall before the first lesson. In weeks 1 and 2, participants completed 8 x 1 min running intervals, in week 3 10 x 1 min running intervals and in week 4 12 x 1 min running intervals, all performed at 90% of their maximal aerobic speed and interspersed with 75 s of passive rest. Vascular function (FMD and peak reactive hyperaemia (PRH)), body composition (fat mass, fat free mass, body fat percentage) and blood biomarkers (glucose, insulin, total cholesterol, high- and low-density lipoprotein, triacylglycerol) were assessed before, 48 h after and two weeks after the intervention for TRAIN and at equivalent time points for CON. All participants in TRAIN completed 100% of all the training sessions with no side effects. Analyses revealed that following HIIT, FMD was significantly greater in TRAIN compared to CON, but this difference was lost two weeks after training cessation. No measurable differences were detected between groups for any of the other outcomes. To conclude, a four-week HIIT intervention improved macrovascular function in healthy adolescent males, however, this training period did not measurably change microvascular function, body composition or blood biomarkers. The inversion of the FMD improvement two weeks after the training emphasizes the importance of the continuation of regular exercise for the primary prevention of cardiovascular disease.

Acute exercise

As training represents the accumulation of single bouts of acute exercise, it is important to also understand what happens to vascular function following an acute exercise bout. Previous research (Bond *et al.*, 2015b) has shown that FMD increases after an acute bout of high-intensity interval exercise whereas FMD remained unchanged following a work-matched bout of moderate-intensity continuous exercise in adolescents, suggesting the existence of an exercise intensity effect. However, the exercise bouts were delivered in interval and continuous form, respectively, and thereby prohibit the direct comparison of intensities.

Another topical issue regarding vascular health is the consumption of sugar-sweetened beverages among adolescents as a source of postprandial hyperglycaemia. It was recently demonstrated that vascular function is impaired following acute hyperglycaemia in both healthy and cardiometabolic diseased subjects. However, the evidence regarding the effect of acute hyperglycaemia on vascular function in youth is inconclusive and warrants further investigation. Therefore, we aimed to examine the effect of high-intensity interval running (HIIR) and moderate-intensity interval running (MIIR) on vascular function in a fasted state and postprandially after a glucose challenge in a group of adolescents (Kranen *et al.*,

2021). Fifteen adolescents (13 male, 14 ± 1 y) volunteered and completed the following experimental conditions on separate days in a counterbalanced order: 1) 8 x 1-min HIIR interspersed with 75 s recovery; 2) distance-matched amount of 1-min MIIR interspersed with 75 s recovery; and 3) rest (CON). Macro- (FMD) and microvascular (PRH) function (see Figure 2) were assessed immediately before and 90 min post-exercise/rest. Participants underwent an oral glucose tolerance test (OGTT) 2 h post-exercise/rest before another assessment of vascular function 90 min post-OGTT.

Following exercise, both HIIR and MIIR increased vascular function with no change in CON and no significant differences between exercise conditions. In contrast, FMD increased significantly in CON with no changes in HIIR and MIIR following the OGTT. It was concluded that vascular function is improved after interval running independent of intensity in adolescents, suggesting the intermittent exercise pattern is more important than the exercise intensity. Acute hyperglycaemia increased FMD, however, prior exercise did not change vascular function post-OGTT in youth. Further studies are required to understand the interaction between glucose, exercise and vascular function in youth and the underpinning mechanisms.

Summary

The aforementioned research provides a more comprehensive understanding of vascular function in youth by addressing both the effect of acute and chronic exercise. The sole improvement in FMD without changes in traditional CVD risk factors in the Training Study demonstrated the importance of including 'novel' CVD risk factors as an outcome measure: the intervention would have been deemed 'ineffective' if only traditional CVD risk factors had been examined. Though it must be acknowledged that further research is required to establish the precise timeline and exercise protocol to achieve improvements in microvascular function and traditional CVD risk factors in a healthy adolescent population. In addition, the reversal of the FMD enhancement during the detraining period of only two weeks shows the short time of permanency of exercise-induced health improvements and indicates that the regularity of exercise is crucial which is also reflected in the current PA guidelines, recommending an average of 60 min of moderate-to-vigorous PA per day for children and adolescents. Although this has not been examined here, several reviews have suggested a beneficial effect of PA in general and HIIT in particular on cognitive function in youth. Scheduling the training session prior to the school start may help with the subsequent cognitive tasks during the school day.

The findings of the acute study indicate that the intensity of an acute bout of exercise is less important for enhancing vascular function than previously thought. This study shows that it is rather the intermittent stimulus, i.e., interval nature of the exercise bout, that drives the acute improvement in vascular function and has thereby laid the basis for future studies in this area. Unlike in adults, the ingestion of an acute glucose load resulted in an augmentation in FMD in adolescents. However, this finding obviously cannot be transferred to the effect of chronic hyperglycaemia on vascular function.

Practical applications

The training study impressively demonstrated the efficacy of implementing a high-intensity exercise intervention in a school environment with the capability to improve vascular function. Training sessions were completed at the school before the first lesson and therefore had no adverse impact on the school day such as missed teaching time. Using shuttle runs as exercise modality enabled training in a group, which may have aided with motivation, and required minimal equipment. All ten participants completed 100% of all training sessions, suggesting that the applied protocol is attractive and could be used in future interventions in schools. However, more research is needed to identify the best strategy on how to embed a HIIE intervention into the school setting.

Although it has been previously shown that adolescents enjoy HIIE more than moderate-intensity exercise (Malik *et al.*, 2017), when it comes to promotion of PA and exercise, it is important to offer different exercise alternatives (e.g., exercise at different intensities) which are equally effective to cater for everyone's needs, especially given the low adherence to PA guidelines in youth. ■

Figure 2. Simultaneous assessment of macrovascular function (FMD) and microvascular function (peak reactive hyperaemia) using ultrasound and Laser Doppler monitor, respectively.

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Sascha is an Associate at the Children's Health and Exercise Research Centre, University of Exeter, and was invited to contribute this article as the 2023 recipient of the BASES Prof. Tom Reilly Doctoral Dissertation Award.

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