Low-Volume Bodyweight Exercise Training Improves Cardiorespiratory Fitness: A Contemporary Application of the 5BX Approach

Linda R. Archila[1], William Bostad[1], Michael J. Joyner[2], Martin J. Gibala[1]

[1]Department of Kinesiology, McMaster University, Hamilton, ON, Canada; [2]Department of Anesthesiology and Perioperative Medicine, Mayo Clinic, Rochester MN, USA 55905.

Corresponding Author:

Martin J. Gibala

Department of Kinesiology, McMaster University

Ivor Wynne Center 1280 Main St. West

Hamilton ON L8S 4K1

Phone: 905-525-9140 ext. 23591

Fax: 905-523-6011

Email: gibalam@mcmaster.ca

Complete list of authors:

Linda R. Archila*: archilal@mcmaster.ca

William Bostad: bostadw@mcmaster.ca

Michael J. Joyner: joyner.michael@mayo.edu

*LRA is now at the Faculty of Health Sciences, Queens University, Kingston, Canada.

Abstract

We examined the effect of a simple bodyweight training (BWT) program, completed thrice weekly for 6 weeks, on cardiorespiratory fitness in inactive adults. The 11-minute session involved five basic exercises, each performed for 60-seconds at a self-selected "challenging" pace, interspersed with recovery periods. Peak oxygen uptake was higher after training compared to a control group (34.2±6.4 vs 30.3±11.1 ml/kg/min, p=0.03). Brief BWT, requiring little space, no equipment, and minimal time commitment, can improve cardiorespiratory fitness.

Novelty Bullet:

- A simple 11-minute bodyweight training program, involving five exercises performed at a self-selected "challenging" pace, improved cardiorespiratory fitness when performed thrice weekly for 6 weeks.

Keywords: peak oxygen uptake; interval training; exercise; cardiorespiratory fitness; human; 5BX

Introduction

Physical inactivity remains prevalent despite strong evidence that cardiorespiratory fitness (CRF) is independently associated with mortality and disease risk (Kodama et al. 2009). Common cited barriers to regular physical activity include a perceived lack of time, and access to appropriate equipment and facilities (Trost et al. 2002). The latter has been exacerbated by public health measures and behavioural changes related to COVID-19. There is value in identifying simple, practical, time-efficient exercise strategies that increase CRF — as objectively measured by peak oxygen uptake ($\dot{V}O_{2peak}$) — given that even a modest improvement in this parameter is associated with a reduction in mortality risk (Imboden et al. 2019).

Vigorous intermittent exercise, including protocols broadly characterized as high intensity interval training (HIIT), can enhance markers of cardiometabolic health despite relatively low time commitment (Batacan et al. 2017). Practical and feasible applications of HIIT include brief, vigorous intermittent stair climbing, which as has been shown to increase CRF without the need for specialized equipment (Allison et al. 2017; Jenkins et al. 2019). Bodyweight training (BWT) is another popular variant of HIIT adopted by many practitioners (Thompson 2019), but limited research has examined the efficacy of BWT on CRF (McRae et al. 2012; Islam et al. 2020). This is especially true for simple BWT protocols that do not require the extraordinarily high levels of motivation demanded by "all out" or "supramaximal" efforts.

5BX — "Five Basic Exercises" — was a fitness plan developed over a half century ago based on classic principles of physical education (The Royal Canadian Air Force 5BX Program for Men, 1961). It was originally designed by the Royal Canadian Air Force for service members stationed in remote outposts, but has continued relevance today as a simple, practical approach to conditioning. The plan required only 11 minutes per day, was not dependent on elaborate facilities or equipment, and could be appropriately scaled based on fitness level. Training programs based on 5BX and performed for several months have been reported to improve submaximal indices of CRF and exercise tolerance (Kappagoda et al. 1979), including in individuals with cardiovascular disease (Raffo et al. 1980). The original 5BX plan included stretching, which places minimal stress on the cardiovascular system, and exercises such as sit-ups that are generally not recommended today. The present study sought to determine whether a contemporary BWT program modelled on the essential aspects of 5BX — involving five basic exercises performed at a self-selected "challenging" pace — would increase CRF in healthy but inactive adults. We hypothesized that the intervention, performed thrice weekly for 6 weeks, would increase CRF compared to a non-training control group.

Methods

Participants

Twenty-two individuals were recruited from the McMaster University community. Participants were deemed healthy, based on completion of the Canadian Society of Exercise Physiology (CSEP) Get Active Questionnaire (GAQ) (CSEP 2017). Participants were inactive, based on self-report of accumulating <150 minutes of moderate to vigorous weekly activity. Exclusion criteria included the diagnosis of a cardiometabolic disease or musculoskeletal condition that would contraindicate BWT. Participants were randomized in a counterbalanced manner to a training group or a non-training control group. The control group was invited to complete the training intervention after study completion. Three individuals withdrew for reasons unrelated to the study, leaving n=9 individuals who completed the intervention (5 males and 4 females; 20±1 years, body mass index=21±5 kg/m^2, mean ±SD) and n=10 in the control group (1 male and 9 females, 19±0 years, 21±5 kg/m^2). The experimental procedures were approved by the McMaster Research Ethics Board, and all participants provided written informed consent.

Experimental protocol

Participants initially performed an incremental ramp test to exhaustion using an electronically-braked cycle ergometer (Excalibur Sport V 2.0, Lode, Groningen, The Netherlands) and metabolic cart (Quark CPET, COSMED, Chicago, IL, USA) to determine $\dot{V}O_{2peak}$ and peak power (W_{peak}) as previously described (Allison et al. 2017; Jenkins et al. 2019). Participants subsequently returned to the laboratory to become familiarized with muscular fitness testing, and baseline testing was completed ~24-72 hours later. After a 2-minute walking warm-up, peak leg power was determined based on the best of three maximal jumps performed from a semi-squat position, and hand grip strength was determined using a dynamometer (Smedley Hand Dynamometer, Stoelting Co, Wood Dale, IL, USA) as detailed elsewhere (CSEP 2013). Muscular endurance was assessed using a wall sit test to volitional fatigue, involving an isometric squat with the knees flexed at 90°, as confirmed by a goniometer (Baseline Plastic Goniometer 12-1000, Fabrication Enterprises, White Plains, NY).

Participants were randomized with a 1:1 allocation ratio using a concealed envelope after baseline testing. The training group returned to the lab for familiarization with the exercise protocol and 6-20 Borg rating of perceived exertion (RPE) scale. Training commenced 72 hours after, occurring thrice weekly for 6 weeks. The protocol involved a 1-minute warm-up of jumping jacks, followed by five exercises performed for 1-minute each: burpees (without push-ups), running in place with "high knees", split squat jumps, running in place with high knees again, and squat jumps. Participants self-selected their relative intensity (i.e. effort level) based on instructions to choose a “challenging pace”, with the goal of completing as many repetitions as possible. The exercises were interspersed with 1-minute recovery periods involving walking in place, for a total session duration of 11 minutes. Sessions were supervised but no additional direction or encouragement was provided. Heart rate (HR) was monitored continuously for subsequent analysis (Polar A300, Kempele, Finland) and RPE was recorded after each exercise bout. All participants completed all training sessions. Enjoyment was assessed using the Physical Activity Enjoyment Scale (Kendzierski and DeCarlo 1991) immediately following the first and last training session. The post-training $\dot{V}O_{2peak}$ test was conducted ~72 hours after the final training session, or 6 weeks after baseline testing in the control group, followed ~24-72 hours later by muscular fitness testing.

Statistical Analysis

All data are expressed as mean ±SD (n=10 for control, n=9 for training). $\dot{V}O_{2peak}$, W_{peak}, peak leg power, wall sit time, and grip strength data were analysed with analysis of covariance (ANCOVA), using baseline values as the covariate (Rausch et al. 2003) on IBM SPSS (IBM Corp., Version 25.0, Armonk, NY, USA) as previously described (Jenkins et al. 2019). Cohen’s *d* was used to determine effect size from baseline to post testing within the training group. Enjoyment during the first and final sessions was compared with a two-tailed paired t-test. Significance was set at $p<0.05$.

Results

ANCOVA revealed a significant difference between groups after the intervention, such that $\dot{V}O_{2peak}$ was higher in the training group compared to control (34.2±6.4 vs 30.3±11.1 ml/kg/min, p=0.03, d=0.38; Figure 1A). The mean increase from baseline in the intervention group was ~7% (2.1±4.5 ml/kg/min), which corresponded to ~0.5 metabolic equivalent (MET). W_{peak} was also higher after training compared to control (211±43 vs 191±50 W, p=0.004, d=0.35, Figure 1B). Grip strength, peak leg power, and wall sit time were not different between groups after the intervention. Mean exercise HR, averaged over all training sessions, was 82±5% of maximum (165±10 bpm) and RPE was 14±3. Enjoyment ratings were similar between the first and last session (98±14 vs 86±12; p=0.06).

Discussion

The major novel finding of the present study was that a simple BWT program, involving five basic exercises performed for 60-seconds each at a self-selected "challenging" pace, and a total time commitment of 11 minutes per session, improved CRF when performed thrice weekly for 6 weeks in previously inactive young adults.

HIIT has re-emerged in recent years as one of the most popular fitness trends worldwide (Thompson 2019), with "Tabata"-style training being one particularly well-known variant. This method is commonly practiced using bodyweight intervals that resemble traditional calisthenics, although the original study (Tabata et al. 1996) involved cycling bouts at a workload equivalent to ~170% of $\dot{V}O_{2max}$. This specific protocol involves eight 20-second cycles of 'all out' effort interspersed with 10-seconds of rest, and requires an extraordinarily high level of motivation. BWT applied using the Tabata method can increase CRF (McRae et al. 2012), although there are equivocal data in this regard (Islam et al. 2020). The very intense nature of the efforts involved, however, makes this type of training unsuited for some individuals. Other studies have demonstrated the potential for less vigorous BWT — requiring ~10-30 minutes per session and often performed in conjunction with equipment-based exercise — to increase CRF (Myers et al. 2015), including in people at risk for cardiometabolic diseases (Fealy et al. 2018).

The protocol in the present study did not precisely mimic the classic 5BX plan, but modelled some of the essential aspects: it involved five basic exercises, required only 11 minutes per session, was not dependent on elaborate facilities or equipment, and was scaled to individual fitness by having participants self-select their effort level (i.e., a "challenging pace"). Despite the relatively training low time commitment, the protocol enhanced exercise tolerance, as evidenced by a higher $\dot{V}O_{2peak}$ and W_{peak} following the intervention, as compared to a non-training control group (Figure 1). The increase in $\dot{V}O_{2peak}$ in the BWT group was modest, however, and less than the ~1 MET improvement typically reported in other recent 6-week training studies that have applied other models of brief intermittent exercise including stairclimbing (Allison et al. 2017) and stationary cycling (Thomas et al. 2020).

Considerable attention has recently been focused on the psychological responses to interval exercise. The emerging data support the viability of this type of activity as an alternative to traditional, moderate-intensity continuous exercise (Stork et al. 2017). High adherence to free-living HIIT in previously sedentary overweight and obese adults has been observed in conjunction with high levels of enjoyment (Vella et al. 2017). In the present study, enjoyment remained high at the end of the 6-week training period and not different compared to the start of the program. These data suggest that at least short-term BWT performed at a self-selected pace could be a sustainable exercise strategy in the previously inactive population. There are equivocal data in this regard however, and adherence to self-paced BWT warrants further study.

In summary, a simple 11-minute BWT program based on classic principles of physical education and the 5BX plan — which involved five basic exercises, minimal space, and no specialized equipment — increased CRF when performed at a self-selected “challenging” pace thrice weekly for 6 weeks in previously inactive participants.

Acknowledgements

This study was supported with funds from McMaster University and the Natural Sciences and Engineering Research Council (NSERC) to MJG. LRA held a NSERC Undergraduate Student Research Award.

References

Allison, M.K., Baglole, J.H., Martin, B.J., MacInnis, M.J., Gurd, B.J., and Gibala, M.J. 2017. Brief intense stair climbing improves cardiorespiratory fitness. Med. Sci. Sports Exerc. **49**(2): 298–307. doi:10.1249/MSS.0000000000001188.

Batacan, R.B. Jr, Duncan, M.J., Dalbo, V.J., Tucker, P.S., and Fenning, A.S. 2017. Effects of high-intensity interval training on cardiometabolic health: a systematic review and meta-analysis of intervention studies. Br. J. Sports. Med. **51**(6):494-503. doi: 10.1136/bjsports-2015-095841.

CSEP. 2013. Canadian Society for Exercise Physiology- Physical activity training for health (CSEP-PATH). Canadian Society for Exercise Physiology, Ottawa, ON. pp. 80-85.

CSEP. 2017. Get Active Questionnaire. Canadian Society for Exercise Physiology, Ottawa, Ont., Canada. Available from http://www.csep.ca/home.

Fealy, C. E., Niewoudt, S., Foucher, J. A., Scelsi, A. R., Malin, S. K., Pagadala, M., Cruz, L. A., Li, M., Rocco, M., Burguera, B., and Kirwan, J. P. 2018. Functional high intensity exercise training ameliorates insulin resistance and cardiometabolic risk factors in type 2 diabetes. Exp. Physiol. **103**(7):85-994. doi: 10.1113/EP086844.

Imboden, M. T., Harber, M. P., Whaley, M. H., Finch, W. H., Bishop, D. L., Fleenor, B. S., and Kaminsky, L. A. 2019. The association between the change in directly measured cardiorespiratory fitness across time and mortality risk. Prog. Cardiovasc. Dis. **62**(2):157–162. doi:10.1016/J.PCAD.2018.12.003.

Islam, H., Siemens, T.L., Matusiak, J.B.L., Sawula, L., Bonafiglia, J.T., Preobrazenski, N., Jung, M.E., and Gurd, B.J. 2020. Cardiorespiratory fitness and muscular endurance responses immediately and 2 months after a whole-body Tabata or vigorous-intensity continuous training intervention. Appl Physiol Nutr Metab. **45**(6): 650-658. doi: 10.1139/apnm-2019-0492. Epub 2019 Nov 29.

Jenkins, E. M., Nairn, L. N., Skelly, L. E., Little, J. P., and Gibala, M. J. 2019. Do stair climbing exercise “snacks” improve cardiorespiratory fitness? Appl. Physiol. Nutr. Met. **44**(6): 681–684. doi: 0.1139/apnm-2018-0675.

Kappagoda, C.T., Linden, R.J., and Newell, J.P. 1979. Effect of the Canadian Air Force training programme on a submaximal exercise test. Q. J. Exp. Physiol. Cogn. Med. Sci. **64**(3): 185-204. doi: 10.1113/expphysiol.1979.sp002472.

Kendzierski, D. and DeCarlo, K. J. 1991. Physical Activity Enjoyment Scale: Two validation studies. J. Sport Exerc. Psychol. **13**(1): 50–64. doi:10.1123/jsep.13.1.50.

Kodama, S., Saito, K., Tanaka, S., Maki, M., Yachi, Y., Asumi, M., Sugawara, A., Totsuka, K., Shimano, H., Ohashi, Y., Yamada, N., and Sone, H. 2009. Cardiorespiratory fitness as a quantitative predictor of all-cause mortality and cardiovascular events in healthy men and women: a meta-analysis. J. Am. Med. Assoc. **301**(19): 2024–2035. doi:10.1001/jama.2009.681.

McRae, G., Payne, A., Zelt, J. G. E., Scribbans, T. D., Jung, M. E., Little, J. P., and Gurd, B. J. 2012. Extremely low volume, whole-body aerobic–resistance training improves aerobic fitness and muscular endurance in females. Appl. Physiol. Nutr. Metab. **37**(6): 1124–1131. doi:10.1139/h2012-093.

Myers, T. R., Schneider, M. G., Schmale, M. S., and Hazell, T. J. 2015. Whole-body aerobic resistance training circuit improves aerobic fitness and muscle strength in sedentary young females. J. Str. Cond. Res. **29**(6): 1592–1600. doi: 10.1519/JSC.0000000000000790.

Raffo, J.A., Luksic, I.Y., Kappagoda, C.T., Mary, D.A., Whitaker, W., and Linden, R.J. 1980.

Effects of physical training on myocardial ischaemia in patients with coronary artery disease. Br Heart J. **43**(3): 262-269. doi: 10.1136/hrt.43.3.262.

Rausch, J.R., Maxwell, S.E., and Kelley, K. 2003. Analytic methods for questions pertaining to a randomized pretest, post-test, follow-up design. J. Clin. Child Adolesc. Psychol. **32**: 467–486. doi:10.1207/S15374424JCCP3203_15.

Stork, M.J., Banfield, L.E., Gibala, M.J., and Martin Ginis, K.A. 2017. A scoping review of the psychological responses to interval exercise: is interval exercise a viable alternative to traditional exercise? Health Psychol Rev. **11**: 324-344. doi: 10.1080/17437199.2017.1326011.

Tabata, I., Nishimura, K., Kouzaki, M., Hirai, Y., Ogita, F., Miyachi, M., and Yamamoto, K. 1996. Effects of moderate-intensity enduance and high-intensity inttermittent training on anaerobic capacity and VO_{2max}. Med. Sci. Sports Exerc. **28**(10); 1327-1330. doi:10.1097/00005768-199610000-00018.

The Royal Canadian Air Force 5BX program for men (1st ed.). Royal Canadian Air Force. 1961.

Thomas, G., Songsorn, P., Gorman, A., Brackenridge, B., Cullen, T., Fitzpatrick, B.L., Metcalfe, R.S., and Vollaard, N.B. 2020. Reducing training frequency from 3 or 4 sessions/week to 2 sessions/week does not attenuate improvements in maximal aerobic capacity with reduced-exertion high-intensity interval training (REHIT). Appl. Physiol. Nutr. Metab. doi: 10.1139/apnm-2019-0750. [Epub ahead of print]

Thompson, W.R. 2019. Worldwide survey of fitness trends for 2020. ACSM's Health Fit. J. **23**(6): 10-18. doi: 10.1249/FIT.0000000000000526

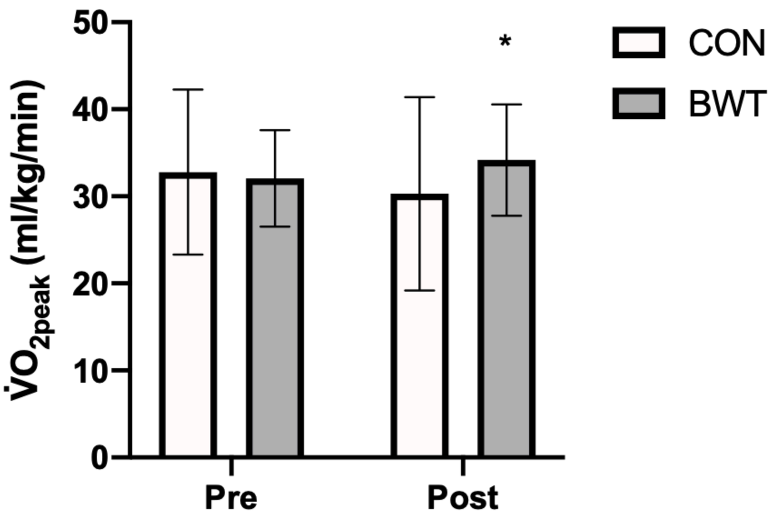
Trost, S. G., Owen, N., Bauman, A. E., Sallis, J. F., and Brown, W. 2002. Correlates of adults'participation in physical activity: review and update. Med. Sci. Sport. Exerc.

34(12): 1996-2001. doi: 10.1097/00005768-200212000-00020.

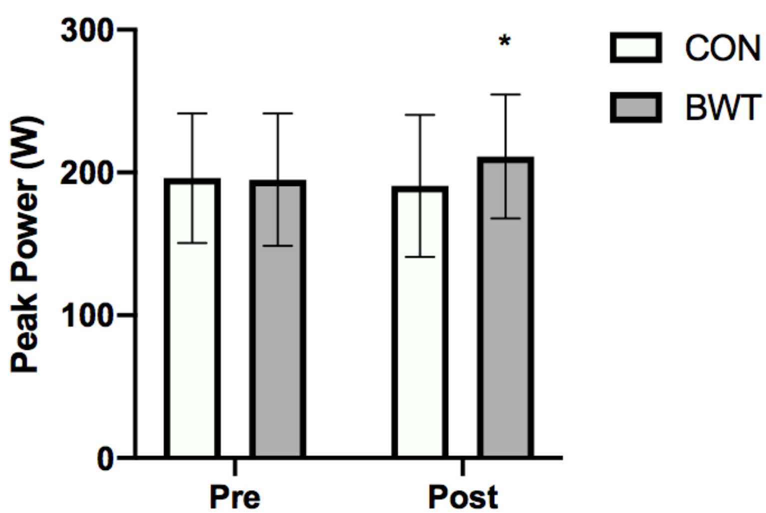
Vella, C. A., Taylor, K., and Drummer, D. 2017. High-intensity interval and moderate-intensity continuous training elicit similar enjoyment and adherence levels in overweight and obese adults. Eur. J. Sport. Sci. 17(9): 1203-1211. doi: 10.1080/17461391.2017.1359679.

Figure 1.

(A)



(B)



Peak oxygen uptake ($\dot{V}O_{2peak}$) (A) and peak power (W_{peak}) (B) measured before (Pre) and after (Post) 6 weeks of bodyweight training (BWT) or an equivalent period without a prescribed exercise intervention (CON). Values are means ± SD. * $P<0.05$ between groups.