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RESEARCH ARTICLE

Effects of Parkour Training on Health-Related Physical Fitness in Male Adolescents

Martin Dvorak[1,*], Neil Eves[2], Vaclav Bunc[1] and Jiri Balas[1]

[1]*Charles University in Prague Faculty of Physical Education, Sport Research Laboratory, Prague, Czech Republic*
[2]*The University of British Columbia - School of Health and Exercise Science Kelowna, British Columbia, Canada*

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Abstract:

Background:

Many children become less active as they age which increases their risk of developing of chronic conditions. Traditional forms of physical activity may not be optimal for them. There is a need for more attractive form of training to try and increase physical activity levels and improve the fitness of children. The aim of this study was to determine the effects of performing parkour training on measures of cardiorespiratory fitness, strength and body composition in adolescents.

Methods:

Using a single-group design, 12 males (age 16 ± 2 yr, weight = 69 ± 12 kg, height = 177 ± 7 cm) took part in a controlled indoor parkour intervention 2 days/week for 10 weeks. Participants underwent cardiopulmonary exercise testing (CPET), strength testing and body composition assessment before and after the exercise intervention.

Results:

Peak oxygen uptake ($\dot{V}O_2$ peak) significantly increased from 50.0 ± 4.9 ml·min^{-1}·kg^{-1} to 52.5 ± 4.3 ml·min^{-1}·kg^{-1}. Oxygen uptake at a standardized submaximal (10 km·h^{-1}) running speed ($\dot{V}O_{2 10km/h}$) significantly decreased from 37.7 ± 1.6 ml·min^{-1}·kg^{-1} to 36.7 ± 1.9 ml·min^{-1}·kg^{-1}. Oxygen uptake at anaerobic treshold ($\dot{V}O_2$@AT) significantly increased from 38.4 ± 4.3 ml·min^{-1}·kg^{-1} to 40.5 ± 3.9 ml·min^{-1}·kg^{-1}, heart rate at anaerobic treshold (HR@AT) and running speed at anaerobic threshold. We also found a significant increase in standing broad jump from 234 ± 29 cm to 251 ± 23 cm and bent arm hang from 34 ± 24 s to 37 ± 24 s.

Conclusion:

Parkour training is an effective intervention to improve cardiorespiratory fitness and strength in adolescent males. Parkour is a viable form of physical activity to improve the health and fitness of children and adolescents.

Keywords: Body composition, Cardiorespiratory fitness, Effects of training, Male adolescents, Parkour, Strength.

INTRODUCTION

There is a considerable body of evidence that regular exercise is essential for the maintenance of human health [1 - 4] and that increasing the level of physical fitness and the volume of physical activity reduces the risk of a wide range of chronic conditions [5, 6]. According to Bunc [7] physically active adults are more likely to be physically active at a young age with more than 70 % of active youth continuing physically active into late adulthood. As such, it is essential to promote sufficient levels of physical activity in youth to maintain lifelong interest and participation in physical activity.

* Address correspondence to this author at the Charles University in Prague Faculty of Physical Education, Sport Research Laboratory, Prague, Czech Republic; Tel: +420 775 198 650; Fax: +420 242 454 700; E-mail: dvorimartin@seznam.cz

The most important aspect in promoting physical activity in children and adolescents is the type of physical activity available [8]. Youth should be given opportunities to experience a wide range of activities and identify an activity that they have access to, enjoy, and have some level of success in, otherwise they will most likely choose to be inactive [9]. There is a broad spectrum of new nontraditional physical activities that are gaining in popularity. One such activity is parkour which was established in France around 1990 [10 - 13] and is also known as freerunning or streetmovement.

The aim of parkour is for the Traceur (parkour participant) to run between two points as quickly and effectively as possible. Running is combined with special techniques for overcoming obstacles [12, 14, 15]. Parkour could be more attractive than traditional sports due to the absence of strict rules and space for creativity.

In 2009 parkour was recognized as part of the national curriculum for gymnastics in United Kingdom [16]. Following the new physical education curriculum introduced, a few schools in England expanded their provision introducing parkour in their classes, and/or as an after school activity. These experiences have shown that parkour is a flexible activity that allows students to be self-directed, increasing their confidence and maturity [17]. Nowadays, parkour is practiced by thousands of youngsters all over the world. Its popularity is growing so rapidly that sport centres, especially designed for parkour, are being built in many different countries: Denmark, Finland, France, Great Britain, Poland, and the USA [18].

Parkour involves many different physical elements and may help to improve many aspects of overall physical fitness in those who participate. Parkour movement shows the predominance of anaerobic glycolytic metabolism with support of aerobic metabolism, however, it seems to be a suitable activity to develop aerobic fitness in youth [19]. Traceurs often use specific landing and jumping techniques, this represents an important eccentric effort for leg muscles [20]. This specific way of training influences the characteristics strength of traceurs, especially plyometric abilities of lower limbs [21]. Also upper body is involved in many parkour techniques, this improves upper limbs strength and if involved during jumping and landing techniques upper-to-lower limbs coordination is improved as well [21, 22].

To our knowledge, no study has examined the effects of a parkour intervention on physical fitness in adolescents. Therefore, we investigated the effects of parkour training on a variety of fitness measures specific to parkour. We hypothesized that ten weeks of parkour training would have a beneficial effect on measures of cardiorespiratory fitness, running economy, strength and body composition.

MATERIALS AND METHODS

Participants

Twelve male participants ([mean ± SD] age = 16 ± 2 years, weight = 69 ± 12 kg, height = 177 ± 7 cm) with no previous parkour experience were included in the study. The only restriction was no professional athletic career in the past and during the time of intervention. Youth with only 1.5 hour of physical activity performed per week were chosen to participate in the study. This amount of physical activity was represented by mandatory school physical education classes. The experimental procedures and possible risks were communicated verbally and in writing to all study participants and their parents, who then gave informed written consent to participate in the study. The experiment was approved by the Ethics Committee of the Faculty of Physical Education and Sports, Charles University in Prague and conformed to the standards set by the Declaration of Helsinki.

Study Design

This study was a prospective, single-arm feasibility study conducted at the department of Sport Research Laboratory, the Faculty of Physical Education and Sports, Charles University. On the first visit participants came to the laboratory, underwent body composition measurement and performed CPET tests. On the second visit, strength testing was performed. Participants then exercised 1 hour per session, 2 times a week for 10 weeks. Parkour intervention program together with mandatory physical education classes should cover physical activity recommendations issued by selected recognized guidelines [23, 24]. Training was held during autumn and spring to avoid the influence of seasonal outdoor activities. All baseline assessments were repeated after the intervention.

Specific Methodology

Cardiopulmonary Exercise Testing

Family medical and medication histories were obtained and following 10 minutes of rest, blood pressure was measured using manual sphygmanometer (Omron Hem 907XL, Omron, Netherlands) to ensure that participants were normotensive. Following an 8 min warm up at speeds of 8 $km \cdot h^{-1}$ and 10 $km \cdot h^{-1}$, participants performed an incremental test on a treadmill to exhaustion (Quasar, Cosmos, Germany). The initial speed was 10 $km \cdot h^{-1}$ with 5 % grade and speed was increased 1 $km \cdot h^{-1}$ every minute until volitional exhaustion as previously reported. The same protocol was used in the study of Boubelikova [25]. Expired gases were measured continuously using a breath-by-breath metabolic system (Cortex Metalyzer, Cortex Biophysik GmbH, Germany). The gas analyzers and pneumotach were calibrated using primary gas standards similar to the expired gas concentration and a 3-litre calibration syringe (Hans Rudolph, inc., USA), respectively. During the test, heart rate was monitored continuously by telemetry (PolarElectro OY, Finland). The two highest consecutive 20s $\dot{V}O_2$ values were considered as $\dot{V}O_2$ peak. Anaerobic threshold was determined using the Beaver technique [26] which utilizes the non-linear increase in V_E in relation to VCO_2.

Strength Testing

Selected exercise field tests were used to measure changes in strength in each subject. These tests were included in Eurofit physical fitness test battery [27]. The sequence of tests was organised according to Eurofit (Standing broad jump, hand grip test, sixty second sit-up test and the bent-arm hang test) using standardized protocols. These tests have previously shown to have hight reliability (R^2 = 0.72 to 0.83) [28, 29].

Body Composition Measurement

Following the measurement of height and weight (Soehnle 7731, Sohnle Industrial Solutions GmbH, Germany), body composition was determined using bioelectrical impedance (B.I.A. 2000M, Data Input, Germany). Resistance and reactance were measured at four frequencies (1, 5, 50 and 100 kHz) on the right side of the body by tetrapolar electrode configuration in accordance with manufacturer's specification. Body cell mass (BCM) was calculated using the total body water (TBW) and phase angle (α) between whole impedance vector and resistance [30]. BCM was calculated as BCM = FFM x 0.29 x ln (α) [31] using the formulae for fat-free mass (FFM) as TBW/0.732 and total body water (TBW) = 0.69 x $height^2/R$ + 0.8 [32]. The extracellular mass (ECM) was then calculated as the difference between the FFM and BCM. The FFM was calculated according to modified formula of Deurenberg & Schouten [33]. The BCM is the sum of the weights of all cells that utilized the oxygen [34]. ECM is metabolically inactive and mainly serves functions of transport and support in the body [35, 36]. ECM, which is 75% extracellular water (ECW), consists of plasma and interstitial fluid. The remaining 25% of ECM consists of extracellular solids (ECS), such as bone, connective tissue, and extracellular proteins and minerals [35 - 37]. This molecular model can be used to evaluate the quality of muscle mass [38].

Exercise Training Intervention

The parkour intervention was held in gymnasium to reduce the potential for injury which could be caused by the conditions of the outdoor environment when working with beginners. Training sessions were prepared in accordance with the Parkour Generations teaching materials [39]. Training session structure was set as follows: 10 min of general warm-up, 10 min of specific parkour warm-up, 25 min of parkour techniques, 10 min of conditioning and 5 minutes of warm-down. Two different types of parkour specific techniques were used to vary workouts each week. The first workout included “dynamic“ jumping techniques and running. The second workout involved “static“ balance technigues and mounts. The parkour intervention included 12 “dynamic“ training sessions and 8 “static“ training sessions. To assess the participants´ perceived exertion of the exercise intensity during training sessions the Borg RPE-scale was used [40]. Heart rate was used to quantify exercise intensity during “dynamic“ and “static“ training sessions, it was monitored during the 11th and 12th training session (PolarElectro OY, Finland).

Statistical Analysis

Paired t-test was used to assess the differences between pre and post tests (IBM, SPSS 21, US). Because of the relatively small sample size we used an unbiased effect size measure omega squared (ω^2) which indicates the percentage of variance explained in dependent variable by the within-subject factor. Pearson two-tailed correlations were used to determine associations between body compositon characteristics and strength performance and between aerobic performance and strength performance. The alpha level was set *a priori* at 0.05 for all statistical analysis.

RESULTS

Ten participants completed the intervention and all the pre and post testing procedures and two participants dropped out. The first participant did not attend 85% of training sessions and the second one did not undergo the posttest procedure due to injury.

Cardiorespiratory Fitness Parameters

Changes in some cardiopulmonary exercise testing outcomes are shown in Fig. (**1**). Parkour training increased $\dot{V}O_2$ peak by 2.5 ml·min^{-1}·kg^{-1} ($p = 0.001$, $\omega^2 = 0.69$). The mean posttest value for $\dot{V}O_{2\ 10km/h}$ significantly decreased by 1.0 ml·min^{-1}·kg^{-1} which represents a 2.8 % change from pre-test values ($p = 0.002$, $\omega^2 = 0.62$). Significant improvements were also observed in the oxygen consumption at anerobic threshold ($\dot{V}O_2$@AT) which increased by 2.1 ml·min^{-1}·kg^{-1} from pre- to post-test ($P = 0.001$, $\omega^2 = 0.70$). The heart rate at anaerobic (HR@AT) also significantly decreased from 178 ± 6 to 175 ± 6 ($p = 0.001$, $\omega^2 = 0.82$) (Fig. **2**). Participants were able to maintain higher running speed at AT following the parkour training (0.2 km·h^{-1} increase from pre training values, $p = 0.011$, $\omega^2 = 0.46$). Peak heart rate, peak ventilation, respiratory exchange ratio and time of running did not significantly change with training. A negative correlation was found ($r = -0.558$) between $\dot{V}O_{2\ 10km/h}$ and explosive power of lower extremities.

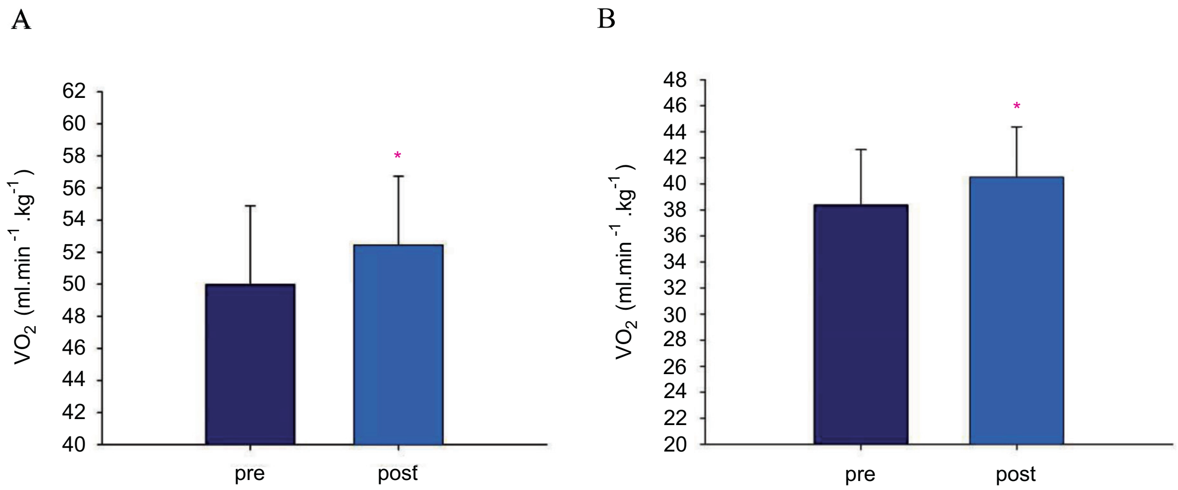

Fig. (1). The effect of parkour intervention on $\dot{V}O_2$ peak (A), $\dot{V}O_2$@AT (B) shown as a mean ± SD. * = significantly different pre vs. post test.

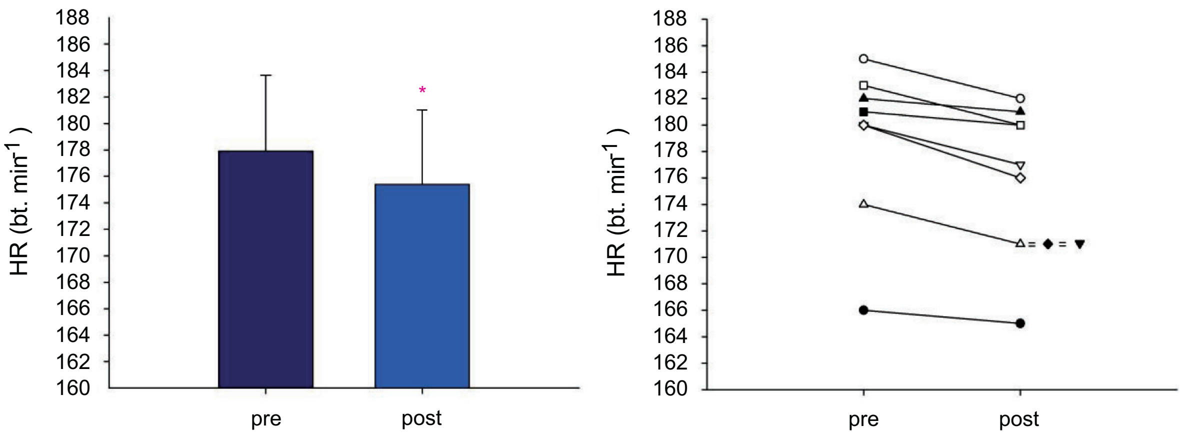

Fig. (2). The effect of parkour intervention on HR@AT shown as a mean ± SD and individual differences. * = significantly different pre vs. posttest.

Strength Parameters

Participants significantly improved standing broad jump distance ($p < 0.001$, $\omega^2 = 0.71$) following parkour training by 17.2 cm, which represents an increase of 7.4 % compare to pretest values Fig. (**3**). We also found a significant increase in the bent-arm hang time (34 ± 24 s vs. 37 ± 24 s, $p = 0.02$, $\omega^2 = 0.41$). Participants increased the number of sit-ups from pretest 49 ± 10 to posttest 54 ± 7, however this finding did not reach significance ($p = 0.06$, $\omega^2 = 0.52$). Additionally, there was no increase in hand grip with the parkour intervention.

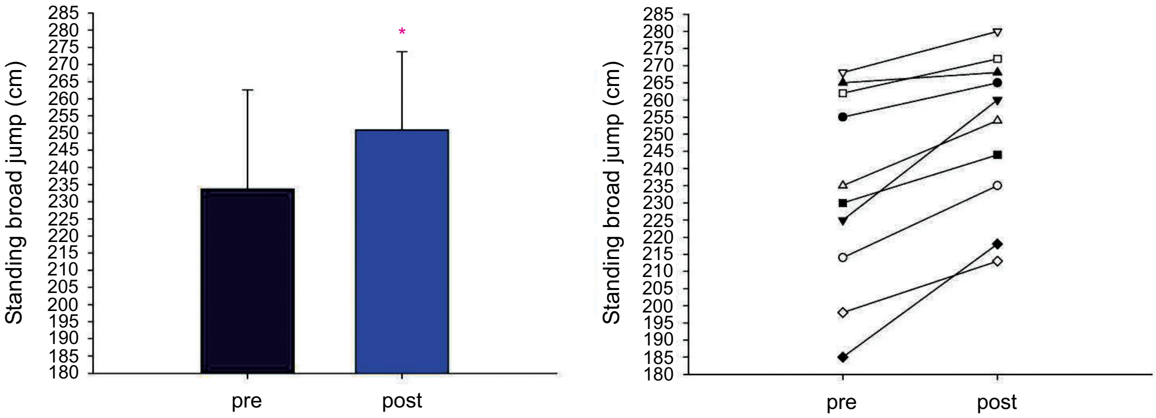

Fig. (3). The effect of parkour intervention on explosive strength (Standing broad jump test) shown as a mean ± SD and individual differences. * = significantly different pre vs. post test.

Body Composition

Changes in body composition are presented in Table **1**. No significant changes in any body composition variables were observed with the parkour intervention.

Table 1. Body composition characteristics reported as mean difference, effect size and significance; 95% CI indicates 95% confidence interval.

Body composition characteristics	Mean diference [95% CI]	Omega Squared	P
Fat (%)	↑0.18 [-0.7 to 1.0]	0.00	0.637
FFM (kg)	↓0.07 [-0.9 to 0.8]	0.00	0.858
ECM/BCM	↓0.02 [-0.05 to 0.01]	0.10	0.125

Exercise Training Intensity During the Parkour Intervention

Participants´ perception of exercise intensity for each training session was assessed. Perceived exertion for the “dynamic“ sessions ranged between 12-14 on the Borg scale (between light and somewhat hard to between somewhat hard and hard). Perceived exertion for the “static“ sessions ranged from 12-13 on the Borg Scale (between light and somewhat hard to somewhat hard). During the “dynamic“ training sessions heart rate averaged 143 ± 10 $bt \cdot min^{-1}$ which presented 72 ± 5 % of mean HR peak. While during the “static“ sessions was 134 ± 11 $bt \cdot min^{-1}$ which presented 67 ± 5 % of mean HR peak.

DISCUSSION

This is the first study to investigate the effect of parkour training in adolescents. The novel finding of this study is that 10 weeks of parkour training improved aerobic fitness and strength in adolescent males without having a signfiicant effect on body composition.

Effect of Parkour on Cardiorespiratory fitness

The parkour intervention had a beneficial effect on $\dot{V}O_2$ peak, $\dot{V}O_{2\ 10km/h}$ and anaerobic threshold demonstrating that parkour training is an effective training stimulus for improving cardiorespiratory fitness in children aged 16 ± 2 years. As no previous study has examined the benefits of a parkour intervention on cardiorespiratory fitness it is difficult to compare our findings to others. However, from a health perspective, an increase in peak oxygen consumption and thus higher cardiorespiratory fitness may prolong the initiation or development of cardiovascular disease in these adolecsents [41]. Getting adolescents involved in an activity like parkour will keep adolescents physically active during early adulthood and help maintain cardiorespiratory fitness during aging.

While no study has investigated the specific effects of a parkour training intevention, a cross-sectional study by Leite *et al.* [22] reported that the average $\dot{V}O_2$ peak in a small group of parkour practioners (mean age = 19.5 ± 2.8 yr) who had been performing parkour for at least 6 months, was 44.2 ± 5.6 $ml \cdot min^{-1} \cdot kg^{-1}$. The difference between our pretest values and Leites´ study could be caused by the use of a field test for estimating $\dot{V}O_2$ peak in Leites´ study, which may have underestimated the true $\dot{V}O_2$ peak. It is difficult to compare subjects due to the age difference between them. Many adolescent males increase body mass and reduce $\dot{V}O_2max$ as they reach adulthood [42].

Parkour training also increased running economy as demonstrated by a decrease of $\dot{V}O_2$ during submaximal running. There is a linear relationship between submaximal running speed and $\dot{V}O_2$ ($ml \cdot min^{-1} \cdot kg^{-1}$) for each individual. However, there is a considerable variation among individuals in how much oxygen it costs to run at a given speed [43]. Morgan *et al.* [44] demonstrated a decrease in oxygen uptake by 2.9 ± 1.8 $ml \cdot min^{-1} \cdot kg^{-1}$ during submaximal treadmill running at 10 $km \cdot h^{-1}$ and thus better running economy in trained subjects compare to untrained. While the decrease in $\dot{V}O_{2\ 10km/h}$ in this study of 1.0 $ml \cdot min^{-1} \cdot kg^{-1}$ would suggest that our subjects are not as "trained" as those in the study of Morgan *et al.* [44] following 10 weeks of parkour training, it is still an important finding considering parkour training is not a purely aerobic activity. Johnson *et al.* [45] found that strength training, when added to an endurance training program, improves running economy in female distance runners. Parkour training includes also the combination of aerobic, strength and power exercise. The negative correlation between $\dot{V}O_{2\ 10km/h}$ and explosive power of the lower extremities supports the potential importance of the strength and power components of parkour for improving movement economy independent of traditional aerobic training modalities.

Effect of Parkour on Strength

Parkour training increased explosive power and muscle endurance of the upper body and abdominal muscles. Muscle strength is considered an essential component of motor performance and is necessary for all physical tasks [2]. Our findings demonstrated a significant increase in explosive power after parkour training as standing broad jump increased by 7.4 % over the 10-week intervention. Our post test findings are very similar to those reported in the cross-sectional study of Leite *et al.* [22] who reported average standing broad jump of 253 ± 23 cm. We can classify our average posttest value into the category higher than the average. Měkota et. al [46] demonstrated the benefits of parkour even in a relatively fit group of Czech male adolescents [47, 48].

Effect of Parkour on Body Composition

There was a nonsignificant but decrease in the ECM/BCM. The lower the ratio, the greater the amount of BCM and the better the predisposition for muscular work. In practice, this coefficient could be an important criterion of exercise program efficiency [7]. For individuals without regular physical exercise training this ratio ranges between 0.75 and 1.05. Interestingly we did not find any significant changes in FFM and fat percentage. We also did not find any correlation between ECM/BCM, FFM respectively and strength. This can mean that all the changes in strength and power performance could be explained from the perspective of improvement in neuromuscular coordination instead of changes in body composition.

Overview

Parkour is an attractive physical activity for youth which is supported by the regular participation and adherence of subjects (96 % across the 10 weeks) to our training sessions. When well introduced, described and demonstrated, parkour is a safe activity as we had no injuries during the intervention. Previously, a number of schools in Great Britain introduced some of the elements from parkour into physical education classes to increase physical activity of students with some success. Parkour may also help with the development of self discipline and ethics in young people [10, 11, 49 - 53]. The principle of parkour philosophy is to be able to adapt in everyday life, to develop the ability to overcome any obstacle through toughness and creativity, and to develop (internal mental and external physical) strength [10, 14, 15]. According to Gilchrist & Wheaton [17] parkour could increase physical activity and promote active lifestyle in young people. Parkour is non-competitive sports discipline where each person individualy develops his own physical fitness and skills and training sessions can be performed alone or in groups.

Special playgrounds for parkour training are built in Europe and USA. It is a relatively safe way to train parkour and on the other hand due to the character of these places parkourists are given direction on how to use the urban environment for physical activity. As such parkour may be an ideal way to increase physical activity and engage young people in a safe, non-traditional sport that may help in the longterm maintainance of an active and healthy lifestyle.

Limitation

One limitation of this study is the nonrandomized design and the relatively small sample size. However, the aim of this study was to first demonstrate that a controlled parkour intervention could enhance physical fitness before comparing it to other forms of physical activity. It was felt that it was not necessary to perform a randomized trial that assessed the effectiveness of parkour in adolescent population compared to a non-exercising control. More studies are now needed to investigate whether parkour has greater health and fitness benefits compared to other forms of physical activity. Additionally, future studies should examine whether parkour offers similar benefits for female adolescents as it does for males.

CONCLUSION

In conclusion, ten weeks of controlled parkour training had a positive effect on aerobic fitness, strength and body composition in male adolescents. Parkour is a natural movement that can be performed with a minimum equipment in any enviroment. Due to the reduction of time spent on physical activity among young people and the decrease of the level of physical fitness, it is necessary to react to this situation and offer attractive physical activity options to youths. As such, parkour could be a novel and affective option to improve the health and fitness of young people.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

Not applicable.

HUMAN AND ANIMAL RIGHTS

No Animals/Humans were used for studies that are base of this research.

CONSENT FOR PUBLICATION

Not applicable.

CONFLICT OF INTEREST

The authors declare no conflict of interest, financial or otherwise.

ACKNOWLEDGEMENTS

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REFERENCES

[1] Cooper KH. Fit Kids. 2nd ed. Nashville, TN: Broadman and Holman Publishing 1999.

[2] Malina RM, Bouchard C, Bar-Or O. Growth, Maturation and Physical Activity. Champaign: Human Kinetics 2004.

[3] Seguin R, Nelson ME. The benefits of strength training for older adults. Am J Prev Med 2003; 25(3)(Suppl. 2): 141-9. [http://dx.doi.org/10.1016/S0749-3797(03)00177-6] [PMID: 14552938]

[4] Strong WB, Malina RM, Blimkie CJ, *et al.* Evidence based physical activity for school-age youth. J Pediatr 2005; 146(6): 732-7. [http://dx.doi.org/10.1016/j.jpeds.2005.01.055] [PMID: 15973308]

[5] Marcus BH, Forsyth LH. Psychology of Active Living: Motivation of People to Be Active. Portal (Baltim, Md) 2010.

[6] Pastucha D, Sovová E, Malincikova J. Physical Activities as a Part of the Prevention of Cardiovacular Diseases. Physician 2010; 90(8): 467-70.

[7] Bunc V. Body Composition in Adolescents as an Indicator of Active Lifestyle. Czech Kinanthropology 2009; 13(3): 11-7.

[8] Doyle-Baker PK, Venner AA, Lyon ME, Fung T. Impact of a combined diet and progressive exercise intervention for overweight and obese children: the B.E. H.I.P. study. Appl Physiol Nutr Metab 2011; 36(4): 515-25. [http://dx.doi.org/10.1139/h11-042] [PMID: 21848443]

[9] Aaron DJ, Storti KL, Robertson RJ, Kriska AM, LaPorte RE. Longitudinal study of the number and choice of leisure time physical activities from mid to late adolescence: implications for school curricula and community recreation programs. Arch Pediatr Adolesc Med 2002;

156(11): 1075-80.
[http://dx.doi.org/10.1001/archpedi.156.11.1075] [PMID: 12413332]

[10] Edwardes D. Parkour. In: Booth D. Thorpe H. Berkshire Encyclopedia of Extreme Sports 2007; pp. 233-6.

[11] Herborn M. Parkour – the Escape Route for the Youth. Play the Game Magazine 2009; 17: 24-5.

[12] Normile D. Urban Gymnastics. International Gymnast 2009; 51: 38-40.

[13] Weigel DM. Foucan, Sébastien Berkshire Encyclopedia of Extreme Sports Berkshire publishing group. 2007.

[14] Schnaufer J. The World is Your Playground. American Fitness 2010; 28: 39-41.

[15] Wasley P. Spring Forward. Chron High Educ 2006; 52: 1-10.

[16] Johnson A, Wroe S. Free Running Could be Taught in Secondary Schools 2009. [cited 2017 April 3]. Available from: http://www.independent.co.uk/news/education/education-news/freerunning-could-be-taught-in-secondary-schools-1515326.html.

[17] Gilchrist P, Wheaton B. Lifestyle Sport, Public Policy and Youth Engagement: Examining the Emergence of Parkour. Int J Sport Policy 2011; 6: 109-31.
[http://dx.doi.org/10.1080/19406940.2010.547866]

[18] Ameel L, Tani S. Parkour: Creating Loose Spaces. Geogr Ann, Ser B 2012; 94(1): 17-30.
[http://dx.doi.org/10.1111/j.1468-0467.2012.00393.x]

[19] Río JF, Suarez C. Feasibility and students' preliminary views on parkour in a group of primary school children. Phys Educ Sport Pedagogy 2016; 21(3): 281-94.
[http://dx.doi.org/10.1080/17408989.2014.946008]

[20] Puddle DL, Maulder PS. Ground reaction forces and loading rates associated with parkour and traditional drop landing techniques. J Sports Sci Med 2013; 12(1): 122-9.
[PMID: 24149735]

[21] Grosprêtre S, Lepers R. Performance characteristics of Parkour practitioners: Who are the traceurs? Eur J Sport Sci 2016; 16(5): 526-35.
[http://dx.doi.org/10.1080/17461391.2015.1060263] [PMID: 26267256]

[22] Leite N, De Aguiar RP, Cieslak F, *et al.* Physical Fitness Profile of Le Parkour Practitioners. Rev Bras Med Esporte 2011; 17: 198-201.
[http://dx.doi.org/10.1590/S1517-86922011000300010]

[23] Physical Activity Guidelines for Americans. Washington, DC: U.S. Department of Health and Human Services 2008.

[24] Tremblay MS, Warburton DE, Janssen I, *et al.* New Canadian physical activity guidelines. Appl Physiol Nutr Metab 2011; 36(1): 36-46, 47-58.
[http://dx.doi.org/10.1139/H11-009] [PMID: 21326376]

[25] Boubelikova B. The Effect of Alcohol Ingestion on Body Composition after Aerobic Maximal Test on the Treadmill Ergometer. B.A. thesis, Charles University in Prague 2015.

[26] Beaver WL, Wasserman K, Whipp BJ. A new method for detecting anaerobic threshold by gas exchange. J Appl Physiol 1986; 60(6): 2020-7.
[PMID: 3087938]

[27] Adam C, Klissouras V, Ravazzolo M, Renson R, Tuxworth W. EUROFIT: European Test of Physical Fitness. Rome: Council of Europe, Committee for the Development of Sport 1988.

[28] Donncha C, Watson AW, McSweeney T, O'Donovan DJ. Reliability of Eurofit Physical Fitness Items for Adolescent Males with and without Mental Retardation. Adapt Phys Activ Q 1999; 16: 86-95.
[http://dx.doi.org/10.1123/apaq.16.1.86]

[29] Tsigilis N, Douda H, Tokmakidis SP. Test-retest reliability of the Eurofit test battery administered to university students. Percept Mot Skills 2002; 95(3 Pt 2): 1295-300.
[http://dx.doi.org/10.2466/pms.2002.95.3f.1295] [PMID: 12578274]

[30] Bunc V, Stilec M, Moravcova J, Matous M. Body Composition Determination by Whole Body Bioimpedance Measurement in Women Seniors. Biom Hum Anthropol 2003; 21(1-2): 1-5.

[31] Lautz HU, Selberg O, Körber J, Bürger M, Müller MJ. Protein-calorie malnutrition in liver cirrhosis. Clin Investig 1992; 70(6): 478-86.
[http://dx.doi.org/10.1007/BF00210228] [PMID: 1392415]

[32] Kushner RF, Schoeller DA. Estimation of total body water by bioelectrical impedance analysis. Am J Clin Nutr 1986; 44(3): 417-24.
[PMID: 3529918]

[33] Deurenberg P, Schouten FJ. Loss of total body water and extracellular water assessed by multifrequency impedance. Eur J Clin Nutr 1992; 46(4): 247-55.
[PMID: 1600921]

[34] Heyward VH, Wagner DR. Applied Body Composition Assessment. Champaign, IL: Human Kinetics 2004.

[35] Shizgal HM. The effect of malnutrition on body composition. Surg Gynecol Obstet 1981; 152(1): 22-6.
[PMID: 6779391]

[36] Jacobs DO, Robinson MK. Body Composition - Nutrition and Metabolism of the Surgical Patient. Boston: Little, Brown and Company 1997.

[37] Moore FD. Energy and the Maintenance of the Body Cell Mass 1980; 4: 228-60.
[http://dx.doi.org/10.1177/014860718000400302]

[38] Bunc V, Skalska M. Functional Characteristics of Paramedics. Czech Kinanthropology 2012; 16(3): 89-100.

[39] Edwardes D. The Parkour and Freerunning Handbook: Virgin Books. 2009.

[40] Borg G. An Introduction to Borg's RPE-Scale. Movement Publications 1985.

[41] Haskell WL, Lee IM, Pate RR, *et al.* Physical activity and public health: updated recommendation for adults from the American College of Sports Medicine and the American Heart Association. Circulation 2007; 116(9): 1081-93.
[http://dx.doi.org/10.1161/CIRCULATIONAHA.107.185649] [PMID: 17671237]

[42] Cheung LW, Richmond JB. Child Health, Nutrition and Physical Activity. Human Kinetics Publishers 1995.

[43] Bransford DR, Howley ET. Oxygen cost of running in trained and untrained men and women. Med Sci Sports 1977; 9(1): 41-4.
[PMID: 870783]

[44] Morgan DW, Bransford DR, Costill DL, Daniels JT, Howley ET, Krahenbuhl GS. Variation in the aerobic demand of running among trained and untrained subjects. Med Sci Sports Exerc 1995; 27(3): 404-9.
[http://dx.doi.org/10.1249/00005768-199503000-00017] [PMID: 7752868]

[45] Johnson RE, Quinn TJ, Kertzer R, Vroman NB. Strength Training in Female Distance Runners: Impact on Running Economy. J Strength Cond Res 1997; 11(4): 224-9.

[46] Mekota K, Kovar R. UNIFITTEST (6–60). Tests and Norms of Motor Performance and Physical Fitness in Youth and in Adult Age. Acta Universitatis Palackianae Olomucensis Gymnica 1995; 25(1): 7-108.

[47] Frankova H. Monitoring of Physical Development of Students of the Second Grade of High School. Ph.D. diss. Masaryk University Brno 2007.

[48] Moravec R, Kampmiller T, Sedlacek J. EUROFIT Physical Development and Physical Fitness of School Population in Slovakia. Bratislava: Slovak Research in Physical Education and Sport 1996.

[49] Andrews C. Cool Runnings. TES 2007; 47: 24.

[50] Beaumont G. Parkour-Related Activity. Phys Edu Matt 2008; 3: 15-6.

[51] Beaumont G, Whitlam P. Parkour. Phys Edu Matt 2010; 5: 45.

[52] Gray L. Parkour is Flying into the Future. Phys Edu Matt 2010; 5: 43-4.

[53] Maddern K. Parkour Leaps into Sport Timetables to Curtail Copycats. TES 2009; 4859: 23.