

HIGH INTENSITY INTERVAL TRAININGS IN SCHOOLCHILDREN

¹²Ilma Čaprić,
¹Mila Manić,
¹Dušan Đorđević,
²Armin Zećirović,
¹²Adem Mavrić,
¹²Raid Mekić,
¹²Samir Hačković

DOI 10.7251/SIZEN2001113M
ISSN 1840-152X
UDK 613.25:373.3-053.5(497.16)
<http://sportizdravlje.rs.ba/>
<https://doisrpska.nub.rs/index.php/SIZ>

¹University of Nis, Faculty of Sport and Physical Education,
Serbia

²State university of Novi Pazar, Srbija

ARTICLE

Abstract: High-intensity interval training is used to improve maximum oxygen intake and aerobic functional capacity of school children. So far, it has been discovered that high-intensity interval training (HIIT) is effective in improving anaerobic capacity. Aim of the study was to determine the effectiveness and impact of HIIT training on the improvement of VO₂ in schoolchildren based on a systematic review of a large number of studies that have addressed the impact of high-intensity interval training. Following electronic databases were searched: Google Scholar, PubMed, Web of Science and Research Gate, using all papers available by April 30, 2020. The following keywords were used: "high-intensity interval", "training", "HIIT", "training". The search was mostly related to English and original scientific papers from available journals. In the first phase of the search, the relevance of the titles and abstracts of the identified papers was checked. In the second phase of the search, the complete papers were downloaded and considered for inclusion. References from all collected papers were reviewed to obtain more research that studied this area. Total of 10 studies met the criteria and were included into the systematic review. High-intensity interval training leads to the improvement of VO₂, VO₂max, O₂ and other physiological parameters in school children by applying various high-intensity interval training programs. Programs in duration of six, ten and twelve weeks lead to the improvement of physiological parameters of school children, while the seven-week program of high-interval training proved to be the best program in relation to the duration and intensity of the program. Based on the analysis and discussion of the papers observed in the systematic research, it can be concluded that, according to the duration of the program, the minimum period where VO₂ and VO₂max and other physiological abilities can improve is six weeks, and the usual weekly load is two to three workouts per week.

Keywords: HIIT, VO₂, VO₂max, O₂, school children.

1. Introduction

An active lifestyle, as well as its benefits, have been well researched and documented (Blair & Morris, 2009; Joyner & Green, 2009). The connection of these benefits is observed in higher level of cardio-respiratory condition (VO₂ max) which has protective effects (Joyner, et al. 2009; Lee, Artero, Sui & Blair, 2010). High-intensity interval training (HIIT) has recently gained in popularity (Garber, Blissmer, Deschenes, Franklin, & Lamont, 2011). Strength training is associated with muscle hypertrophy and increased strength-building ability, while endurance training is associated with improved capacity for aerobic energy metabolism and fatigue resistance. (Baar, 2006; Egan & Zierath, 2013; Hawley, Hargreaves, Joyner & Zierath, 2014). HIIT training comes in a variety of forms, from aerobic interval training to sprint interval training. Since the beginning of the 20th century, aerobic interval training achieved by long-term continuity of high and moderate intensity (90–110% VO₂ max), with passive or active recovery periods of equal duration, is usually used for the purpose of improving aerobic power (maximum oxygen intake, VO₂ max), (Billat, 2001). The importance of HIIT training is reflected in the stimulation of the secretion of catecholamine, epinephrine (Williams, Zelt, Castellani, Little, Jung, et al. 2013), norepinephrine (Peake, Tan, Markworth, Broadbent, Skinner, et al. 2014) and growth hormone (Shen, Heymsfield, Reyes-Vidal, Geer, et al. 2008), which accelerate fat breakdown (Bracken & Brooks, 2010; Zouhal, Jacob, Delamarche, & Gratas-Delamarche, 2008). Also, HIIT training leads to depletion of muscle glycogen (Sperlich, De Marées, Koehler, et al. 2007). It plays an important role in improving cardio-pulmonary fitness (MacInnis & Gibala, 2017). The maximum oxygen consumption VO₂ max represents the largest amount of oxygen that the body can receive i.e., consume during one minute of maximum intensity load. The VO₂ max value can be directly measured or estimated depending on the technical characteristics of the equipment used, the test protocol, the time and duration of the load (Armstrong, Welsman & Winsley, 1996). Previous research has shown that high-intensity interval training (HIIT) effectively affects the improvement of maximum oxygen intake (VO₂ max), as well as overall measures of cardiorespiratory fitness or aerobic functional capacity of a person. (Riebe, et al. 2018; Baquet, et al. 2002; Lau, et al. 2014; Baquet, et al. 2001; Tjønnå, et al. 2009). Recent studies indicate that higher exercise intensity is more effective in improving VO₂ max than moderate-intensity exercise (Gomley, et al. 2008), as well as in improving anaerobic capacity than continuous work methods (Pery, et al. 1998). Future research should also identify the optimal time for high-intensity exercise to improve the physical, physiological, and cognitive health of young children. This systematic review study will include a large number of high-intensity tests (Shuttle runs (100–130% MAS)), after applied HIIT training programs, as well as parameters

related to duration. Aim of the research was to determine the effectiveness and impact of HIIT training on the improvement of VO₂ in school children based on a systematic review of a large number of studies which dealt with the impact of high-intensity interval training.

2. Methods

Review and analysis were performed in accordance with PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-analyzes) guidelines (Moher, D., Liberati, A., Tetzlaff, J., & Altman, D.G., 2009).

Research strategy

Searches were conducted in the following electronic databases: Google Scholar, PubMed, Web of Science and Research Gate, using all papers available until April 30, 2020. The following keywords were used: "high-intensity interval", "training", "HIIT", "training". The search was mostly related to English and original scientific papers from available journals. In the first phase of the search, the relevance of the titles and abstracts of the identified papers was checked. In the second phase of the search, the complete papers were taken over and considered for inclusion. References from all collected papers were reviewed to obtain more research that studied this area.

Inclusion criteria

For the selection of papers to be included in the final analysis, the following inclusion criteria were defined: (1) original scientific papers; (2) papers based on longitudinal design; (3) papers written in English; (4) sample of respondents – school children; (5) experimental treatment under HIIT training conditions; (6) a minimum of two groups of respondents (1 experimental – 1 control group or 2 or more experimental groups); (7) papers covering the impact of HIIT training; (8) papers containing tests for VO₂; (9) papers where only school children were tested.

Exclusion criteria

Based on the following criteria, the papers were excluded from further analysis: (1) papers based on transversal design; (2) inadequate sample of respondents; (3) papers with a lack of a control group or other experimental group; (4) papers in which the experimental treatment was not realized in the conditions of HIIT training; (6) papers in which the results are not adequately presented or the parameters required for further analysis are missing; (7) papers based on case studies.

Data extraction

Papers selected to be used in this research are presented in Table 1. Each research paper is represented with the following parameters: research (first author and year of publication of the paper), sample of respondents (number of respondents (N), age and groups (E and K)), experimental treatment (monitored variables, program and duration of research) and results. Data extraction, as well as verification of extracted works, was realized independently by the author.

3. Results

Table 1. Results overview

Author	Age	Sample of respondents	Experimental program	Measuring instruments (sample of tests and measures)	Duration	Results
Baquet, et al. 2002	8-11	N = 53 M=23 F=30 K=20 E=33	Shuttle runs (100–130 % MAS)	VO2	7	K Δ= -0.01 ± 0.13 E Δ= 0.14 ± 0.13 P= < 0.001 (14.1)
Baquet, et al. 2004	8-11	N=100 M=46 F=54 E=47 K=53	Shuttle runs (100–130 % MAS)	SBJ, SAR, SHR, SUP, MS.	7	K Δ= -0.04 ± 0.14 E Δ= 0.15 ± 0.11 P= < 0.001 (14.4)
Nourry, et al. 2005	9-10	N=18 M=11 F=7 E=9 K=9	Shuttle runs (100–130 % MAS)	VO2peak VO2 Rpeak	8	VO2peak= 43.2 ± 7.6↑ VO2=1.75 ± 0.44↑ Rpeak=103 ± 25↑
Baquet, et al. 2010	9,6±1,0	N= 77 M=43 F=34	MAV(km.h ⁻¹) 22.22m (100%MAV) 24.44m (110%MAV) 26.66m (120%MAV)	MAV, O2	7	CGΔ=0.1±0.4 CTGΔ=0.9±0.4 ITGΔ=0.7±0.5 P<0.001 (15.5)
Sperlich, et al. 2011	13,5 ± 0,4	M=19	HIIT -90% HVT- 60-75%	O2max 1000 m	5	HRmax HIIT-17,4± 1,5↑ HVT-12,2± 0,6

De Araujo, et al. 2012	8-12	N=30 ET-15 HIIT-15	ET-80%HR HIIT-100%HR	VO ₂		VO ₂ ET-3,1% HIT- 14,6%↑
Lau, et al. 2015	10,4 ± 0,9	N=48 M=36 F=12 K=12 LIIE= 21 HIIE=15	Running LIIE- 100% MAV HIIE-120% MAV	SWOC	6	MAS (km·h ⁻¹) K= 10.8 ± 0.4 LIIE=10.9 ± 0.1 HIIE=10.9± 0.1
Lambric, et al. 2016	8-10	N=55 M=32, F=23	Games for kids (average 93% max. HR)	VO ₂ peak, Brzina trčanja	6	VO ₂ peak (F(1,51)=5.60, P < .05), Running speed(F(1,51) = 7.01, P <.05;
Huerta, et al. 2017	13± 0,6	N=28 K=14 E=14	20mSRT	VO ₂ max	8	VO ₂ max(mlO ₂ ·K g ⁻¹ ·min ⁻¹) K=0.015 E=0.245↑
Baker, et al. 2020	15,4 ± 0,7	N=57 M=47 F=10 HIT=17 (high int.) MOD =40 (moderat e int.)	20 MSFT, CMJ, 505 agility test 10 m sprint.	VO ₂ max	7	MOD 20MSFT 26.8 %↑ CMJ 7.3↑ HIT 20MSFT 8,3↑ CMJ 5,1% ↑ Spring 10 m 1,5% ↑ 505agilnom 5%↑

Significantly different code before the test at $p < 0.05$; Δ - difference between post-and pre-training; P differs significantly from the previous test ($p < 0.001$); MAV -maximum aerobic velocity; CTG - continuous training; CG -control group; ITG or CG - occasional training group; SBJ - High jump; SAR -sit-and-reach; SHR -10 x 5 meter shuttle ride; SUP -sit-ups; MS - maximum shuttle speed; GXT - max aerobic capacity; $LIIE$ and $HIIE$ - Intermittent exercises with lower and higher intensity; CMJ - countermovement jump; ↑ improvement; $20mSRT$ - test Course Navette; ET - endurance training; $HIIT$ -high-intensity interval training; VO_2 - Oxygen consumption; CO_2 - carbon dioxide output; HR - Heart rate; VO_{2peak} - Maximum oxygen consumption;

4. Discussion

This study was conducted with the aim of systematically presenting studies that dealt with high-intensity interval training in school children. The main finding of this study is that high-intensity interval training is effective for improving aerobic performance in school children. A total of 403 relevant studies were identified by searching the relevant databases. After removing the duplicates, 214 studies remained. Based on a review of the title and abstracts, 40 studies were rejected (after analyzing the title 17 and 23 after analyzing the abstract). The complete text of 189 remaining papers was subjected to detailed analysis. Each study was read and selected based on the characteristics of the study, information about the

respondents, a description of the training program and the results of the study. According to the inclusion criteria, 42 studies were excluded because they failed to meet the inclusion criteria, while 10 studies that met the inclusion criteria were included in the systematic review. All the studies that met the inclusion criteria were original scientific studies published in English between 2002 and April 2020. The total number of samples was 485, male and female respondents. The age of the respondents ranged from 8 to 15. Studies performed on a seven-week program (Baquet, et al. 2002) showed that high-intensity aerobic training twice a week in boys and girls leads to significant increase in VO₂, which is associated with an increase in aerobic performance. The same collaborators (Baquet, et al. 2004), two years later, developed a high-intensity intensive running program that also showed a significant improvement in aerobic performance in children of both sexes. Also, well-individualized continuous and intermittent sessions affect a significant increase in O₂ maximum aerobic velocity. So, by applying adequate combinations of high-intensity exercises, they can significantly influence the increase of aerobic fitness (Baquet, et al. 2010). The seven-week HIIT program is a time-efficient way to improve health components. Given the short duration of physical education classes, HIIT training may be a good choice for the health education of children and adolescents (Baker, et al. 2020). In a study (Huerta, et al. 2017) conducted over an eight-week period of high intensity, it was observed that children who are physically active for several hours a week have a progressive increase in VO₂ max and a maximum heart rate. Also, (Nourry, et al. 2005) conducted an eight-week training program with intense running that improved vital capacity and VO₂ max. In pre-pubertal children, occasional high-intensity running training caused changes in lung function at rest and altered exercise ventilation. During exercise ventilation becomes slower and deeper which enables better efficiency. These beneficial effects were obtained after a short training period (8 weeks) that could easily be integrated into the endurance cycle of physical education classes for school children. The findings show that HIIT (6 times a week) significantly reduces body fat (skin folds), increases aerobic capacity and functional ability of walking in overweight children. Consequently, the effectiveness of occasional running exercises may be more attractive to overweight children compared to traditional continuous running exercises. Also, exercise with intermittent running of lower and higher intensity can contribute to behavior modification in two ways: time efficiency and the perception of tolerable physical effort. The effectiveness of intermittent running exercises may be more appealing to overweight children and may result in improved exercise programs (Lau, et al. 2014). Lambrick, et al (2016) also applied a six-week program of high-intensity exercise in the form of games, which can improve cardio-respiratory performance and anthropometric measures in boys and girls aged 8 to 10. In particular, this study showed improvements in maximum functional capacity

(VO₂ max and maximum running speed, reduced O₂ consumption during sub-maximal exercise, and improved body composition indices) for those children who are active in the exercise program. A game-based high-intensity exercise intervention can increase the sense of enjoyment and intriguingly motivate children to continue exercising after the program is over. A HIIT of five weeks of training procedure should be considered an effective method of training in football games when the training procedure time is short. However, care should be taken against the potential risk of overtraining or injury (Sperlich, et al. 2011). By investigating the differences between HIIT and endurance training, they are equally effective in improving important health parameters (e.g., aerobic fitness, insulin sensitivity, BMI) in obese children (De Araujo, et al 2012).

5. Conclusion

High-intensity interval training leads to the improvement of VO₂, VO₂ max, O₂ and other physiological parameters in school children by applying various high-intensity interval training. Programs of six, ten and twelve weeks, lead to the improvement of physiological parameters of school children, while the seven-week program of high-interval training proved to be the best program in relation to the duration and intensity of the program. This systematic review provides evidence of the beneficial effects of high-intensity interval training. The application of the HIIT program leads to positive changes in the results of tests for aerobic and anaerobic abilities. Based on the analysis and discussion of the papers observed in the systematic overview it can be concluded that according to the duration of the program, the minimum period where VO₂ and VO₂ max and other physiological abilities can improve is six weeks, and that the usual weekly load is two to three trainings per week. The analyzed studies have confirmed that this type of training is suitable for improving the ability of school children who apply plyometric training in addition to the main training. HIIT training can contribute a lot, as a regular training program, to improving physiological abilities that are very important for proper growth and development. Plyometric training is easy to organize, and there is a wide range of programs and exercises, as well as tests to assess VO₂ and VO₂max.

Significance of research

The significance of this research is that it provides information on the impact of HIIT exercise programs in school-age respondents, i.e. what changes occur in the values of VO₂ and VO₂ max using HIIT training, based on a systematic review of papers that had the same or similar research goals. Previous research contains the necessary information on gender, age of respondents, program duration, exercise

intensity and effects achieved. Based on these data, the analysis of the results provided information on which program is best for improving VO₂ and VO₂ max in school children of both sexes, whether the effects differ in relation to the beginning of testing and after the applied HIIT training program.

REFERENCES

- Armstrong, N., Welsman, J., & Winsley, R. (1996). Is peak VO₂ a maximal index of children's aerobic fitness?. *International journal of sports medicine*, 17(5), 356-359.
- Baar, K. (2006). Training for endurance and strength: lessons from cell signaling. *Medicine and science in sports and exercise*, 38(11), 1939.
- Babajić, F., Pojskić, H., Kovačević, E., & Abazović, E. PRIMJENA VISOKO INTENZIVNE INTERVALNE METODE U KONDICIJSKOJ PRIPREMI SPORTAŠA.
- Baker, J. S., Buchan, D. S., Malina, R. M., & Thomas, N. E. (2020). Benefits of high intensity anaerobic exercise for adolescents and school children.
- Baquet G, Guinhouya C, Dupont G, et al. Effects of a short-term interval training program on physical fitness in prepubertal children. *J Strength Cond Res*. 2004;18:708–13.
- Baquet, G., Berthoin, S., Dupont, G., Blondel, N., Fabre, C., & Van Praagh, E. (2002). Effects of high intensity intermittent training on peak V̇O₂ in prepubertal children. *International journal of sports medicine*, 23(06), 439-444.
- Baquet, G., Berthoin, S., Gerbeaux, M., & Van Praagh, E. (2001). High-intensity aerobic training during a 10 week one-hour physical education cycle: effects on physical fitness of adolescents aged 11 to 16. *International journal of sports medicine*, 22(04), 295-300.
- Baquet, G., Gamelin, F. X., Mucci, P., Thévenet, D., Van Praagh, E., & Berthoin, S. (2010). Continuous vs. interval aerobic training in 8-to 11-year-old children. *The Journal of Strength & Conditioning Research*, 24(5), 1381-1388.
- Billat, L. V. (2001). Interval training for performance: a scientific and empirical practice. *Sports medicine*, 31(1), 13-31.
- Bjelica, D. (2002). Opšti pojmovi sportskog treninga:(skraćena verzija). *Podgorica: Crnogorska sportska akademija*.
- Blair SN, Morris JN (2009) Healthy hearts—and the universal benefits of being physically active: physical activity and health. *Ann Epidemiol* 19: 253–256.
- Bracken, R. M., & Brooks, S. (2010). Plasma catecholamine and naphrine responses following 7 weeks of sprint cycle training. *Amino Acids*, 38(5), 1351-1359.
- De Araujo, A. C. C., Roschel, H., Picanço, A. R., do Prado, D. M. L., Villares, S. M. F., de Sa Pinto, A. L., & Gualano, B. (2012). Similar health benefits of endurance and high-intensity interval training in obese children. *PloS one*, 7(8), e42747.
- Egan B & Zierath JR (2013). Exercise metabolism and themolecular regulation of skeletal muscle adaptation. *CellMetabolism* 17, 162–18
- Freda, P. U., Shen, W., Heymsfield, S. B., Reyes-Vidal, C. M., Geer, E. B., Bruce, J. N., & Gallagher, D. (2008). Lower visceral and subcutaneous but higher intermuscular

- adipose tissue depots in patients with growth hormone and insulin-like growth factor I excess due to acromegaly. *The Journal of Clinical Endocrinology & Metabolism*, 93(6), 2334-2343.
- Garber, C. E., Blissmer, B., Deschenes, M. R., Franklin, B. A., Lamonte, M. J., Lee, I. M., ... & Swain, D. P. (2011). Quantity and quality of exercise for developing and maintaining cardiorespiratory, musculoskeletal, and neuromotor fitness in apparently healthy adults: guidance for prescribing exercise.
- García-Pinillos, F., Cámara-Pérez, J. C., Soto-Hermoso, V. M., & Latorre-Román, P. Á. (2017). A high intensity interval training (HIIT)-based running plan improves athletic performance by improving muscle power. *The Journal of Strength & Conditioning Research*, 31(1), 146-153.
- Gormley, S. E., Swain, D. P., High, R. Spina, R. J., Dowling, E. A., Kotipalli, U. S., Gandrakota, R. (2008). Aerobic High-Intensity Intervals Improve VO2max More Than Moderate Training. *Medicine and Science in Sport and Exercise*, 39(4), 665-671.
- Hawley, J. A., Hargreaves, M., Joyner, M. J., & Zierath, J. R. (2014). Integrative biology of exercise. *Cell*, 159(4), 738-749.
- Huerta, O. Á., Galdames, M. S., Cataldo, G. M., Barahona, F. G., Rozas, V. T., & Cáceres, S. P. (2017). Effects of a high intensity interval training on the aerobic capacity of adolescents. *Revista medica de Chile*, 145(8), 972.
- Joyner MJ, Green DJ (2009) Exercise protects the cardiovascular system: effects beyond traditional risk factors. *J Physiol* 587: 5551–5558.
- Lambrick, D., Westrupp, N., Kaufmann, S., Stoner, L., & Faulkner, J. (2016). The effectiveness of a high-intensity games intervention on improving indices of health in young children. *Journal of sports sciences*, 34(3), 190-198.
- Lau, P. W., Wong, D. P., Ngo, J. K., Liang, Y., Kim, C. G., & Kim, H. S. (2015). Effects of high-intensity intermittent running exercise in overweight children. *European journal of sport science*, 15(2), 182-190.
- Lee DC, Artero EG, Sui X, Blair SN (2010) Mortality trends in the general population: the importance of cardiorespiratory fitness. *J Psychopharmacol* 24: 27–35.
- MacInnis, M. J., & Gibala, M. J. (2017). Physiological adaptations to interval training and the role of exercise intensity. *The Journal of physiology*, 595(9), 2915-2930.
- Moher, D., Liberati, A., Tetzlaff, J., & Altman, D.G. (2009). Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. *PLoS Medicine*, 6(7):e1000097.
- Nourry, C., Deruelle, F., Guinhouya, C., Baquet, G., Fabre, C., Bart, F., ... & Mucci, P. (2005). High-intensity intermittent running training improves pulmonary function and alters exercise breathing pattern in children. *European journal of applied physiology*, 94(4), 415-423.
- Peake, J. M., Tan, S. J., Markworth, J. F., Broadbent, J. A., Skinner, T. L., & Cameron-Smith, D. (2014). Metabolic and hormonal responses to isoenergetic high-intensity interval exercise and continuous moderate-intensity exercise. *American Journal of Physiology-Endocrinology and Metabolism*, 307(7), E539-E552.
- Perry, A., Mosher, P., La Perriere, A., Roalstad, M. & Ostrovsky, P. (1988). A Comparison of Training Responses to Interval Versus Continuous Aerobic Dance. *Journal of Sports Medicine and Physical Fitness*, 28, 274-279

- Riebe Dur. (2018). ACSM's Guidelines for exercise testing and prescription. 10. izd. Philadelphia, PA: Wolters Kluwer Health.
- Sabag, A., Way, K. L., Keating, S. E., Sultana, R. N., O'Connor, H. T., Baker, M. K., ... & Johnson, N. A. (2017). Exercise and ectopic fat in type 2 diabetes: a systematic review and meta-analysis. *Diabetes & metabolism, 43*(3), 195-210.
- Sperlich, B., De Marées, M., Koehler, K., Linville, J., Holmberg, H. C., & Mester, J. (2011). Effects of 5 weeks of high-intensity interval training vs. volume training in 14-year-old soccer players. *The Journal of Strength & Conditioning Research, 25*(5), 1271-1278.
- Tjønnå, A. E., Stølen, T. O., Bye, A., Volden, M., Slørdahl, S. A., Ødegård, R., ... & Wisløff, U. (2009). Aerobic interval training reduces cardiovascular risk factors more than a multitreatment approach in overweight adolescents. *Clinical science, 116*(4), 317-326.
- Vučetić, V., Sukreški, M., & Sporiš, G. (2013, January). Izbor adekvatnog protokola testiranja za procjenu aerobnog i anaerobnog energetskeg kapaciteta. In *11. godišnja međunarodna konferencija Kondicijska priprema sportaša 2013*. Str. 99-100.
- Williams, C. B., Zelt, J. G., Castellani, L. N., Little, J. P., Jung, M. E., Wright, D. C., ... & Gurd, B. J. (2013). Changes in mechanisms proposed to mediate fat loss following an acute bout of high-intensity interval and endurance exercise. *Applied Physiology, Nutrition, and Metabolism, 38*(12), 1236-1244.
- Zouhal, H., Jacob, C., Delamarche, P., & Gratas-Delamarche, A. (2008). Catecholamines and the effects of exercise, training and gender. *Sports medicine, 38*(5), 401-423.
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Received: 30.10.2020.

Approved: 07.12.2020.

Correspondence:

Ilma Čaprić

Faculty of Sport and Physical Education, University of Niš

Crnojevića 10a, 18000 Niš, Serbia

Tel.: +381 66 151 063

e-mail: capricilma.np@gmail.com