

A REVIEW OF RESEARCH OF STRENGTH DEVELOPMENT USING COMPLEX TRAINING

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Abstract: Using complex training for developing strength is a method which is becoming more frequently used with athletes and one which is simply defined as a combination of heavier and lighter (plyometric) load within one series. The scientific study is based upon the assumption that complex training has given positive results in the development of explosive strength of professional athletes. The methodical procedure included an overview of research on the affects of complex training done in the last twenty years and up to now, using Google Scholar, PubMed, Scopus and Web of Science. The results of the reviewed studies mostly show that complex training has given positive effects with professional athletes, which were physically prepared.

Keywords: strength training, complex strength training, methods of strength development

INTRODUCTION

The basic criterion of evaluation in sports is the result, or success at the sports event, which requires permanent improvement of the content of sports training as a tool for achieving the goal, especially in the training of strength. Optimal training techniques designed to maximize power/force are of particular interest to fitness and sports trainers, as well as to sports scientists and researchers (Macdonald et al., 2013). Particularly interesting is the application and effects of complex strength training (CT), dealt also by a series of conducted studies (Eben, 1997; Backer, 2003; Chatzopoulos et al, 2007; Dobbs, Gill, Smart, McGuigan, 2015; Adams et al, 1992). Complex training is defined as changed classical training under load (higher loads) to which plyometric exercises (lower loads) are added within one series of exercises

PREGLED ISTRAŽIVANJA RAZVOJA SNAGE KOMPLEKSNIM TRENINGOM

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Sažetak: Kompleksni trening u razvoju snage je jedan od metoda koji se sve češće primenjuje kod sportista, a jednostavno se definiše kao kombinacija težih opterećenja i lakših (plimetrijskih) vežbi unutar jedne serije. U naučnu studiju se pošlo sa pretpostavkom da je kompleksni trening dao pozitivne rezultate na razvoj eksplozivne snage kod vrhunskih sportista. Metodski postupak je podrazumevao pregled dosadašnjih istraživanja preko pretraživača Google Scholar, PubMed, Scopus i Web of Science u proteklih dvadeset godina na temu uticaja kompleksnog treninga. Rezultati ukazuju na to da je u većini pregledanih naučnih radova kompleksni trening (KT) dao pozitivne efekte i to kod vrhunskih sportista koji su dobro fizički pripremljeni.

Cljučne reči: trening snage, kompleksni trening snage, metode razvoja snage.

Uvod

Osnovni kriterijum vrednovanja u sportu predstavlja rezultat, odnosno uspeh na sportskom takmičenju, što iziskuje permanentno unapređenje sadržaja sportskog treninga kao sredstava za ostvarivanje cilja, posebno u treningu snage. Optimalne trenažne tehnike dizajnirane da maksimalno povećaju karakteristike snage/sile su od posebnog interesa za kondicione i sportske trenere, kao i za sportske naučnike i istraživače (Macdonald et al., 2013). Posebno interesovanje se javlja za primenu i efekte kompleksnog treninga snage (KT) o čemu govori i niz sprovedenih istraživanja (Eben, 1997; Backer, 2003; Chatzopoulos i sar., 2007; Dobbs, Gill, Smart, McGuigan, 2015; Adams i sar., 1992). Kompleksni trening je definisan izmenom klasičnog treninga sa opterećenjem (teža opterećenja) kome su dodate plimetrijske vežbe (lakša opterećenja) unutar jedne serije vežbi (Eben,

(Eben, 1997; 2002; Sale, 2002). These two methods of performing strength exercises together form a complex pair and are considered to be the optimal strategy for increasing the strength through increased neuromuscular activity (Docherty et al., 2004, Adams et al., 1992), which is the result of an post-activation potentiation (PAP). PAP is a common technique used to induce short-term strength increase and generation of force during training and competition (Hodgson, Docherty, Robbins, 2005; Robbins, 2005), where previous intense muscular contractions increase subsequent force and strength level relative to the initial level. Mechanisms that cause PAP are associated with metabolic changes within the muscle (e.g., phosphorylation of light chain myosin; (Grange et al., 1993), as well as corrections of motoneurons and their irritability reflecting changes in H-reflex (Zucker and Regehr 2002; Misiaszek, 2003). The essence of PAP (post-activation potentiation) is in the action of high loads that cause a high degree of nerve stimulation. There are two basic ways of applying complex training from the aspect of load. One way refers to a combination of high and low loads which are performed between the series while the other way refers to the "super series" which is made up of high and low loads within one series. As complex training in modern training technology is increasingly applied, scientific questions arise which create a series of open questions for athletes, trainers and pedagogues of physical culture. One of the essential concerns of using CT relates to its objective effects on explosive strength, as well as on the profile of athletes who apply it, that is, whether they are top athletes or recreational athletes. The goal of the paper will therefore be to review and analyze the current studies on the subject of CT, where authors will try to answer the above questions.

METHOD

In order to make a more relevant overview of the previous research from the field of complex strength training, the authors have primarily opted for scientific papers which, on their own subject, deal with different effects of complex strength training in order to gain insight into the training effects. Scientific literature is available through *GoogleScholar*, *PubMed*, *Scopus* and *Web of Science*, while key words included "strength training", "complex strength training", "strength development methods". Search was limited to studies that have been conducted in the last 20 years. The study began with the assumption that complex training gave positive results on the development of explosive strength in athletes who are well-prepared.

1997; 2002; Sale, 2002). Ova dva načina izvođenja vežbi snage zajedno daju kompleksan par i smatraju se optimalnom strategijom u povećanju snage preko povećane neuromuskularne aktivnosti (Docherty i sar., 2004, Adams i sar., 1992) koja predstavlja rezultat post aktivacione potencijacije (PAP). PAP predstavlja uobičajenu tehniku koja se koristi za izazivanje kratkoročnog povećanja snage i razvoj sile tokom treninga i takmičenja (Hodgson, Docherty, Robbins, 2005; Robbins, 2005), gde prethodne intenzivne mišićne kontrakcije povećavaju naknadnu silu i manifestaciju snage u odnosu na početni nivo. Mehanizmi koje uzrokuju PAP povezani su sa metaboličkim promenama unutar mišića (npr. fosforilacija miozinskog lakog lanca; (Grange i sar., 1993), kao i korekcije motoneurona i njihova razdražljivost što se odražava promene H-refleksa (Zucker i Regehr 2002; Misiaszek, 2003). Suština PAP-a (postaktivacijske potencijacije) je u dejstvu velikih opterećenja koja uzrokuju visok stepen nervne stimulacije. Postoje dva osnovna načina primene kompleksnog treninga sa aspekta opterećenja. Prvi se odnosi na kombinaciju velikih i malih opterećenja koja se izvode između serija, dok se drugi način odnosi na tzv. "super serije", odnosno kombinacije većih i manjih opterećenja unutar jedne serije. Kako se kompleksni trening u savremnoj trenažnoj tehnologiji sve češće primenjuje, otvara se niz naučnih pitanja na koja treba dati odgovor kako bi treneri, pedagozi fizičke kulture i sportisti bili efikasniji prilikom primene kompleksnog metoda razvoja snage. Jedna od suštinskih nedoumica primene KT se odnosi na njegove objektivne efekte na eksplozivnu snagu, kao i na profil sportista koji ga primenjuju, odnosno da li se radi o vrhunskim sportistima ili o rekreativcima. Cilj rada će dakle biti usmeren na pregled i analizu dosadašnjih studija na temu kompleksnog treninga, gde će autori pokušati da odgovore na gore navedena pitanja.

METOD

U cilju pravljenja što relevantnijeg pregleda dosadašnjih istraživanja iz prostora kompleksnog treninga snage, autori su se prvenstveno opredelili za naučne radove koji po svojoj tematici istražuju različite efekte kompleksnog treninga snage, u cilju lakšeg uvida u trenažne efekte. Korištena je dostupna naučna literatura preko pretraživača Google Scholar, PubMed, Scopus i Web of Science, dok su ključne reči uključivale „trening snage“, „kompleksni trening snage“, „metode razvoja snage“. Pretraga je ograničena na studije koje su sprovedene u poslednjih 20 godina. U studiju se pošlo sa pretpostavkom da je kompleksni trening dao pozitivne rezultate na razvoj eksplozivne snage kod sportista koji su dobro pripremljeni.

RESULTS WITH DISCUSSION

Table 1. An overview of previous research related to complex training

REZULTATI SA DISKUSIJOM

Tabela 1. Pregled dosadašnjih istraživanja koja se odnose na kompleksni trening

Studija	N	Sport	Rezultati studije
Gossen & Sale (2000)	13 M 10 F	Mačevaoci	Kod muškaraca koji su u vrhunskom treningu može se očekivati povećanje vertikalne skočnosti i snage nogu metodom PAP.
Hamada, Sale, McDougall, & Tarnopolsky (2000)	20	Aktivni sportisti	Mišići sa kraćim vremenom trzaja imaju veću šansu da brže i efikasnije iskoriste PAP efekat u kompleksnom treningu.
Duthie, Young, Aitken (2002)	11	Žene različitog sporta	Kompleksni trening daje očekivano povećanje snage kod vrhunskih i fizički dobro pripremljenih sportistkinja.
Backer (2003a)	16	Ragbi igrači	U drugom setu vežbi sa opterećenjem nastaju najveći efekti kompleksnog treninga
Backer (2003b)	27	Ragbi igrači	Veliki broj ponavljanja u malom vremenskom periodu može da dovede do smanjenja efekata kompleksnog treninga.
Backer & Newton (2005)	24	Ragbi igrača	Snaga mišića nogu nakon primene kompleksnog treninga se povećala za 4,7% .
French, Kraemer, Cooke (2003)	14	Atletičari	Podaci ukazuju da izvođenje serije ponavljanja maksimalne izometrijske ekstenzije kolena (3 ponavljanja po 3 sekunde) pre izabrane dinamičke vežbe (# 0.25 sekunde) može imati povoljnije efekte na performanse u odnosu na standarde postignute bez prethodnog velikog opterećenja
Hamada et al. (2003)	20	Različiti sportisti	Mišićno vlakno koje je opterećeno trenigom ima uticaj na ispoljavanje PAP kao i na pojavu zamora od momenta trzaja do pojave PAP nakon primene kompleksnog treninga
Jensen & Ebben (2003)	21	NCAA lige - košarkaši	Kompleksni trening ne daje očekivane rezultate u poboljšanju visine vertikalnog skoka ako se skok ne izvede odmah nakon opeterećenja većom težinom u prvoj fazi (ne sme biti veća pauza)
Smith & Fry (2007)		Rekreativni vežbači	Rekreativci neće imati koristi od efekata postaktivacijske potencijacije tokom izvođenja vežbi sa različitim opterećenjem ako je oporavak između serija 7 minuta
Ingle, Sleep, Tolfrey (2006)	26	Nesportisti	Kompleksni trening daje malo povećanje snage eksplozivnog karaktera mišića ruku, ramenog pojasa i nogu u dinamičkim radnjama
Kukrić et al. (2009)	33	Košarkaši	Nema statistički značajne razlike između primene pliometrijskog i kompleksnog treninga
Chatzopoulos et al. (2007)	15	Košarkaši, fudbaleri, odbojkaši	Kompleksni trening može da poboljša brzinu trčanja ako se istrčavanja kratkih deonica primenjuju nakon 5 minuta od momenta vežbi sa opterećenjem
Folland, Wakamatsu, Fimland (2008)	8	Rekreativni vežbači	Nema uticaja na povećanje snage m. quadriceps-a
Dobbs, Gill, Smart, McGuigan (2015)	20	Atletičari	Kompleksni trening kroz dinamičke pokrete izaziva poboljšanje snage i veličine vertikalnog odraza

Study	N	Sport	Study results
Gossen& Sale (2000)	13 M 10 F	Swordsmen	In men who are in top training, it is possible to expect an increase in vertical jump and leg strength by using the PAP method.
Hamada, Sale, McDougall, & Tarnopolsky (2000)	20	Active athletes	Muscles with faster muscle twitches have a greater chance to use the PAP effect more quickly and effectively in complex training.
Duthie, Young, Aitken (2002)	11	Women engaged in different sports	Complex training gives the expected increase in strength in top-level and physically well-prepared sportswomen.
Backer (2003a)	16	Rugby players	The greatest effects of complex training are generated in the second set of exercises under load
Backer (2003b)	27	Rugby players	A high number of repetitions over a short period of time can lead to a reduction in the effects of complex training.
Backer&Newton (2005)	24	Rugby players	The strength of the leg muscles after the application of complex training increased by 4.7%.
French, Kraemer, Cooke (2003)	14	Athletes (athletics)	The data indicate that performing a series of repetitions of the maximum isometric knee extension (3 reps of 3 seconds) prior to the selected dynamic exercise (# 0.25 seconds) may have more favorable performance effects compared to the standards achieved without the previous high load.
Hamada et al. (2003)	20	Various athletes	The muscular fibers under load during training have an effect on the expression of PAP as well as on the appearance of fatigue from the moment of twitch to the onset of PAP after the application of complex training
Jensen&Ebben (2003)	21	NCAA Leagues – basketball players	Complex training does not give the expected results in improving the vertical jump if the jump is not performed immediately after the application of load with higher weight in the first stage (there must be no longer breaks)
Smith&Fry (2007)		Recreational athletes	Recreational athletes will not benefit from the effects of post-activation potentiation during exercises under different loads if the recovery between the series is 7 minutes
Ingle, Sleep, Tolfrey (2006)	26	Non-athletes	Complex training gives a slight increase in the explosive strength of the arms, shoulders and legs muscles in dynamic actions.

Kukrić et al. (2009)	33	Basketball players	There is no statistically significant difference between the application of plyometric and complex training.
Chatzopoulos et al. (2007)	15	Basketball, football and volleyball players	Complex training can improve running speeds if the running of short sections takes place after 5 minutes of the exercise under load.
Folland, Wakamatsu, Fimland (2008)	8	Recreational exercisers	No effect on increase of strength of quadriceps
Dobbs, Gill, Smart, McGuigan (2015)	20	Athletes (athletics)	Complex training through dynamic movements causes an increase in strength and size of the vertical jump.

In recent years, science has confirmed the trainer's assumptions and in research laboratories it has come to the conclusion that alternate use of high-load and low-load exercises can result in great training effects and increase in strength (Blakey, 1987; Ebben, Blackard, 1998; Duthie, Young, Aitken, 2002). Dynamic (Chatzopoulos et al, 2007, Kilduff et al, 2007), isometric (French, Kraemer, Cooke, 2003); Gossen and Sale, 2000; Hamada et al, 2000) and ballistic or plyometric (Hilfiker et al., 2007, Masamoto et al., 2003, Till & Kuk, 2009) contractions at maximum or sub-maximal load give positive results. According to the results of the research so far, it can be noticed that almost all research deal with active professional athletes, which can be justified by specific requirements and the construction of complex training.

Hamada, Sale, McDougall & Tarnopolsky (2000) found that faster-twitch muscles have a greater chance of using the PAP effect in complex training more quickly and efficiently. This fact explains why complex training is most commonly used in sports where explosive strength plays a dominant role. The question arises whether the use of CT is justified in sports where strength does not have a dominant role, which opens up space for further research on CT. The results of the Kukrić et al (2009) show that there is no statistically significant difference between the use of pure plyometric training and CT. This result confirms the effect of CT if we have in mind that it is conceived from a plyometric exercises.

The application of higher training loads, such as preloading with plyometric exercises, will lead to improvement in explosive motions. Previous performance of high-load exercises enables the next action to be temporarily enhanced due to increased excitation of the central nervous system (Jense et al, 1999; Fatouros et al, 2000). Consequently, the greatest effects of complex training are achieved in the second set of exercises, which is shown in the research by Backer (2003). Excitation of the central nervous system is the result of acute physiological adaptation, which lasts from 8 to 10 min and is called post-activation potentiation - PAP (Sale, 2002).

If PAP is performed in people who are physically fit, an increase of the explosive strength of the leg muscles may be expected, and hence the performance of the jump. However, the conditioned contraction leads to fatigue, so

Nauka je poslednjih godina potvrdila pretpostavke trenera i u istraživačkim laboratorijama došla do saznanja da se smanjenjem vežbi velikog i malog opterećenja može doći do velikih trenažnih efekata i napretka u snazi (Blakey, 1987; Ebben, Blackard, 1998; Duthie, Young, Aitken, 2002). Dinamičke (Chatzopoulos i sar., 2007, Kilduff i sar., 2007), izometrijske (French, Kraemer, Cooke, 2003); Gossen i Sale, 2000; Hamada i sar., 2000) i balističke ili pliometrijske (Hilfiker i sar., 2007, Masamoto i sar., 2003, Till i Kuk, 2009) kontrakcije pri maksimalnom ili submaksimalnim opterećenju daju pozitivne rezultate. Sagledano kroz rezultate dosadašnjih istraživanja može se uočiti da se u gotovo svim istraživanjima radi o aktivnim-profesionalnim sportistima, što se može objasniti specifičnim zahtevima i konstrukcijom kompleksnog treninga.

Hamada, Sale, McDougall i Tarnopolsky (2000), su ustanovili da mišići sa kraćim vremenom trzaja imaju veću šansu da brže i efikasnije iskoriste PAP efekat u kompleksnom treningu. Upravo ova činjenica objašnjava iz kog razloga se kompleksni trening primenjuje najčešće u sportovima gde eksplozivna snaga igra dominantnu ulogu. Postavlja se pitanje, da li je primena KT opravdana u sportovima u kojima snaga nema dominantnu ulogu i time se otvara prostor za dalja istraživanja na temu kompleksnog treninga. Rezultati studije Kukrić i sar. (2009), ukazuje na nepostojanje statistički značajne razlike u primeni čistog pliometrijskog treninga i KT. Ovim rezultatom se potvrđuje efekat kompleksnog treninga ako se uzme u obzir da je koncipiran od vežbi pliometrijskog karaktera.

Primena većih trenažnih opterećenja, kao predopterećenje pliometrijskim vežbama dovešće do poboljšanja eksplozivnih kretnji. Izvođenjem vežbi velikog opterećenja omogućuje se da naredna akcija bude privremeno poboljšana zbog povećanog nadražaja centralnog nervnog sistema (Jense i sar., 1999; Fatouros i sar., 2000). Samim tim se ostvaruju najveći efekti kompleksnog treninga u drugom setu vežbi, što pokazuje istraživanje Backer (2003). Ekscitacija centralnog nervnog sistema rezultat je akutne fiziološke adaptacije, koja traje od 8 do 10 minuta i naziva se postaktivacijska potencijacija-PAP (Sale, 2002).

Ukoliko se PAP izvodi kod ljudi koji su fizički spremni, može se očekivati povećanje eksplozivne sna-

the time of generation of fatigue and the effect of post-activation potentiation will greatly affect the manifestation of strength.

Post-activation potentiation depends on the volume and intensity of contractions caused by higher loading in the first part of the exercise (activity) and its duration (Tillin & Bishop, 2009). Therefore, in further research, it is necessary to see which performances of complex training and the time of its application (breaks between two loads) lead to the best results regarding the manifestation of strength.

In order to encourage further adaptation to specific training objectives, the progressive strength training protocols must be observed. Optimal characteristics of specific strength increase programs, including complex training, include the use of concentric, eccentric and isometric muscular contractions and the performance of bilateral and unilateral exercises. In addition, it is recommended that strength increase programs contain a series of exercises to optimize and preserve the intensity of the exercises (high load before a low load, large muscle groups must be affected before small muscle groups, stronger and higher intensity before low intensity).

CONCLUSION

Based on the literature reviewed, it can be concluded that the effect of complex training is greater if it is an active and top-level athletes. The effects of complex training depend on the progressiveness of the load, the overload, the ratio of the higher and the lower load, and the duration of the PAP effect. The effect of acute nerve excitation or PAP effect is a physiological response to high loads that favor a more efficient and explosive exercise of movements under lower load. The PAP effect is directly related to the intensity and duration of the pause between the series, otherwise the fatigue may occur which does not favor the execution of the "second phase" movement. The application of complex training in almost all of the examined studies has led to an increase in the manifestation of the explosive strength. Complex training gives the best results if applied to top athletes, or athletes who are well prepared, by properly dosing pauses between the series as one of the conditions on which the effect of CT depends, which can be seen as the general finding. What also may be seen from the literature reviewed is that the effect of complex training depends on the type of muscle fiber, that is, the fast-twitch muscle fibers efficiently use the PAP effect, which can be an "open field" for further scientific studies.

ge mišića nogu, a time i performansi skoka. Međutim, uslovljena kontrakcija dovodi do zamora, pa će vreme nastajanja zamora i dejstvo postaktivacijskog potencijala u velikoj meri uticati na ispoljavanje snage.

Postaktivacijska potencijacija zavisi od obima i intenziteta kontrakcija izazvanih većim opterećenjem u prvom delu vežbe (aktivnosti) i vremena njegovog trajanja (Tillin, & Bishop, 2009). Zato je potrebno u daljim istraživanjima sagledati od kojih sve performansi kompleksnog treninga i vremena njegove primene (pauze između dva opterećenja) se ostvaruju najbolji rezultati na ispoljavanje snage.

U cilju podsticanja daljeg prilagođavanja ka određenim ciljevima treninga, moraju se poštovati protokoli progresivnog treninga snage. Optimalne karakteristike specifičnih programa snage, pa i kompleksnog treninga uključuju upotrebu koncentričnih, ekscentričnih, i izometrijskih mišićnih kontrakcija i performansi bilateralnih i unilateralnih vežbi. Pored toga, preporučuje se da programi snage sadrže niz vežbi za optimizaciju i očuvanje intenziteta vežbi (veliko opterećenje pre malog opterećenja, velike mišićne grupe moraju biti zahvaćene pre malih mišićnih grupa, jači i veći intenzitet pre manjeg intenziteta).

ZAKLJUČAK

Na osnovu pregledane literature, može se izvesti zaključak da je efekat kompleksnog treninga veći ukoliko se radi o aktivnim i vrhunskim sportistima. Efekti kompleksnog treninga zavise od progresivnosti opterećenja, preopterećenja, odnosa većeg i manjeg opterećenja kao i dužine PAP efekta. Efekat akutne nervne nadraženosti ili PAP efekat, je fiziološki odgovor na velika opterećenja koja pogoduju efikasnijem i eksplozivnijem izvršavanju pokreta pod manjim opterećenjem. PAP efekat je i direktnoj vezi sa intenzitetom i vremenom trajanja pauze između serije, jer u suprotnom može doći do zamora koji ne pogoduje izvršavanju pokreta "druge faze". Primena kompleksnog treninga je u gotovo svim sagledanim istraživanjima dovela do povećanja ispoljavanja eksplozivne snage. Kompleksni treninga daje najbolje rezultate ukoliko se primenjuje kod vrhunskih sportista, odnosno kod sportista koji su dobro pripremljeni, i to pravilnim doziranjem pauza između serija kao jedan od uslova od kojih zavisi efekat kompleksnog treninga, što se može posmatrati i kao generalni zaljučak. Ono što se još može uočiti na osnovu pregledane literature je da efekat kompleksnog treninga zavisi od tipa mišićnog vlakna, odnosno da mišićna vlakna brzog trzaja efikasnije koriste PAP efekat, što može da bude "otvoren ulaz" za dalje naučne studije.

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