Теорія та методика фізичного виховання
Physical Education Theory and Methodology
Teorìâ ta Metodika Fìzičnogo Vihovannâ

ISSN 1993-7989 (print)
ISSN 1993-7997 (online)
ISSN-L 1993-7989

ORIGINAL SCIENTIFIC ARTICLE

EFFECT OF COMPLEX TRAINING ON AEROBIC AND ANAEROBIC POWER ON AMATEUR ATHLETES

Gopal Kumar[1ABCD] and Vivek Pandey[1ABCD]

[1]Lakshmibai National Institute of Physical Education

Authors' Contribution: A – Study design; B – Data collection; C – Statistical analysis; D – Manuscript Preparation; E – Funds Collection

Corresponding Author: Gopal Kumar, E-mail: gopalk.kumar8@gmail.com
Accepted for Publication: January 15, 2023
Published: February 28, 2023

DOI: 10.17309/tmfv.2023.1.09

Abstract

The study purpose was to investigate the effect of complex training on aerobic and anaerobic power of amateur athletes.

Materials and methods. The study included 30 amateur athletes in soccer and hockey, which were equally divided into two groups, namely an Experimental group who underwent 6 weeks of complex training along with regular training in their sports and a Control Group who only performed their regular sports training. Anaerobic power was assessed by Running-based Anaerobic Sprint Test (RAST) and aerobic power (VO_2max) was assessed by 12-min Cooper run/walk test. The study used the Pre-test Post-test Randomized Group Design, and Paired t-test was used as the statistical technique for data analysis at a significance level of 0.05.

Results. At the end of six weeks, the Experimental group showed significant improvement in anaerobic power and VO_2max, while only VO_2max was improved in the Control group ($p<0.05$). No significant improvement was observed in anaerobic power for the Control group ($p>0.06$). Therefore, this shows that complex training has significant effect on anaerobic power, while it does not produce significant improvements in aerobic power.

Conclusions. Six weeks of complex training integrated with regular sports training can improve anaerobic power. Coaches and athletes, specifically in soccer and hockey, can implement the complex training program in their regular training.

Keywords: complex training, amateur, anaerobic power, aerobic power.

Introduction

Strength and conditioning experts, strength coaches, and researchers are all very interested in the best training methods that maximise strength. It is now well researched and accepted by most professionals that the combination of resistance training and plyometric training results in greater muscular power gains (Faude et al., 2013; Hammami et al., 2017; Ebben et al., 1997). This combination is termed as complex training (Fleck & Kontor, 1986). This regime comprises of performing an exercise set that includes a high-load resistance training exercise, then performing a low-load plyometric power exercise right after. In this training style, two biomechanically comparable exercises are typically combined, with the high-load resistance exercise coming first. [e.g., squat at 80% of one repetition maximum (1RM)], followed by the low-load power exercise (e.g., squat jumps) (Fleck & Kontor, 1986; Docherty et al., 2004).

Since the last few decades, the area of complex training has been well researched and numerous researchers had investigated the effect of complex training on various components of physical fitness on athletes of different sports such as soccer, basketball, volleyball, rugby etc. (Christopher et al., 2012; Wallenta, C et al., 2016; Alves et al., 2010). Meta-analyses had tried to convene the vast literature of complex training and findings revealed that complex training has positive effect on physical fitness variables such as countermovement jump, sprints, agility, repeated sprint ability etc. (Christopher et al., 2012; Wallenta et al., 2016; Alves et al., 2010). But there is scarcity of studies related effect of complex training on aerobic and anaerobic power.

It is a well-accepted fact that aerobic and anaerobic power are important physical fitness attributes that contribute in the overall performance of various sports and thus players should have well developed aerobic and anaerobic fitness (Modric et al., 2020; Reilly et al., 2000). Maximal aerobic power (VO_2max) is defined as the highest oxygen uptake that can be achieved during dynamic exercise with the involvement of large muscle groups (Wagner, 1996). Well-developed VO_2max helps in maintaining repetitive high-intensity runs and accelerating recovery process during a soccer game (Slimani et al. 2019). Anaerobic capacity is the maximal amount of ATP resynthesized via anaerobic metabolism (by the whole organism) during a specific type of short duration, maximal exercise (Green, 1994). Whether complex training can improve VO_2max is a question of debate. Meta-analyses by Ramirez-Campillo, Andrade, et al. (2021) and Thapa et al. (2022) reported small or moderate improvements in time-trial endurance performance. Similarly, the effect of complex training on anaerobic power has not been well-researched. Study conducted by Ingle et al. (2006) reported small increases (≤5.5%) in peak and mean power, while Perez-Gomez et al. (2008) found no improvements in anaerobic power.

Therefore, it is evident that area of aerobic and anaerobic power has not been congruously studied and the studies which are conducted reported contrasting results. Thus, the purpose of the present study was to investigate the effect of complex training on aerobic and anaerobic power on amateur athletes.

Materials and Methods

Study Participants

For the purpose of the study, a total of 30 male, amateur players were selected as subjects. The subjects belonged to Hockey (n=14) and Soccer (n=16) sport. The participants were randomized into one of the two groups – Experimental Group (n=15) and Control Group (n=15) (using an online randomization tool; www.randomizer.org). The physical characteristics of the subjects (Mean ± Standard Deviation) are presented in Table 1.

The inclusion criteria for the participants were – free from any musculo-skeletal or neuromuscular injury or disorder that could limit their ability to perform the training or tests, represented their institute at the inter-university level, training age of at least 4 years and had experience of doing weight training. All the participants were informed about the purpose of the study, benefits and risks involved with the training. Informed consent forms were signed by all the participants. The study was approved by the institutes Departmental Research Committee with considerations regarding ethical issues reported in Helsinki Declaration.

Study Organization

The study used pre-test post-test randomized group design with a training period of six weeks. Experimental Group underwent six weeks of complex training (three times a week i.e. on Mondays, Wednesdays and Fridays) while Control Group was not given any sort of complex training or traditional resistance training. Along with this, both the groups were involved in their regular training of respective sports. Complex training protocol is presented in Table 1.

Two familiarization sessions were conducted for participants before baseline testing. 1-RM testing and demographic data was also collected before the baseline testing. Participants were asked to abstain from any strenuous physical activity 24-hours and take proper rest before the baseline testing. Baseline testing was conducted on a standard track of 400 meters. Participants were tested for anaerobic power and maximal aerobic power (VO_2max) using Running-based Anaerobic Sprint (RAST) Test and 12-Minute Cooper Run/Walk Test respectively.

RAST Test involves six sprints of 35 meters, with a recovery period of 10 seconds between each sprint (total five 10-sec recovery periods) (Andrade et al., 2015). The timing of all six sprints was noted and power (P) in each effort (P = total body mass × distance2)/time3) was calculated (Zagatto et al., 2009). As variables of RAST, the peak power (PP), defined as the greater power achieved among the 6 efforts, the mean power (MP), defined as mean power among the 6 efforts, and minimum power (Pmin), defined as minimum power achieved among the 6 efforts, were determined relative to body weight. For VO_2max, participants were asked to run

Table 1. Protocol for complex training

Indicator	High-load resistance activity		Low-load high-velocity activity	
	Exercise	Sets × repetitions	Exercise	Sets × repetitions
Week 1-2 65% 1RM	Squat	3 × 10	Squat jump	3 × 6
	Romanian deadlift	3 × 10	Kettlebell swing	3 × 10
	Barbell lunge	3 × 10	Barbell high knees	3 × 15 sec
	Bench press	3 × 10	Plyo-push up	3 × 6
Week 3-4 70% 1RM	Squat	3 × 10	Squat jump	3 × 8
	Romanian deadlift	3 × 10	Kettlebell swing	3 × 10
	Barbell lunge	3 × 10	Barbell high knees	3 × 20 sec
	Bench press	3 × 10	Plyo-push up	3 × 8
Week 5-6 75% 1RM	Squat	3 × 10	Squat jump	3 × 10
	Romanian deadlift	3 × 10	Kettlebell swing	3 × 10
	Barbell lunge	3 × 10	Barbell high knees	3 × 25 sec
	Bench press	3 × 10	Plyo-push up	3 × 10

1RM: one repetition maximum.

continuously for twelve minutes and cover as much distance as possible. At the end of twelve minutes, distance covered by the participant was recorded in kilometres. VO_2max was calculated using the formula $VO_2max = (22.351 \times \text{kilometres}) - 11.288$ (Cooper, 1968).

Statistical Analysis

With the help of IBM SPSS version 20.0 (IBM, New York, USA) data was analysed. Normality of the data was tested by Shapiro-Wilk test. Data was found to be normally distributed. Data are presented as means and standard deviations in Table 3. Further analysis was carried out at 0.05 level of significance. Paired t-test was used to investigate the effect of intervention by comparing the baseline testing with the post-test.

Results

All the participants of the study received the training as planned and designated. None of the participant reported any adverse effect or injury and also none of the participant left the study without completion. Demographic characteristics of both the groups i.e. age, height, weight and BMI are presented in Table 2 and there was no significant difference found between experimental and control group. Descriptive statistics (means and standard deviations) are presented in Table 2 during pre-test and post-test for both groups for the following variables – VO_2max, average anaerobic power, maximum power, minimum power and fatigue index.

Paired t-test analysis, as presented in Table 4, found that there is significant increase in VO_2max in experimental and control group ($p<0.05$); while significant effect is observed only in experimental group in case of average anaerobic power ($p<0.05$). No significant effect of complex training was observed for average anaerobic power in control group ($p>0.05$).

Discussion

The present study was conducted with the purpose to investigate the effect of complex training on aerobic and anaerobic power among amateur athletes. 30 subjects, equally divided into two groups (Experimental and Control) underwent six weeks of intervention period. The results of the study showed a significant improvement in VO_2max and average anaerobic power in experimental group, while only VO_2max improved in control group.

Soccer and hockey matches consists a lot of high-intensity runs. Strength, power and endurance have proven to be of importance for players of both the games. According to this study research, a 6-weeks complex training program along with regular training of respective games, significantly improved the anaerobic power while significant improvements were not observed in VO_2max. VO_2max was seen improved in both the groups, while the improvements were not significantly different in Experimental and Control Group, while led to the interpretation that improvement in VO_2max among the subjects was because of the regular training of their respective sports, and not because of complex training. Average VO_2max in post-test observation in Experimental and Control Group was 49.42 mL/kg/min and 47.25 mL/kg/min respectively. It shows that VO_2max improvements were slightly higher in Experimental Group than Control Group. These findings are in line with the results

Table 2. Demographic Characteristics of the Participants (Mean ± SD)

Group	Age	Height	Weight	BMI
Experimental Group	21.33 ± 1.83	172.5 ± 5.75	67.04 ± 5.04	21.17 ± 1.03
Control Group	21.06 ± 1.87	171.86 ± 8.20	65.69 ± 6.06	22.56 ± 1.79

Table 3. Descriptive Statistics (Mean ± SD)

Indicator	Experimental Group		Control Group	
	Pre-test	Post - test	Pre - test	Post - test
VO_2max	45.82 ± 3.55	49.42 ± 3.94	44.01 ± 3.30	47.25 ± 3.49
Average Anaerobic Power	448.48 ± 74.44	490.02 ± 66.65	464.48 ± 54.99	458.96 ± 40.68
Maximum Power	531.43 ± 92.45	558.75 ± 84.51	518.67 ± 60.58	510.65 ± 56.60
Minimum Power	365.68 ± 57.48	429.14 ± 60.54	409.01 ± 47.66	420.11 ± 40.45
Fatigue Index	4.95 ± 2.11	3.99 ± 1.53	3.25 ± 1.01	2.67 ± 1.09

Table 4. Paired t-test

Group	Variable	t-value	df	p-value
Experimental Group	VO_2max_Pre – VO_2max_Post	-11.26	14	0.000
	AAP_Pre – AAP_Post	-6.34	14	0.000
Control Group	VO_2max_Pre – VO_2max_Post	-9.75	14	0.000
	AAP_Pre – AAP_Post	0.702	14	0.494

AAP – Average Anaerobic Power

reported where improvements are observed for VO_2max in the intervention group, but the change in score did not differ significantly from that of the control group (Beattie et al., 2017; Ferrauti et al., 2010; Pellegrino et al., 2016).

Since for assessing VO_2max, 12-min Cooper Run/Walk test was used, literature has shown that strength training – induced neuromuscular adaptations including maximum strength, jumping power, and Post-activation potentiation (PAP) response, has beneficial effect on running performance, such as such as improved running economy and force production during running in endurance runners (Mikkola et al., 2011; Ramírez-Campillo et al., 2014; Blagrove et al., 2017). Running Economy (RE), which has been defined as oxygen uptake required at a given submaximal velocity (Ferrauti et al., 2010), has some neuromuscular characteristics such as muscle force and stiffness, fiber-type distribution, elasticity, or neural input (Guglielmo et al., 2009). These factors could also be improved by strength training (Jung, 2003; Laursen et al., 2005; Sunde et al., 2010), increasing the muscle work efficiency, and permitting aerobic activity at a lower oxygen consumption at submaximal intensities (Guglielmo et al. 2009; Millet et al., 2002; Paavolainen et al., 1999; Sunde et al., 2010; Taipale et al., 2010). Complex training elicits PAP response, which allows the athletes to produce more power on subsequent exercises (Carter & Jeremy, 2014). The specific mechanisms include stimulating high order motor unit recruitment and excitability, increasing phosphorylation of the myosin light chain, and changes in limb stiffness (Blagrove, Howatson & Hayes, 2018; Tillin & Bishop, 2009). These neuromuscular adaptations may also benefit long-distance performance such as improvement in RE and maximal running speed (Beattie et al., 2014; Blagrove, Howatson & Hayes, 2018). A study conducted by Li et al. (2019) to investigate the effect of complex training and heavy resistance training on running economy, neuromuscular and 5-km running performance concluded that 8-weeks of complex training as well as heavy resistance training did not improved VO_2max, but 5-km running performance was significantly improved. The author speculated that the 5-km performance improvements were due to the comprehensive effects of neuromuscular adaptations and running economy increase (Li et al., 2019).

Some of the researches conducted with longer intervention period has shown some improvement in VO_2max. Study conducted by Sporis, G. et al. (2011) had shown that 12 weeks of strength training may improve aerobic power by 4.6 percent among female soccer players (Sporis et al., 2011). Similar results have been reported by Gettman and Pollock (1981), Hickson (1980) and Hurley et al. (1984). No statistically significant changes were reported in VO_2max for any group in the majority of studies that assessed this parameter (Karsten et al., 2016; Vikmoen et al., 2016; Giovanelli et al., 2017; Johnston et al., 1997).

In a study on volleyball players, the impact of eight weeks of strength training on aerobic and anaerobic power was examined. The results showed that the experimental group, which included strength training in addition to regular volleyball training, significantly improved their anaerobic and aerobic power, while the control group, which included only traditional volleyball training, showed no differences (Bicer, 2021). Another study showed that after twelve-weeks of complex training, experimental group showed small increases in anaerobic power (less than 5%) among early pubertal boys (Ingle et al., 2006). This is in line with previous research that has reported absolute peak power between 400 and 420 W in trained 11- to 13-year-old boys (Docherty et al., 1987). Following complex training, mechanisms for improving anaerobic performance may involve greater force generation and neural adaptation. Mahon (2000) proposed that improved coordination and increased motor neurone firing rate were the causes of higher performance. Similar results were obtained by Ozmun, Mikesky, and Surburg (1994), who suggested that better contractile activity efficiency in young children was the product of neurological changes by measuring increased muscle activation using integrated electromyography after training. Because of this, complex training may improve the transfer of force between the concentric and eccentric phases of muscle activity and bestow a positive transfer of neuromuscular demands, leading to better coordination and synchronisation of active muscle groups (Chu, 1996).

Six weeks of complex training has significant effect on anaerobic power while it has lacks potential to produce significant increases in VO_2max. Resistance Training can be expected to improve concurrently both muscular and cardiovascular fitness within a single mode of resistance training when young and old persons have initially low fitness levels (Ozaki et al., 2013). Therefore, complex training can be integrated with regular training of respective sports to improvement of anaerobic power. Further research can be conducted with a longer intervention period or different participants to investigate its effect on aerobic power.

Conclusion

Based on the results of the study, it can be concluded that six weeks of complex training integrated with regular games training, can significantly improve anaerobic power, while it does not produce significant improvements in aerobic power among amateur athletes. Coaches and athletes can implement the complex training program in their training for improving their anaerobic power.

Acknowledgement

We would like to thank all the participants for being a part of this study. We also thank Dr. Deepak Sharma, Associate Professor, LNIPE Gwalior and Dr. Rahul Kanojiya, Assistant Professor, LNIPE Gwalior, for providing the necessary permissions.

Conflict of Interest

All authors declare no conflict of interest.

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ВПЛИВ КОМПЛЕКСНИХ ТРЕНУВАНЬ НА АЕРОБНУ ТА АНАЕРОБНУ ПОТУЖНІСТЬ СПОРТСМЕНІВ-ЛЮБИТЕЛІВ

Гопал Кумар[1ABCD], Вівек Пандей[1ABCD]

[1]Національний інститут фізичного виховання імені Лакшмі Бай

Авторський вклад: A – дизайн дослідження; B – збір даних; C – статаналіз; D – підготовка рукопису; E – збір коштів

Реферат. Стаття: 7 с., 4 табл., 53 джерела.

Метою дослідження було вивчення впливу комплексних тренувань на аеробну та анаеробну потужність спортсменів-любителів.

Матеріали та методи. Учасниками дослідження були 30 спортсменів-любителів – гравців у футбол і хокей, яких порівну розділили на дві групи, а саме: експериментальну групу, яка проходила 6 тижнів комплексних тренувань разом зі звичайними тренуваннями у своїх видах спорту, і контрольну групу, яка виконувала лише свої звичайні спортивні тренування. Анаеробну потужність оцінювали за допомогою анаеробного спринт-тесту на основі бігу (RAST), а аеробну потужність (максимальне споживання кисню – VO_2max) оцінювали за допомогою 12-хвилинного тесту Купера на біг/ходьбу. У дослідженні використовували план попереднього та підсумкового тестування на двох групах із випадковим розподілом учасників, а для аналізу даних як статистичний метод використовували парний t-критерій Стьюдента за рівня значущості 0,05.

Результати. Після завершення шести тижнів експериментальна група продемонструвала статистично значуще покращення анаеробної потужності та показника VO_2max, тоді як у контрольній групі покращився лише показник VO_2max ($p<0,05$). Статистично значущого покращення анаеробної потужності для контрольної групи не спостерігалося ($p>0,06$). Таким чином, це показує, що комплексні тренування мають значний вплив на анаеробну потужність, але не спричиняють значного покращення аеробної потужності.

Висновки. Шість тижнів комплексних тренувань у поєднанні зі звичайними спортивними тренуваннями можуть покращити анаеробну потужність. Тренери та спортсмени, зокрема в таких видах спорту, як футбол і хокей, можуть реалізувати програму комплексних тренувань у своїх звичайних тренуваннях.

Ключові слова: комплексні тренування, любитель, анаеробна потужність, аеробна потужність.

Information about the authors:

Kumar, Gopal: gopalk.kumar8@gmail.com; https://orcid.org/0000-0002-4764-3690; Department of Exercise Physiology, Lakshmibai National Institute of Physical Education, Shakti Nagar, Mela Road, Gwalior, 474002, India.

Pandey, Vivek: pandey_vivek61@yahoo.com; https://orcid.org/0000-0003-2247-0671; Department of Exercise Physiology, Lakshmibai National Institute of Physical Education, Shakti Nagar, Mela Road, Gwalior, 474002, India.

Cite this article as: Kumar, G., & Pandey, V. (2023). Effect of Complex Training on Aerobic and Anaerobic Power on amateur athletes. *Physical Education Theory and Methodology, 23*(1), 65-71. https://doi.org/10.17309/tmfv.2023.1.09

Received: 27.09.2022. Accepted: 15.01.2023. Published: 28.02.2023