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„The combination of strength and power training to enhance athletic sports performance: A systematic review "

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Abstract

It is well established in the literature that combined strength and power trainings have a high impact on various parts of the force-velocity curve and subsequently sports performance (Cormie et al., 2011). Especially the concept of complex training, where strength and power are combined in one training session has gained popularity in the last years (Hammami et al., 2016; Kobal et al., 2016; Ronnestad et al., 2008). However, the effectiveness of this training concept remain unclear. Therefore, we conducted a systematic review in four electronic databases (Pubmed, Web of Science, SportDiscus, CINHAL and Scopus). In total, 29 trials met the in- and exclusion criteria. The content of included studies (i.e.: subjects, training intervention, outcome measures, etc.) was critically analysed. Additionally, the methodological quality was assessed by the 11 item PEDro scale (Maher et al., 2003). Overall the quality of included trials was poor to fair (Foley et al., 2003). However, it seems that complex training is effective to improve jump, sprint and strength performance compared to no training (i.e.: control). The analysis revealed that complex training is similar effective as traditional training methods. To maximize the transfer to sports performance, literature suggests that training interventions should consist of movements similar to those used in competition. However, our findings are limited because of qualitative evaluation. A systematic review with meta-analysis should confirm these findings quantitively.

Key words: Complex training; Strength training; Power training; Athletic performance

Kurzzusammenfassung

Trainingsformen bei der Kraft- und Schnellkraftinhalte kombiniert werden, werden in der Literatur mit hohem Interesse diskutiert. Diesbezüglich wird der hohe Einfluss hinsichtlich der Kraft-Geschwindigkeitskurve beschrieben, die im Folgenden die sportspezifische Leistungsfähigkeit steigern soll (Cormie et al., 2011). Im speziellen generiert die Methode des Komplextrainings, bei dem Kraft und Schnellkraftinhalte in einer Trainingseinheit kombiniert werden, einen Anstieg verschiedener Leistungsvariablen (Hammami et al., 2016; Kobal et al., 2016; Ronnestad et al., 2008). Aufgrund der heterogenen Studienergebnisse wurde diese systematische Übersichtsarbeit erstellt um das Komplextraining hinsichtlich ihres Effektes zu evaluieren. Dazu wurde in 4 elektronischen Datenbanken (Pubmed, Web of Science, SportDiscus, CINHAL and Scopus) relevante Studien identifiziert. Im Zuge des Such- und Selektionsprozesses konnten 29 Studien eingeschlossen werden. Zusätzlich wurden die eingeschlossenen Untersuchungen mit Hilfe der PEDro Skala geprüft (Maher et al., 2003), bei der eine schlechte bis durchschnittliche Validität festgestellt wurde (Foley et al., 2003). Die Ergebnisse der systematischen Evaluierung zeigten, dass ein Komplextraining im Vergleich zu einer inaktiven Kontrollgruppe klar im Vorteil ist. Gegenüber anderen Trainingsinterventionen können keine eindeutigen Verbesserungen gezeigt werden. Um einen möglichst hohen Effekt erzielen zu können, sollten sportartspezifische Bewegungsmuster in einem Komplextraining implementiert werden. Eine quantitative Analyse sollte weitere Aufschlüsse hinsichtlich dieser Trainingsintervention geben können.

Schlagwörter: Komplextraining; Krafttraining; Schnellkrafttraining; sportliche Leistung

Thank you…

… Pascal for your support and collaboration to realise this systematic review.

… my parents for giving me the opportunity and support throughout the time of being a student.

… and finally, my girlfriend, Lisa, to be with me in all kind of situations and pushing me forward.

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1 Introduction

To succeed in individual and team sports it is necessary to perform the most general movement patterns, like sprinting, jumping or the change of direction at an exceptional high level. Therefore, athletes have to generate maximal external forces in the (minimum) available time (Suchomel et al., 2016; Baker, 2001).

Literature suggests that there is a high correlation between the strength level and athletic performance (Suchomel et al., 2016). Thus, a basic strength level is critical to enhance sports performance (Suchomel et al., 2016; Cormie, et al., 2011; Comfort, 2013; Wisloff, 2004).

On the other hand, sports performance can also be enhanced through plyometric or explosive training. These training methods are especially effective for athletes already possessing high strength levels (Villareal et al., 2009; Cormie et al., 2011). Indeed, many authors propose that both training methods should be used in the preparation of athletes (Cormie et al., 2011).

Furthermore, several investigators have observed the high potential in combining these two methods in one training session. It is postulated that athletes can improve general strength and specific athletic performances at the same time, without having to divide the two training methods into separate training sessions. This theory is supported by several investigations, which examined the combination of resistance and power training (Verkoshansky and Tetyan, 1973, Ebben, 2002; Kotzmanidis et al., 2005; Ronnestad et al., 2008; Walker et al., 2010; Rodriguez-Rosell et al., 2015, Lesinski, et al., 2014). In contrast, some well-designed studies failed to find any effect of combined training methods compared to traditional training programs (Alemdaroglu et al., 2013, Wallenta et al., 2016). Therefore, the aim of this thesis is a systematically summarise to the previous findings of this topic. The author wants to evaluate, if a combined training programme can enhance athletic performance and if it is superior to traditional training methods.

Additionally, careful inspection of the scientific literature reveals that the investigators do not use consisted definitions to describe the combined training methods (Duthie et al., 2002). The most frequently used terms for a combined strength and power training are complex training, contrast training, combined training, compound training, maxex training, mixed method training (Verkhoshansky & Tetyan, 1973; Fleck and Kontor, 1986; Newton and Kraemer, 1994; Chu, 1996; Ebben und Watts, 1998; Bompa,1999; Mihalik, et al., 2008 and Carter and Greenwood, 2014).

Therefore, a secondary aim of this thesis is to propose a model to define the different training methods. This thesis will potentially extend the knowledge of sport science staff in this field and gives advice for further research.

Objectives

Due to the aforementioned problem, the following research questions can be formulated:

RQ1: Can athletes enhance strength, sprint, jump and agility performance with a combined strength and power training?

RQ2: Are these training methods superior to traditional training methods?

RQ3: Is there an influence of age, training level or the method of combining strength and power training on the outcome variables?

2 Theory

2.1 Influence of Strength and Power Training on Athletes Performance

To discuss the influences of maximal power production in sports it is necessary to understand the basic biomechanical definition of power. Power is determined by the product of force and velocity as demonstrated below.

„Power = Work / Time

Power = Force x Distance / Time

Power = Force x Velocity" (Kawamori & Haff, 2004, S. 675)

This mathematical equation exhibits the high impact and interaction of force and velocity on mechanical power. The inverse relationship of high force and high velocity is demonstrated in figure 1 (Haff and Nimphius, 2012).

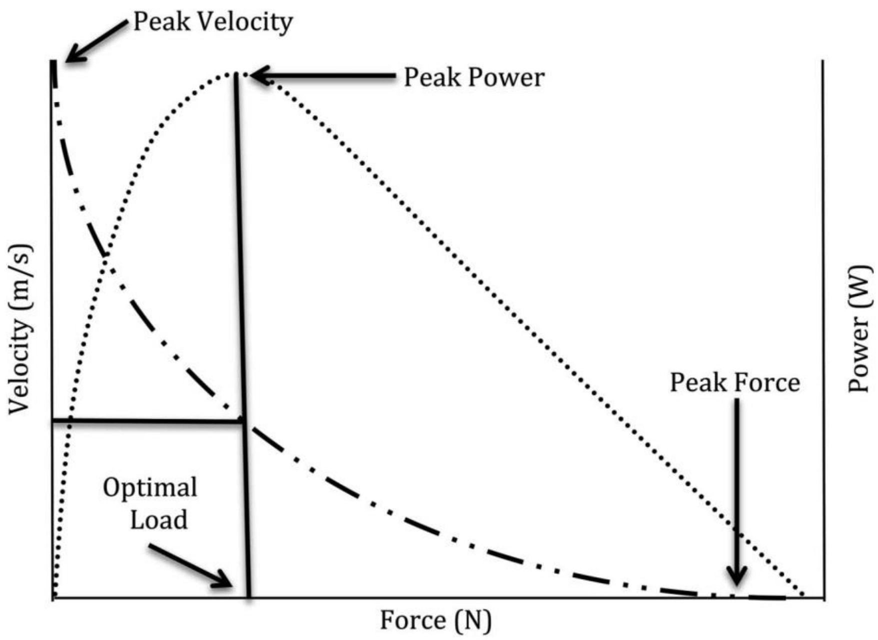

Figure1: Force-velocity, force-power, velocity power, and optimal load relationship (Haff and Nimphius, 2012, S. 4. Cited and adapted to Newton and Kraemer, 1994 and Kawamori and Haff, 2004)

Regarding to the development of athletes performance, it is necessary to apply both, force and velocity. Therefore, individuals should be first relatively strong, to generate maximal external power (Cormie et al., 2011; Suchomel et al., 2016). Haff and colleagues (1997) pointed out, that weaker athletes are not able to produce maximal force as fast as stronger athletes. Therefore, heavy resistance training result in a right ward shift of the force-velocity curve. Consequently, lighter loads can be moved with a higher velocity. Regarding to this finding, Seitz et al., (2014) pointed out that lower body strength improvements leads to better sprint times.

Beside the adaptions of maximal strength training, ballistic or plyometric exercises could potentially require specific improvements to the rate of force development (RFD) and furthermore enhance movement velocity in different movement patterns, like sprinting or jumping (Newton and Kraemer, 1994; Suchomel et al., 2016; Kawamori and Haff 2004, Cormie et al., 2011). Therefore the RFD is considered as the second important variable to increase power output, beside the force-velocity relationship (Suchomel et al., 2016). The theory is determined by the rate of rising muscle force and is a primary factor in an explosive movement patterns (Suchomel et al., 2016; Andersen and Aagaard, 2006). Thus, it is recommended that sport scientists and practitioners implement various training methods to target the specific demand of sports and subsequently realise the optimum level of strength and explosiveness (see figure 2).

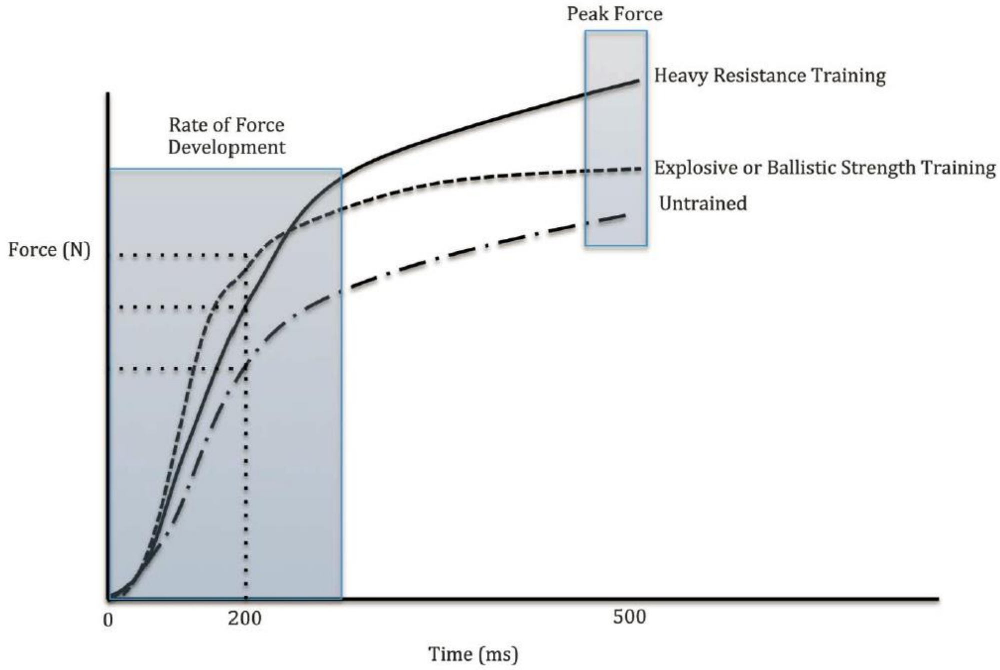

Figure 2: Theory to influence the RFD by specific training interventions (Haff and Nimphius, 2012, S. 6. Cited and adapted from Newton and Kraemer, 1994)

To specify plyometric training and the transfer from training to sport specific skills, explosive training can be further divided into two methods, related to the stretch-shortening cycle (SSC). The SSC takes place in movements where an eccentric contraction proceed a concentric phase. In this order, a specific amount of potential energy could be stored and partially recovered throughout the following concentric contraction (Komi and Bosco, 1978).

Villareal and colleagues (2009) pointed out, that training with the SSC seems to be superior to training methods without SSC, to enhance vertical jump height. Specifically, the short SSC (e. g. drop jump, DJ) produce somewhat greater enhancements in comparison to the long SSC (e. g. countermovement jump, CMJ).

Adaptions to the RFD are caused by explosive training interventions and should be a main part in athletes development. Especially for those, who perform their specific sport movements below 300 milliseconds (Newton and Kraemer, 1994; Haff and Nimphius, 2012).

Strength and power training can be done in several ways, therefore, different prescriptions result in different adaptions. To understood the influence of various movement patterns, loads and velocities, the specific interactions are outlined in the sections below.

2.1.1 Adaptions Based on Specific Movement Patterns

Traditional resistance exercises are suggested to improve peak power and furthermore general sports specific movements (Suchomel et al., 2016; Cormie et al., 2011). Nevertheless, due to the increased antagonist muscle activation to reduce speed at the end of the movement, the transfer effect of traditional resistance exercises is somehow restricted (Cormie et al., 2011).

Consequently, traditional resistance exercises are typically utilised with heavy loads, because heavy load prescriptions result in lower movement velocities and furthermore result in a shorter deceleration phase (Cormie et al., 2007; Cormie et al., 2011; Newton et al., 1996). Accordingly, traditional resistance training should be used in the early phases of training and/or with weaker athletes. For stronger athletes, more specific movements are necessary to enhance maximal power production (Cormie et al., 2011).

One of these specific movement patterns are ballistic exercises. Within this method, an athlete uses a wide range of loads, from 0 to 80 % of 1RM (Cormie et al., 2007; Newton et al., 1996). In comparison to traditional strength training, literature suggests that this training method is more similar, to sport specific movement patterns. Furthermore, movement velocity, force production, power output and muscle activation are higher than those are generated with traditional resistance exercises (Cormie et al., 2007; Newton et al., 1996).

It should be noted that plyometric training interventions are ballistic in nature, but are typically performed in an unloaded or light loaded fashion. Therefore, SSC can be maximised and an athlete can generate maximal force in minimum time (Villareal et al., 2009). Specific adaptions to plyometric training are similarly to ballistic training and cause in specific adaptions to the neural system, the muscle-tendon complex, and additionally enhance RFD (Villareal et al., 2009; Schmidtbleicher, 1992).

Weightlifting exercises are the fourth common movement pattern to develop athletes performance. This specific movements can be described as a mix of ballistic and traditional resistance training. While performing a snatch, clean and jerk or some derivatives, athletes have to accelerate through the whole concentric phase and decelerate their body mass explosively to prepare the catch and the end of the motion (Cormie et al., 2011; Garhammer 1992; Schilling et al., 2002). The high transfer of weightlifting to sport specific movements is attributed to the similar kinematic values. Authors suggest that weightlifting exercises can be used effectively to enhance RFD and performance in jumps and sprints. Particularly this method should be utilised by athletes which have to move heavy loads, explosively, like football linemans (Hori et al., 2005; Suchomel et al., 2017; Carlock et al., 2004).

2.1.2 Adaptions Based on Specific Loads

Beside the specific adaptions to different movement patterns, the applied load is linked to specific adaptions. Therefore, power output is highly variable in context to the given load (Cormie et al., 2011). For instance, maximal power output varies from 37 % of 1RM to 85 % of 1RM, in the case of an unloaded or loaded CMJ. Consequently, the various loads, cause in different physiological adaptions and develop different parts of the force-velocity curve (Cormie et al., 2007).

Heavy loads (> 79 % 1RM) maximise muscular strength and additionally enhance power output, by two main theories (Moss et al., 1997; Häkkinen et al., 1985; Wilson et al., 1993). First, the inherent relationship between force and power leads to improvements of maximal strength and maximal power (Moss et al., 1997; Wilson et al., 1993; Cormie et al., 2011). Second, due to the size principle for motor unit recruitment, type 2 muscle fibres are innervated first, which is essential for powerful movements in sports (Schmidtbleicher and Bührle, 1987). Heavy loads were commonly performed with ballistic, weightlifting and traditional movement pattern (Cormie et al., 2011) and seem to be superior to sport specific movements under loaded conditions. Consequently, athletes which have to perform high external forces (e.g. rugby or football lineman), specifically benefit from training regimes with heavy weights (Moss et al., 1997; Haff and Nimphius, 2012).

In contrast, light loaded exercises are usually done with weights below 60 % of 1RM and are commonly performed in a ballistic or plyometric movement pattern (Cormie et al., 2011; Moss et al., 1997; Winchester et al, 2008). Studies found substantial improvements in power output and athletic performance with plyometric or ballistic training methods (Cormie et al., 2011). Contrary, the use of light loads in traditional resistance training, does not require any adequate training effect. Subsequently, athletes who apply low external forces in movement patterns benefit from interventions with light loaded exercises (Newton and Kraemer, 1994).

Beside to light and heavy loaded protocols, literature propose to perform movements with the optimal load (figure 1) to improve maximal power output (Cormie et al., 2007). Soriano et al., (2015) examined adaptions of an optimal loaded training and suggest the usage of different loads for different movements, depending on the specific biomechanical requirements. For instance, peak power in weightlifting exercises, is achieved with loads more than 70 % of 1RM, while peak power of jump squats is reached with loads of approximately 0-30 % of 1RM. Nevertheless, literature is indistinct if an intervention period with optimal loads is superior, to other load prescriptions (Soriano et al., 2015; Cormie et al., 2011; Crewther et al., 2005; Haff and Nimphius, 2012).

Summed up, different adaptions are the consequence of various loading conditions. Therefore, literature supposes to train with different loads, to target all areas of the RFD curve (Cormie et al., 2011; Cormie et al., 2007; Haff and Potteiger., 2001; Soriano et al., 2015). Nevertheless, further research is necessary to give a valid statement throughout various strength levels (Cormie et al., 2011).

2.1.3 Adaptions Based on Specific Movement Velocities

In the literature two theories are concerning the enhancement of athletes performance, due to the given velocity in training exercises (Cormie et al., 2011). First, similar movement velocities in training and sport specific movements suggest a high transfer and a specific adaption to the RFD curve (Narici et al., 1989; Moffroid and Whipple, 1970; Lesmens 1978; Coyle et al., 1981; Caiozzo et al., 1981; Kanehisa and Miyashita, 1983). Second, adaptions seem to be superior, if movements are done with the intention to move as explosive as possible (Häkkinen et al., 1985; Fielding et al., 2002). Consequently, athletes should achieve a similar velocity, than in sports movements and with the intention to perform as fast as possible, to guarantee a high transfer from athletic training to sports performance.

2.2 Combination of Various Training Methods

As shown before, different methods within different conditions undergoes specific physiological and performance adaptions. To guarantee a high transfer effect from training to complex sports performances, sport scientists and practitioners investigated different combinations of training methods. In case of power related movements, athletes must generate maximal RFD and subsequently utilise peak force as fast as possible. Therefore, the combination of different methods seem to be more effective than performing them independently (Adams et al., 1992; Duthie et al., 2002; Cormie et al., 2011). This combined training approach is supported by the theory to improve all parts of the force-velocity curve (Haff and Nimphius 2012; Haff and Potteiger, 2001; Cormie et al., 2011; Suchomel et al., 2016; Cornin and Sleivert, 2005).

Consequently, the aforementioned aim of this thesis is to examine the effect of a combined strength and power training, performed in the same training session. Thus, the most common methods should be evaluated if they are superior to other training methods to improve peak power output and subsequently sports performance (Verkhoshansky and Tetyan, 1973, Ebben, 2002; Kotzmanidis et al., 2005; Ronnestad et al., 2008; Walker et al., 2010; Rodriguez-Rosell et al., 2015, Lesinski et al., 2014; Duthie et al., 2002).

2.2.1 Definition of Combined Strength and Power Training, from Up to Now

One of the first scientists who investigated the combination of strength and power contents in one training session was Verkhoshansky (1966).

Unfortunately, the author did not provide sufficient information about the training load, intensity and other training variables. Additionally, Verkhoshansky did not use any specific phrases like “complex-” or “contrast training” to describe the training method, in his paper. The author only used the wording to describe the “complex nerve muscle interaction and the complex relationship of heavy and light loaded exercises” (Verkhoshansky, 1966).

Next to Verkhoshansky (1966), Fleck and Kontor (1986) advocated a combined strength and power training. As one of the first investigators the authors used the term “complex training” to define a combined strength and power training in the same session. Interestingly, the paper was written after a NSCA (National Strength and Conditioning) conference in Moscow, while Fleck and Kontor attended a lecture of Verkhoshansky. The authors pointed out that “complex training” is defined by continuously alternating a block of a strength exercise and a biomechanically similar block of a plyometric exercise. For instance, 3 sets squats are immediately in front of 3 sets depth jumps and consequently were described as a complex pair. Figure 3, shows how Fleck and Kontor (1986) suggest to carry out complex training.

Complex 1

Back squats: 2 x 2-3 repetitions at 90% of 1 RM.
Perform the concentric and eccentric portions slowly
Rest Periods: 3-4 minutes between sets
4-6 minutes after both sets
Depth Jumps: 2 x 10. Recommended height: .75 meters
Rest Periods: 3-4 minutes between sets
Perform the complex 2-3 times per training session with 8-10 minutes of rest between complexes.

Complex 2

Back Squats: 2 x 2-3 repetitions at 90% of 1 RM.
Perform the concentric and eccentric portions slowly
Rest Periods: 3-4 minutes between sets
4-6 minutes after both sets
Sequence of 5 standing long jumps: 2 x 6 repetitions (5 jumps = 1 repetition) Sequence is (L, R, L, R, both)
Rest Periods: 3-4 minutes between sets
Perform the complex 2-3 times per training session with 8-10 minutes between complexes.

Figure 3: Complex training designed by Fleck and Kontor (Fleck and Kontor, 1986, S. 67)

Furthermore, Chu (1996) influenced the wording of combined strength and power training. The author pointed out that complex training is improving peak power output better than other training methods. Unfortunately, it was unclear if he supposes a block by block protocol (multiple sets of strength exercises before multiple sets of power exercises) or a training protocol which alternates in a set by set basis. During an email conversation (13th December, 2016) Dr. Chu stated to perform a strength exercise and a biomechanical similar power related exercise alternating in a set by set basis.

The recommendations of Fleck and Kontor (1986) and Chu (1996) lead to some confusion because both publications use the term complex training, but showed different training protocols. Therefore, Fleck and Kontor (1986) annotated a block by block training while Chu (1996) suggested alternating in a set by set basis. Also, Baker (2001) reported that Fleck and Kontor (1986) used the incorrect definition and the training program should be defined as contrast training instead of complex training. To the authors knowledge the term contrast training was defined a few years earlier by the same author (Baker, 1995). He defined the training method to the use of contrast loads and exercises. Therefore, he suggests to alternate a heavy loaded exercises and biomechanical similar light loaded exercise in a set by set basis (Baker, 1995).

In addition to that, Young et al., (1998) used the words contrast and complex interchangeably and created further confusion in this research area (Duthie, 2002). In a systematic review Ebben (2002) pointed out the effectiveness of a complex training a described how to use this method in a training process. Many authors described the training program and called it complex training (Adams et al., 1992; Chu 1995; Chu 1996; Ebben et al., 2000; Ebben and Watts, 1998; Fleck 1986; Verkhoshansky and Medvedyev, 1986; Verkhoshansky and Tetyan, 1973).

To clarify the inconsistent definitions, table 1 provides a possible solution for further research in this area and how to understand the terms in this thesis. Basically, all types of a combined strength and power training in one training session are defined as *complex training* in this model. This classification follows the previous findings of Verkhoshansky (1966), because he supposes that these different movement patterns, cause in complex mechanism to the nerve muscle interaction in case of heavy and light loaded exercises. To perform a combined strength and power training, in literature three main approaches throughout a complex training could be identified (table 1). Further methods which use a combination throughout a training process, can be understood as periodisation models (Issurin, 2010).

Block contrast load (BCL) is designed by Fleck and Kontor (1986) based on the work Verkoshansky (1966), but the authors used in their wording complex training. BCL follows the training regime of several sets of a strength exercise (e. g. heavy loaded squat) prior to several sets of a power exercise (e. g. CMJ). Furthermore, these two biomechanical similar exercises are described as a complex pair. Based on these prescription, multiple complex pairs build up a training session.

Combined load (COMB) is similarly to BCL, but in contrary all strength exercises and sets are performed after each other. Subsequently, all power related exercises are done immediately after the last set of the entire strength exercises (Ronnestad et al., 2008; Arabatzi et al., 2010; Franco-Marquez et al., 2015).

The third method is *contrast load (CL),* based on the description of Baker (2001, 2003) and Young and colleagues (1998). CL alternates strength exercises (e. g. heavy loaded squat) and power exercises (e. g. CMJ) in a set by set basis.

Additionally, some authors also studied the outcomes of a "reverse complex training" where strength exercises are performed after the power (Alemdaroglu et al., 2013; Kobal et al., 2016; and Talpey et al., 2016). The author of this thesis will define these methods as reverse block contrast load (RevBCL), reverse combined load (RevCOMB) or reverse contrast load (RevCL).

Further methods using longer rest periods between the two components, are named as undulating periodisation. Therefore, *compound load (COMP),* is defined as a training method whereas strength and power contents are separated from each other, but stay in a temporal context (Mihalik, et al., 2008; Arazi et al., 2014).

Combining strength and power in different micro-, meso- and macrocycles could be understood as *block periodisation (BKP*; Issurin, 2010).

Table 1: Modelling complex training methods

Complex Training

	Contrast Loads
	Within one Workout
Complex pair 1	Strength Set
	Power Set
	Strength Set
	Power Set
	Strength Set
	Power Set
Complex pair 2	Strength Set
	Power Set
	Strength Set
	Power Set
	Strength Set
	Power Set
Complex pair 3	Strength Set
	Power Set
	Strength Set
	Power Set
	Strength Set
	Power Set

	Block Contrast Loads
	Within one Workout
Complex pair 1	Strength Set
	Strength Set
	Strength Set
	Power Set
	Power Set
	Power Set
Complex pair 2	Strength Set
	Strength Set
	Strength Set
	Power Set
	Power Set
	Power Set
Complex pair 3	Strength Set
	Strength Set
	Strength Set
	Power Set
	Power Set
	Power Set

	Combined Loads
	Within one Workout
Strength	Strength Set
	Strength Set
	Strength Set
	Strength Set
	Strength Set
	Strength Set
	Strength Set
	Strength Set
	Strength Set
Power	Power Set
	Power Set
	Power Set
	Power Set
	Power Set
	Power Set
	Power Set
	Power Set
	Power Set

Further periodisation models

	Compound Loads		
	Day 1		Day 2
Strength	Strength	Power	Power
	Strength		Power
	Strength		Power
	Strength		Power
	Strength		Power
	Strength		Power
	Strength		Power
	Strength		Power
	Strength		Power

	Block periodisation		
	Meso I		Meso II
Strength	Strength	Power	Power
	Strength		Power
	Strength		Power
	Strength		Power
	Strength		Power
	Strength		Power
	Strength		Power
	Strength		Power
	Strength		Power
	Strength		Power
	Strength		Power
	Strength		Power
	Strength		Power
	Strength		Power
	Strength		Power

2.2.2 Underlying Mechanism – Post Activation Potentiation (PAP)

In general, PAP is defined as an acute improvement of athletes explosive performance after performing a conditioning activity (CA). Furthermore, authors use the PAP-effect as a rational for the effectiveness of complex training intervention (Docherty et al, 2004; Robbins and Docherty, 2005; Lesinski et al., 2014; Lorenzo, 2011; Ebben and Watts, 1998; Ebben, 2002; Hodgson et al., 2005). In contrast, Sale (2002) pointed out, that PAP should be understood as acute muscle phenomenon. In this case, a training intervention would not enhance PAP and subsequently sports performance. Lesinski and colleagues (2014) reviewed the complex training approach and annotated that further investigations are necessary, if PAP is responsible for the benefits during a long-term training programs.

In the literature PAP is explained by two physiological processes. First, the phosphorylation of myosin regulatory light chains (Grange et al., 1993) and second, the recruitment of higher order motor units (Güllich and Schmidtbleicher, 1996). Sale (2002) as well as Güllich and Schmidtbleicher (1996) pointed out that PAP results neither in a development of peak force, nor in a development of peck velocity. Nevertheless, power output results on a higher force production to a given velocity after performing a CA. This effect is determined due to a rightward shift of the RFD curve, without any changes at the endpoints. These adaptions seem to improve sport specific movements, especially in sports with light load situations, for instance in jumping, sprinting or throwing conditions (Sale, 2002; Güllich and Schmidtbleicher, 1996).

To effectively use PAP two main things should be addressed (see also figure 4). First, the potential to enhance performance is related to the balance between PAP and fatigue after performing a CA. Second, the recovery time after the CA is essential to use a high PAP-effect. Therefore, it should be mentioned that a longer rest period results in a better recovery after CA but also PAP effects should disappear over time (Sale, 2002). Consequently, it is important to figure out if and when the PAP-fatigue balance is positive and performance is improved.

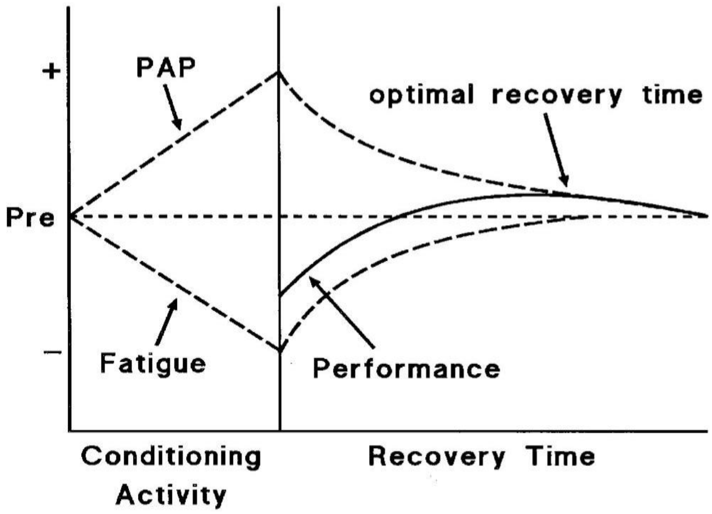

Figure 4: Exploiting PAP (Sale, 2002, p. 142)

Systematic reviews with meta-analysis showed small to large effects of PAP during athletic performance (Seitz and Haff, 2015; Wilson et al.,2013). In general, the authors pointed out that PAP is influenced by various variables and probably underlies to a responder versus non-responder phenomenon. Tillin and Bishop (2009) summarises the complex interaction of possible variables affecting the PAP-effect (figure 5).

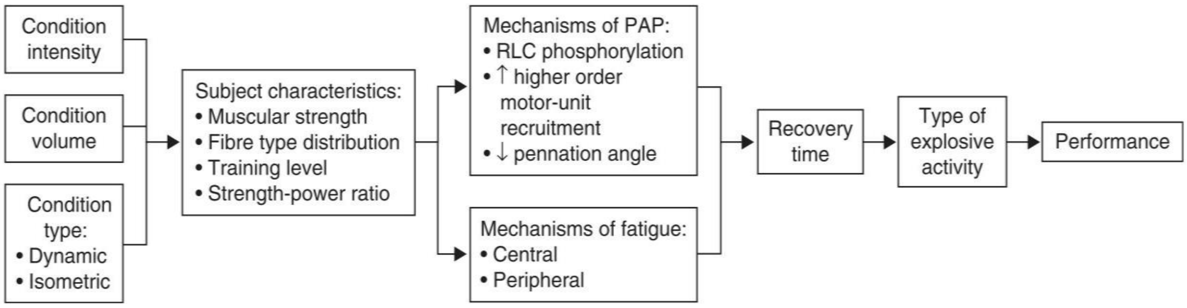

Figure 5: Factors to influence performance after CA (Tillin & Bishop, 2009)

Conditioning activity and PAP

The CA is responsible for the specific amount of PAP and fatigue and cannot be generalised for various exercise prescriptions (Seitz and Haff, 2015; Wilson et al., 2013). Seitz and Haff (2015) reported higher PAP-effects following maximal loaded squats in comparison to submaximal squats. In contrast, Wilson et al., (2013) reported superior PAP effects for moderate versus maximal loads. The inconsistent outcomes can potentially be attributed to a variable amount of fatigue. Furthermore, plyometric exercises are also effective as a CA and it seems that under certain circumstances plyometric exercises are even superior to strength exercise as CAs.

In relation to the given volume for a CA, literature suggests a higher PAP effect after performing multiple sets instead performing single sets. However, the increased amount of fatigue for untrained subjects can outweighs the PAP-effect and therefore multiple sets seems to be better suited for stronger athletes (Seitz and Haff, 2015; Wilson et al., 2013).

Moreover, the high effect of PAP in dynamic, eccentric-concentric movement patterns cannot be found to CAs to maximal isometric contractions. Thus, Tillin and Bishop (2009) suggested that kinematics of a CA and post exercise should be matched closely to generate maximal PAP response.

Subjects characteristic and PAP

The PAP-fatigue relationship after performing a CA depend on individual subject characteristics and can therefore not be generalised. Nevertheless, a high strength level is associated with a better PAP response compared to low strength levels (Seitz and Haff, 2015; Wilson et al., 2013; Tillin and Bishop, 2009). Literature suggests that stronger athletes may have a higher portion of type II muscle fibres in comparison to weaker athletes. Due to the composition in muscle fibres, performance results in greater phosphorylation of myosin light chain and could consequently enhances fatigue resistance (Seitz and Haff., 2015; Maughan et al., 1983; Aagaard and Andersen, 1998; Moore, 1984; Chiu, 2003; Tillin and Bishop, 2009). These adaptions in muscle architecture and physiological changes lead to a higher capacity to overcome fatigue and consequently, stronger athletes dissipate fatigue earlier than weaker ones (Seitz and Haff, 2015). Furthermore, the different outcomes, based on the given loads for CA, could be associated to the athletes strength level and experience to resistance training. It has been suggested, that weaker athletes generate higher PAP through lighter loads and stronger athletes are able to perform better with heavy loads (Seitz and Haff, 2015).

Recovery post CA

Higher effect sizes have been reported for longer rest intervals (Seitz and Haff, 2015; Wilson et al., 2013). In their systematic review, Seitz and Haff (2015) reported the highest effect size after 5 to 7 minutes of rest, after CAs. Slightly different, Wilson et al., (2013) pointed out a rest period up to 10 minutes can be used PAP-effects.

Nevertheless, it seems problematic to generalise the rest period after a CA given the complex interaction of volume, intensity and subject characteristics. Interestingly, there is evidence showing that plyometric exercise as CAs can induce PAP-effects after 1 to 4 minutes post CA (Tobin and Delahunt, 2014). Furthermore, strength level and resistance training experience results in different rest periods (Seitz and Haff, 2015; Wilson et al., 2013). Weaker athletes display more fatigue than stronger athletes to the given CA and recovery could be extended up to 8 for these athletes (Seitz et al, 2015).

To guarantee an optimal PAP response further research is needed (Sale, 2002). Nevertheless, literature suggests that subjects who are experienced in resistance training, possess a higher percentage of type II muscle fibres, and have a lower power-strength ratio, can potentially benefit the most from the PAP phenomenon (Tillin and Bishop, 2009).

3. Methods

3.1 Protocol

The study protocol follows the guidelines of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA; Moher et al., 2009).

3.2 Search Strategy

The systematic search was carried out in the electronic databases, Pubmed, Web of Science, SportDiscus, CINHAL and Scopus. The keyword combination below was created for the following search process in each database.

“combined training" OR "complex training" OR "contrast training" OR "compound training" OR ("light loads" AND "heavy loads") OR" contrast load" OR “complex pair” OR (("strength training" OR "weight training" OR "resistance training" OR "weight lifting" OR "weightlifting") AND (“plyometric” OR “explosive” OR “explosive performance” OR "explosive training" OR "ballistic performance" OR "ballistic training"))

The results were restricted to studies written in english and german, as well as humans. The search profile was adapted by a manual cross matching strategy to identify additional resources. In case of missing crucial data in original paper the authors were contacted to obtain the relevant information.

3.3 Inclusion and Exclusion Criteria

Two independent investigators determined the in- and exclusion criteria for the following selection process.

1) included training interventions lasted longer than 4 Weeks and had at least 8 training sessions; 2) only peer reviewed articles were included; 3) outcome measures are jump, sprint, 1RM lower body and ability performance; 4) participants are older than 14 and younger than 50; 5) Combination of resistance and power exercises have to be in one and the same training sessions, the break between the exercises have to be shorter than 15 min and should be carried without any kind of exhausting physical activity; 6) lighter, power related exercises are carried out after heavy strength exercises in at least one group; 7) only controlled trials were included (no simple pre-post design; other training regimes are

also defined as control group); 8) only original investigation published in peer-reviewed journals were included.

3.4 Selection Process

The first search process was conducted on January the 19th, 2017 and updated on April the 24th, 2017. The literature selection of the systematic review was done by two independent investigators (ÜB and Mag. Bauer Pascal, Bakk). The first extraction was done based on title and abstract screening. Clearly not relevant articles and duplicates were removed before full text screening by means of the inclusion and exclusion criteria. Disagreements between the two investigators were solved in consent. For the second extraction process, a full text screen was done.

3.5 Quality Assessment

The included studies were evaluated for quality using the Physiotherapy Evidence Database (PEDro) scale. The 11-items scale supposes to analyse the methodological quality of randomised controlled trials (Maher et al., 2003). Two independent investigators (ÜB and Mag. Bauer Pascal Bakk.) screened the methodical quality of each article, through the PEDro scale items and operational definitions. The 11 items could reach a maximum score of 10 points and a minimum of 0 points. It was calculated by the sum of each satisfied item (1 point). However, item 1 (eligibility criteria were specified) was not included, because it applies to the external validity (Maher et al., 2003).

4. Results

4.1 Study Selection

The bibliographic search profile results in a total of 8196 articles. After the of removal duplicates, trials have been eliminated due to title and abstract, based on in- and exclusion criteria. Following the final evaluation process of 198 studies, 29 studies (5 studies had to be excluded because no outcome data were available) met the in- and exclusion criteria and could be included in the systematic review. Details of the described selection process can be seen in figure 6.

4.2 Methodical Quality

Overall, the included studies reached a mean PEDro score of 3,5 (table 2). However, the poor to fair quality score probably depends on the difficulty to satisfy the criteria of blinding subjects, therapists and assessors, while an intervention period. Nevertheless, for included studies the final score ranged from 2 to 5 points. No trial could reach a score for concealed allocation, blinding subjects, blinding therapists and intention to treat. Only one trial was positive for blinding assessors (Juarez et al., 2009). All included trials receive scores from the item, point measures and variability measures. Furthermore, all except Juarez and colleagues (2009), reached a point for statistical group comparisons.

Flow Chart Diagram

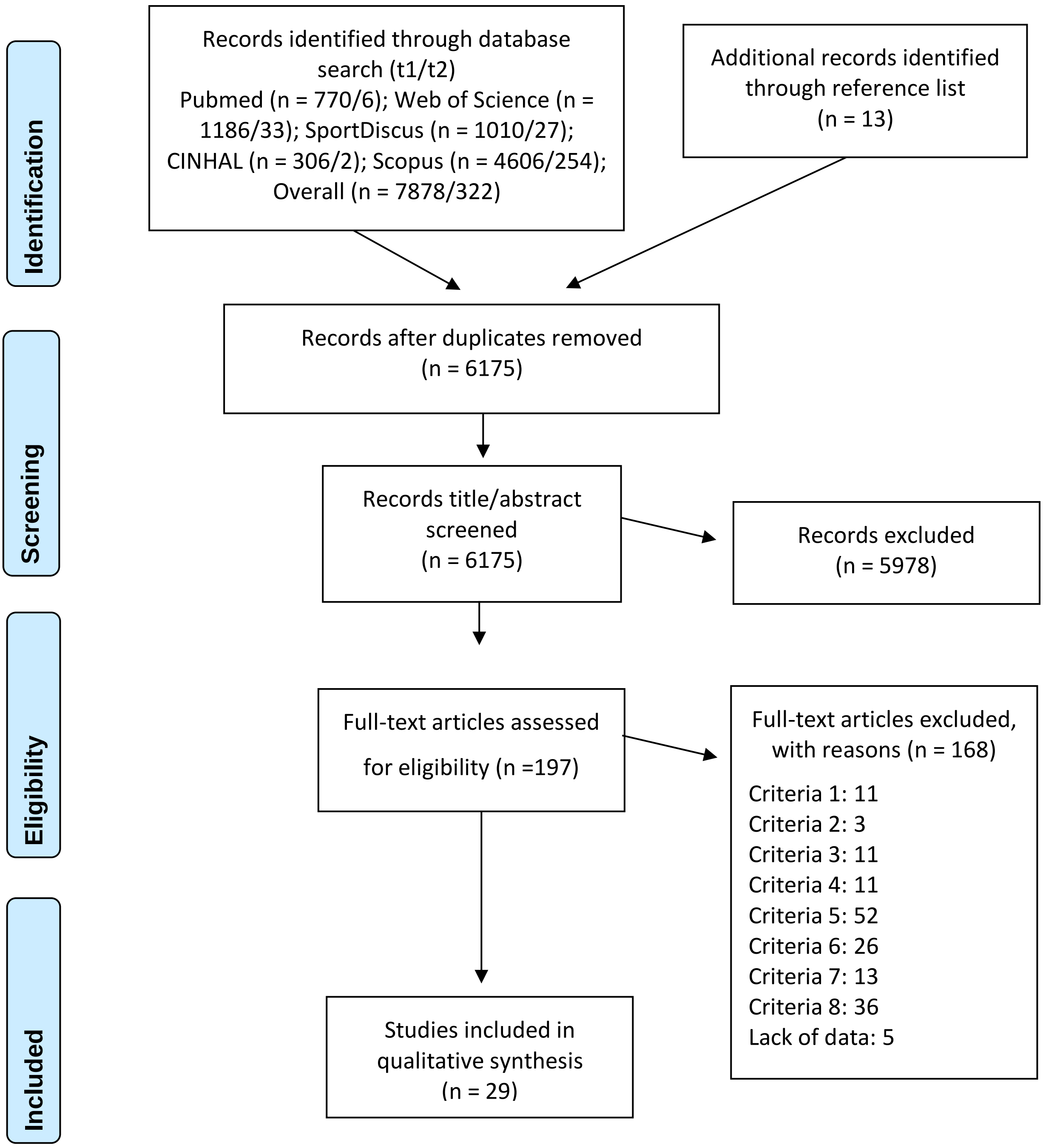

Figure 6: Flow chart diagram of the study selection. t1: First search process; t2: Second search process (adapted from Moher et al., 2009)

Table 2: PEDro Score of included Studies (adapted from Maher et al., 2003)

References	1.eligibility criteria were specified	2. Randomly allocated groups	3. Concealed allocation	4. no diff. at baseline between groups	5. Blinded subjects	6. Blinded therapist	7. Blinded assessors	8. Dropout < 15 %	9. Intention to treat method	10. Statistical group comparisons were given	11. Point measures and variability were given	Final score
Alemdaroglu et al., (2013)	0	1	0	0	0	0	0	0	0	1	1	3
Arabatzi et al., (2010)	1	1	0	0	0	0	0	0	0	1	1	3
Arazi et al., (2014)	1	1	0	0	0	0	0	0	0	1	1	3
Brito et al., (2014)	0	1	0	1	0	0	0	0	0	1	1	4
Dodd and Brent (2007)	1	1	0	0	0	0	0	0	0	1	1	3
Villareal et al., (2011)	1	1	0	1	0	0	0	0	0	1	1	4
Villareal et al., (2013)	0	1	0	1	0	0	0	0	0	1	1	4
Faude et al., (2013)	0	1	0	0	0	0	0	0	0	1	1	3
Franco-Marquez et al., (2015)	1	0	0	0	0	0	0	0	0	1	1	2
Garcia-Pinillos et al., (2014)	0	1	0	1	0	0	0	1	0	1	1	5
Juarez et al., (2009)	0	1	0	1	0	0	1	0	0	0	1	4
Kotzmanidis et al., (2005)	0	0	0	1	0	0	0	0	0	1	1	3
Lloyd et al., (2016)	0	1	0	0	0	0	0	1	0	1	1	3
Hammami et al., (2017)	0	1	0	0	0	0	0	0	0	1	1	3
Wallenta et al., (2016)	1	0	0	1	0	0	0	0	0	1	1	3
Veliz et al., (2015)	0	1	0	1	0	0	0	0	0	1	1	4
Veliz et al., (2014)	0	1	0	1	0	0	0	0	0	1	1	4
Talpey et al., (2016)	0	1	0	1	0	0	0	0	0	1	1	4
Stasinaki et al., (2015)	0	0	0	1	0	0	0	1	0	1	1	4
Smith et al., (2014)	1	1	0	1	0	0	0	0	0	1	1	4
Ronnestad et al., (2008)	0	1	0	1	0	0	0	0	0	1	1	4
Tsimahidis et al., (2010)	0	1	0	1	0	0	0	0	0	1	0	3
Mihalik et al., (2008)	0	1	0	0	0	0	0	0	0	1	1	3
Alves et al., (2010)	0	0	0	1	0	0	0	0	0	1	1	3
MacDonald et al., (2012)	1	1	0	1	0	0	0	0	0	1	1	4
Lyttle et al., (1996)	0	1	0	0	0	0	0	0	0	1	1	3
Torres-Torrelo et al., (2017)	0	1	0	1	0	0	0	1	0	1	1	5
Voelzke et al., (2012)	0	1	0	1	0	0	0	0	0	1	1	4
Kobal et al., (2016)	0	1	0	1	0	0	0	0	0	1	0	3

4.3 Characteristics of Study Design

The characteristics of each included study are outlined in table 3. Articles that met the in- and exclusion criteria were all published in english, except one (Wallenta et al., 2016) which was published in german. The first article was released in 1996 (Lyttle et al., 1996) and the most recent published articles were released in 2017 (Hammami et al., 2017, Torres-Torrelo et al., 2017). All except 5 studies are randomised (Franco-Marquez et al., 2015; Kotzmanidis et al., 2005; Wallenta et al., 2016; Stasinaki et al., 2015; Alves et al., 2010). Only one study used a counterbalance study design (Dodd and Brent, 2007).

4.3.1 Characteristics of Training Methods

Included training studies had at least one group performing complex training as defined earlier (see section 2.2.1). To evaluate the effect of complex training regimes, these methods are compared to non-training control groups as well as alternative training groups. Combined strength and power training interventions which are not performed in the same session or in a reverse order (COMP, RevBCL, RevCOMB and BKP), as well as training interventions without any combined training approach (RT, PLYO and OLY) were categorised as alternative training groups. Non-training intervention groups where defined as control groups (CTRL).

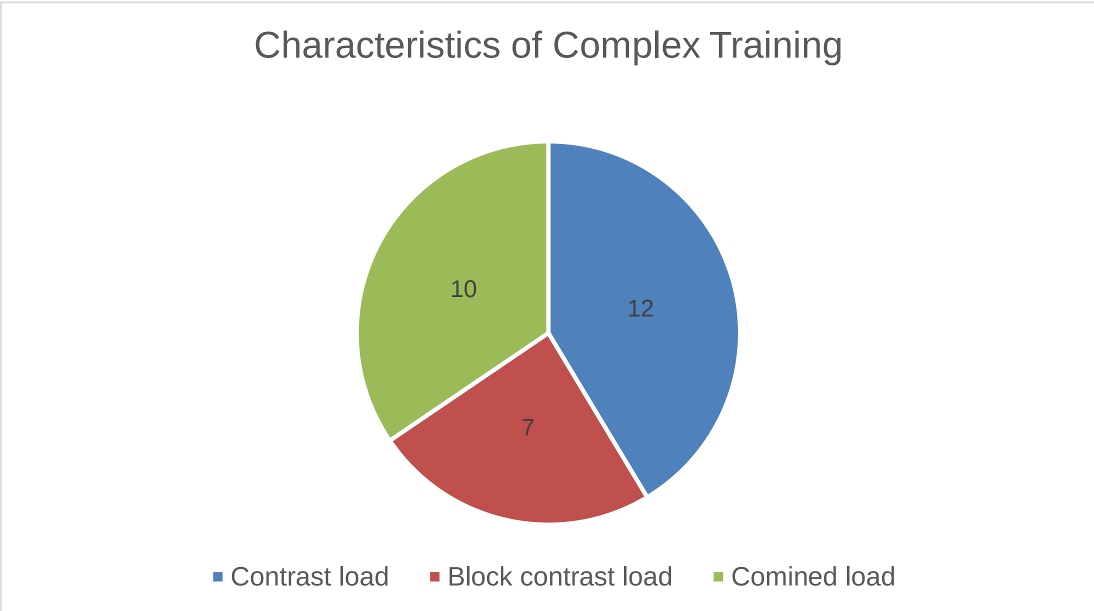

Figure 7: Frequency of complex training interventions

Twelve studies utilised CL (Alemdaroglu et al., 2013; Arazi et al., 2014; Brito et al., 2014; Garcia-Pinillos et al., 2014; Tsimahidis et al., 2010; Wallenta et al., 2016; Stasinaki et al., 2015; Smith et al., 2014; Alves et al., 2010; MacDonald et al., 2012; Voelzke et al., 2012; Kobal et al., 2016; Dodd and Brent 2007; Faude et al., 2013; Hammami et al., 2017; Talpey et al., 2016), seven opted for BCL (Alemdaroglu et al., 2013; Villareal et al., 2011; Villareal et al., 2013; Lloyd et al., 2016; Mihalik et al., 2008; Torres-Torrelo et al., 2017; Kobal et al., 2016) and ten studies choose COMB (Arabatzi et al., 2010; Villareal et al., 2011; Villareal et al., 2013; Franco-Marquez et al., 2015; Juarez et al., 2009; Kotzmanidis et al., 2005; Veliz et al., 2014; Veliz et al., 2015; Ronnestad et al., 2008; Lyttle et al., 1996).

It should to be mentioned that for two included studies the training intervention could not be clearly assigned to one of the complex training methods (BCL respectively COMB) because only one complex pair has been used (Villareal et al., 2011; Villareal et al., 2013).

The following alternative training interventions were used in the included studies: Three times the COMP training method (Arazi et al., 2014; Stasinaki et al., 2015; Mihalik et al., 2008), two designs each BKP model (Wallenta et al., 2016; Juarez et al., 2009), three times reverse training interventions modalities, two interventions utilised a RevBCL (Alemdaroglu et al., 2013; Kobal et al., 2016) and one training group exploited a RevCOMB (Talpey, et al., 2016).

Additional to the alternative groups which combined strength and power some studies also just used a single training method. Nine studies used plyometric training (Arabatzi et al., 2010; Arazi et al., 2014; Brito et al., 2014; Dodd and Brent 2015; Villareal et al., 2011; Villareal et al., 2013; Lloyd et al., 2016; MacDonald et al., 2012; Lyttle et al., 1996), eleven utilised traditional resistance training (Arazi et al., 2014; Brito et al., 2014; Dodd and Brent 2015; Villareal et al., 2011; Villareal et al., 2013; Kotzmanidis et al., 2005; Lloyd et al., 2016; Hammami et al., 2017; Ronnestad et al., 2008; MacDonald et al., 2012; Torres-Torrelo et al., 2017) and one olympic weightlifting (Arabatzi et al., 2010).

Beside the active training groups, seventeen trials used control groups without any training systematic training (Alves et al., 2010; Arabatzi et al., 2010; Brito et al., 2014; Faude et al., 2013; Franco-Marquez et al., 2015; Garcia-Pinillos et al., 2014; Kotzmanidis et al., 2005; Lloyd et al., 2016; Hammami et al., 2017; Veliz et al., 2014; Veliz et al., 2015; Tsimahidis et al., 2010; Stasinaki et al., 2015; Smith et al., 2014; Ronnestad et al., 2008; Lyttle et al., 1996; Torres-Torrelo et al., 2017).

Additional to the described methods, Voelzke and colleagues (2012), investigated electro myostimulation (EMS) combined with plyometric training in comparison to a CL program.

Most of the authors used more than one combined or alternative training methods in their evaluation and therefore they are represented in two or more categories.

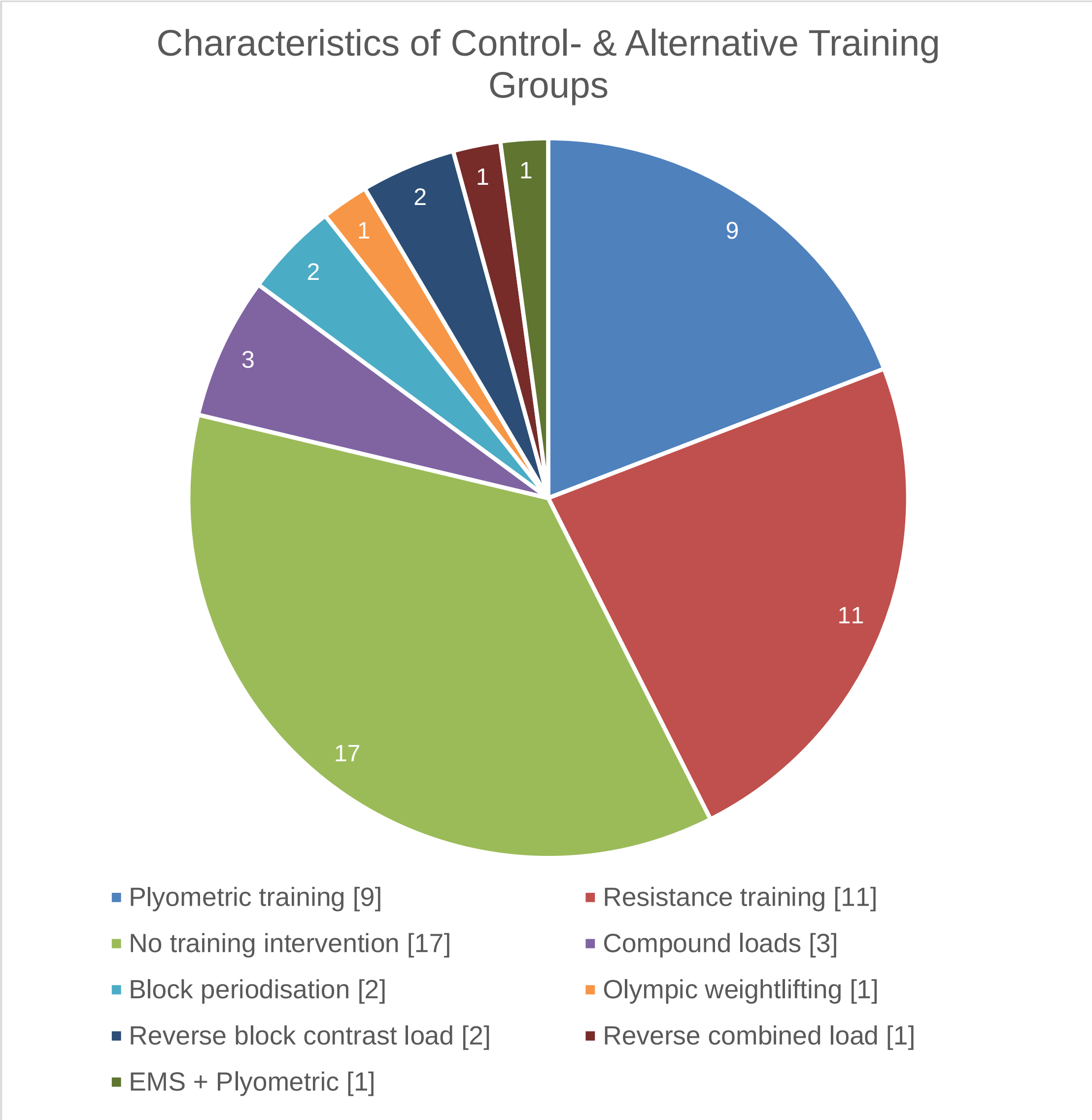

Figure 8: Frequency of alternative training methods & control groups

4.3.2 Characteristics of Training Duration and Frequency

The duration of the included studies lasted from 4 to 16 weeks, with a mean (± SD) of 7,7 (± 2,9) weeks. The training frequency per week varied from 1 to 3 workouts with a mean (± SD) of 2,2 (± 0,47) training sessions per week. The total amount of training sessions was at least 6 sessions and a maximum of 32 sessions with a mean (± SD) of 16,6 (± 6,6) for all studies.

Six of the included studies utilised a familiarisation period. All of these studies performed a 2-week familiarisation, except Brito and colleagues (2014), who carried out only one week. Within this familiarisation, subjects performed 2 to 6 practicing the resistance and power exercises (Arabatzi et al., 2010; Brito et al., 2014; Hammami et al., 2017; Franco-Marquez et al., 2015; Torres-Torrelo et al., 2017; Kobal et al., 2016).

4.3.3 Characteristics of Exercises Used

Training protocols for included studies seem to use one or up to 4 different exercises in a resistance and/or power training session. Most of the trials utilised the squat or variation of it as the main resistance training exercise. Additional exercise used in the studies were, leg press, lunges, power clean, snatch, clean and jerk, knee flexion, knee extension, CMJ loaded, calf rise, step-ups, deadlifts and kettle bell swings.

Vertical jumps (i.e.: CMJ unloaded and loaded, SJ, DJ), were the most frequently used exercises to perform power related movements. Additionally, olympic weightlifting derivatives, hurdle-jumps, change of directions, sprints from 5 up to 30 meters, skipping, ball headers, split-squat-jumps, step-jumps and leg press throws were used in the studies.

4.3.4 Characteristics of Load Prescription

Most of the studies used loads range from 70 to 90 % of 1RM and progressed intensity during the intervention period of at least 45 % of 1RM (Franco-Marquez et al., 2015) to almost 100 % (Alves et al., 2010). Loads below 60 % of 1RM were used throughout the trials of Franco-Marquez and colleagues (2015) and Torres-Torrelo and colleagues (2017).

Beside traditional load prescription four studies utilised velocity based load prescription for the strength exercises (Franco-Marquez et al., 2015; Veliz et al., 2014; Veliz et al., 2015; Torres-Torrelo et al., 2017) Furthermore, one study used isometric contractions while squats (90 ° knee angle; Garcia-Pinillos et al., 2014) and one utilised a EMS training method (Voelzke et al., 2012).

To evaluate the total volume of included studies the amount of resistance- and power related exercises must be calculated (repetition*sets*exercises*frequency*duration). The mean (±SD) volume for resistance training of included trials and groups were 628,8 ± 676,7. The total volume reached from a minimum of volume 94 out of 18 training sessions (Juarez et al., 2009), up to a total volume of 2160 out of 24 workouts (Arabatzi et al., 2010). Only seven trials equated the volume between their different training groups (Alemdaroglu et al., 2013; Juarez et al., 2009; Wallenta et al., 2016; Talpey et al., 2016; Stasinaki et al., 2015; Mihalik et al., 2008; Kobal et al., 2016). For the trials of Garcia-Pinillos and colleagues (2014) and Voelzke and colleagues (2012) volume calculation have not been possible (isometric and EMS training).

The total volume for plyometric training show the same variability between studies. The mean (±SD) total volume of trials for power related contents and groups were 529,3 ± 487,6. A minimum of total volume 96 out of 8 training sessions was used in the study of Dodd and Brent (2007). The maximal total volume of 3160 within 24 workouts was trained in the study of (Arabatzi et al., 2010), which investigating only sprint or a combination of sprint to other power exercises were not included in volume calculation because volume could not be calculated (Brito et al., 2014; Faude et al., 2013; Juarez et al., 2009; Kotzmanidis et al., 2005; Tsimahidis et al., 2010; Alves et al., 2010; Lyttle et al., 1996; Torres-Torrelo et al., 2017).

4.3.5 Characteristics of Subjects

In total 906 subjects participated in the included trials (726 male and 79 female). Because of mixed groups, 101 athletes could not be categorised by gender (Smith et al., 2014; Villareal et al., 2011). Even tough, in the trials of Mihalik and colleagues (2008) and Alemdaroglu and colleagues (2013) both female and male were included and the authors provided the precise gender distribution. Beside these studies most (23 trials) examined only male participants. Only two studies have been carried out using only female subjects. Over all, studies investigated a mean of 31,2 (SD ± 12,9) subjects participated per study. The minimum sample size of 12 subjects was used by Wallenta et al., (2016) and the maximum of 65 participants in the trial of Villareal et al., (2011).

The age ranged from about 14,7 (SD ± 0,5) years to 26,4 (SD ± 4,3). More precisely, 33 were adolescent with a mean age of 14-16 (Alemdaroglu et al., 2013; Arabatzi et al., 2010), 222 were post adolescent with a mean age of 16-18 (Arabatzi et al., 2010; Arazi et al., 2014; Brito et al., 2014; Dodd and Brent 2007; Villareal et al., 2011), 169 were young adults with a mean age of 18-20 (Villareal et al., 2011; Villareal et al., 2013; Faude et al., 2013; Franco-Marquez et al., 2015; Garcia-Pinillos et al.,2014), 371 participants had a mean age of 20-22 (Garcia-Pinillos et al., 2014; Juarez et al., 2009; Kotzmanidis et al., 2005; Lloyd et al., 2016; Hammami et al., 2017; Wallenta et al., 2016; Veliz et al., 2015; Veliz et al., 2014; Tsimahidis et al., 2010; Talpey et al., 2016; Stasinaki et al., 2015; Smith et al., 2014; Ronnestad et al., 2008; Mihalik et al., 2008), 76 subjects had a mean age of 22-24 (Alves et al., 2010; MacDonald et al., 2012; Lyttle et al., 1996) and 88 had a age over than 24 (Torres-Torrelo et al., 2017; Voelzke et al., 2012).

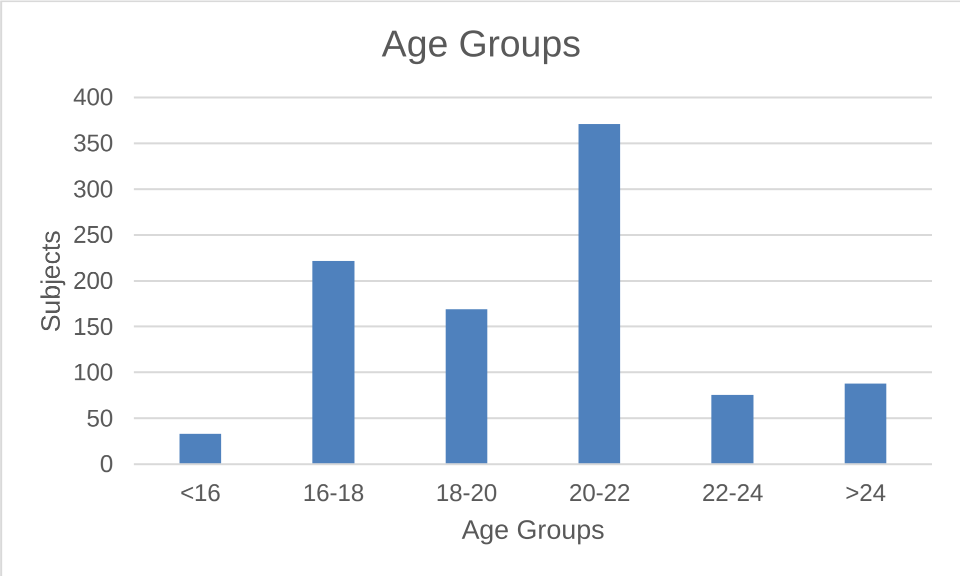

Figure 9: Age groups across studies

Beside the age, subjects had a high variation in training and strength level. Fourteen studies included recreational sports, nine trials used junior or amateur level athletes, five studies used professionals and one used untrained female participants (table 2; Arazi et al., 2014). Confusingly, two trials reported elite athletes but also stated that their subjects are not used to a systematic strength training (Wallenta et al., 2016; Kobal et al., 2016). It should be critically noted that Kotzmanidis and colleagues (2005) used different subjects for their groups. More precisely they used soccer players for their intervention group and physical education students for their non-training control group. It could be hypothesised that this allocation influenced the outcomes of the study.

Table 3: Subjects category due to training level

Recreational sports	Junior or amateur sports	Elite/professional sports
Alemdaroglu et al., (2013)	Dodd and Brent (2007)	Wallenta et al., (2016)
Arabatzi et al., (2010)	Faude et al., (2013)	Ronnestad et al., (2008)
Brito et al., (2014)	Franco-Marquez et al., (2015)	Alves et al., (2010)
Villareal et al., (2011)	Garcia-Pinillos et al., (2014)	Voelzke et al., (2012)
Villareal et al., (2013)	Hammami et al., (2017)	Kobal et al., (2016)
Juarez et al., (2009)	Veliz et al., (2015)	
Kotzmanidis et al., (2005)	Veliz et al., (2014)	
Lloyd et al., (2016)	Tsimahidis et al., (2010)	
Talpey et al., (2016)	Mihalik et al., (2008)	
Stasinaki et al., (2015)	Kotzmanidis et al., (2005)	
Smith et al., (2014)		
MacDonald et al., (2012)		

Lyttle et al., (1996) Torres-Torrelo et al., (2017)		

Additionally, 18 studies measured the pre-intervention strength level, for squat (most of them carried out a half squat – 90 ° knee angle). The lowest 1RM (mean 58,87, SD± 4,33 kg) was found by Veliz and colleagues (2015). The highest 1RM in squat (mean 181, SD ± 41 kg) was reported by Stasinaki and colleagues (2015).

Only 10 trials reported, that included participants had experience in strength training (Alemdaroglu et al., 2013; Arabatzi et al., 2010; Dodd and Brent, 2007; Hammami et al., 2017; Talpey et al., 2016; Ronnestad et al., 2008; Mihalik et al., 2008; Alves et al., 2010; MacDonald et al., 2012; Voelzke et al., 2012).

4.4 Study Outcomes

The basic characteristics of the studies as well as the main outcomes (ES: effect sizes; percentage changes, PEDro score) are shown in table 2.

Table 4: Included studies which met the in- and exclusion criteria

References	PED-ro Score	Subjects			Training intervention							Results % of change (Effect size)
		n	Training Level	Age	Training method	D/F (w)	Resistance exercises	Power Exercises	Set/Rep (RT) % 1RM	Set/Rep (Power)	Volume (RT/ Power)	
Alemdaroglu et al., (2013)	3	8 (5m; 3f)	Recreation-ally trained athletes with experience in resistance and plyometric training	21,6 ± 2,3	RevBCL	6x2	Split-squats, leg-press, leg-curls	Split jumps, SJ; front tuck jumps	3x6 85-90 %	3x8	648/ 864	CMJ (m) RevBCL 7,3 % (0,56) (m) BCL 8,5 % (0,82) (m) CL 7,7 % (1,25) (f) RevBCL 26,8 % (1,00) (f) BCL 1,8 % (0,05) (f) CL 13,8 % (1,65) SJ (m) RevBCL 8,1 % (0,80) (m) BCL 4,9 % (0,28) (m) CL 9,7 % (0,93) (f) RevBCL 29,5 % (3,13) (f) BCL 4,5 % (0,15) (f) CL 9,5 % (0,72)
		8 (5m; 3f)		21,3 ± 2,1	BCL	6x2	Split-squats, leg-press, leg-curls	Split jumps, SJ; front tuck jumps	3x6 85-90 %	3x8	648/ 864	
		8 (5m; 3f)		21,9 ± 2,6	CL	6x2	Split-squats, leg-press, leg-curls	Split jumps, SJ; front tuck jumps	3x6 85-90 %	3x8	648/ 864	
Arabatzi et al., (2010)	3	9 (m)	Sport students; at least 1 year experience in resistance and plyometric training	20,3 ± 2,0	COMB (OLY+PLYO)	8x3	Power clean, snatch, clean and jerk, high pull, half-squats	Double leg hurdle hops, alternated single leg hurdle hops, double-leg hops, half-squats	4-6x4-6 75-90 %	4-6x4-6	80-150/ 120-144	CMJ COMB 15,1 % (0,59) OLY 15,0 % (0,69) PLYO 14,6 % (0,69) CTRL 5,7 % (0,33) SJ COMB 14,6 % (0,54) OLY 20,3 % (0,97) PLYO 14,1 % (0,48) CTRL 5,4 % (0,33)
		9 (m)		20,3 ± 2,0	OLY	8x3	Power clean, snatch, clean and jerk, high pull, half-squats		4-6x4-6 75-90 %		80-150/0	

References	PEDro Score	Subjects			Training intervention							Results % of change (Effect size)
		n	Training Level	Age	Training method	D/F (w)	Resistance exercises	Power Exercises	Set/Rep (RT) % 1RM	Set/Rep (Power)	Volume (RT/ Power)	
		9 (m)		20,3 ± 2,0	PLYO	8x3		Double leg hurdle hops, alternated single leg hurdle hops, double-leg hops, half-squat		4-6x4-6	0/120-144	
		9 (m)		20,3 ± 2,0	CTRL	8x0					0/0	
Arazi et al., (2014)	3	8 (f)	Untrained females; familiar with resistance and plyometric training; no resistance and plyometric exercises in the last 6 months	20,8 ± 0,7	PLYO	6x2		DJ, multiple jumps, zigzag drills, lunge jumps		6x6	0/432	1RM leg press PLYO 44,3 % (2,73) RT 48,9 % (3,41) COMP 40,2 % (2,85) CL 37,6 % (1,59) CMJ PLYO 19,3 % (1,53) RT 20,0 % (0,89) COMP 28,3 % (1,98) CL 17,3 % (0,95) 20m sprint PLYO -15,7 % (-1,47) RT -7,2 % (-1,41) COMP -15,7 % (-2,08) CL -9,7 % (-1,02) Agility (T-Test) PLYO -7,7 % (-1,16) RT -6,3 % (-4,49)
		7 (f)		20,7 ± 1,1	RT	6x2	Half-squats, knee extensions, knee flexion, single leg lunges		6x6 60 %		432/0	
		7 (f)		20,7 ± 0,7	COMP	6x2	Half-squats, knee extensions, knee flexion, single leg lunges	DJ, multiple jumps, zigzag drills, lunge jumps	6x6 60 %	6x6	216/ 216	

Refer-ences	PED-ro Score	Subjects			Training intervention							Results % of change (Effect size)
		n	Training Level	Age	Training method	D/F (w)	Resistance exercises	Power Exercises	Set/Rep (RT) % 1RM	Set/Rep (Power)	Volume (RT/ Power)	
		7 (f)		20,6 ± 0,5	CL	6x2	Half-squats, knee extensions, knee flexion, single leg lunge	DJ, multiple jumps, zigzag drill, lunge jump	3x6 60 %	3x6	216/ 216	COMP -7,9 % (-1,02) CL -3,2 % (-0,44)
Brito et al., (2014)	4	12 (m)	College students, local soccer players; CTRL performed routine soccer training only; no experience in strength and power training	20,3 ± 0,9	RT	9x3	Squats, calfs extensions, leg extension		1x6 80-90 %		486/ n. c.	1RM squat RT 22,8 % (1,12) PLYO 17,3 % (1,01) CL 24,2 % (1,62) CTRL 2,4 % (0,14) CMJ CL 1,0 % (0,08) RT 0,4 % (0,03) PLYO 1,9 % (0,18) 20m sprint RT -5,3 % (-0,96) PLYO -4,7 % (-1,52) CL -6,2 % (-2,40) CTRL -1,2 % (-0,31)
		12 (m)		20,0 ± 0,6	PLYO	9x3		Skippings 5m thigh parallel to the ground, 5m sprints, 8 CMJ, Ball headers, 6 SJ, 3 DJ,		1x3-8	0/n. c.	
		12 (m)		19,9 ± 0,5	CL	9x3	Squats, calf extensions, leg extension	Skippings 5m thigh parallel to the ground, 5m sprints, 8 CMJ, Ball headers, 6 SJ, 3 DJ,	1x6 80-90 %	1x3-8	486/ n. c.	
		12 (m)		20,7 ± 1,0	CTRL	9x0					0/0	

Refer-ences	PED-ro Score	Subjects			Training intervention							Results % of change (Effect size)
		n	Training Level	Age	Training method	D/F (w)	Resistance exercises	Power Exercises	Set/Rep (RT) % 1RM	Set/Rep (Power)	Volume (RT/ Power)	
Dodd and Brent (2007)	3	32 (m)	Division II junior college baseball players, specifically infielders, outfielders, and catchers; had at least 1 year strength experience	18-23 (n. m. & SD)	CL	4x2	Squat, lunges, split squats	Box-jumps, DJ, and split-squat- jumps	2x6 80-90 %	2x6	96/96	20m sprint CL -0,6 % (-0,16) RT 0,5 % (0,12) PLYO -0,1 % (-0,04) 40m sprint CL -0,3 % (-0,07) RT 0,7 % (0,20) PLYO 1,3 % (0,37) 60m sprint CL -0,3 % (-0,07) RT -0,2 % (-0,04) PLYO 0,3 % (0,07) Agility (T-Test) CL -2,3 % (-0,61) RT -1,2 % (-0,30) PLYO 0,0 % (0,01)
		31 (m)		18-23 (n. m. & SD)	RT	4x2	Squat, lunges, split squats		4x6 80-90 %		192/0	
		28 (m)		18-23 (n. m. & SD)	PLYO	4x2		Box-jumps, DJ, and split-squat- jumps		4x6	0/192	
Villareal et al., (2011)	4	14 (m/f)	Sport student; no competitive athletes; active 2-3 week; experienced in resistance training (upper body); no experience in strength and	19,4 ± 1,9	COMB / BCL	7x3	Full-squats; squats-power; CMJ loaded	Rebound jumps	3-4x4-6	5-8x5	948/ 615	CMJ COMB 8,6 % (0,39) RT 10,9 % (0,47) RT 13,0 % (0,69) RT 7,5 % (0,43) PLYO 8,4 % (0,54)
		13 (m/f)		20,4 ± 2,1	RT	7x3	Full-squats		3-4x3-6 60-86 %		302/0	
		13 (m/f)		20,2 ± 1,9	RT	7x3	Squats		3-4x2-6 MP-MP+30%		319/0	
		13 (m/f)		19,6 ± 1,5	RT	7x3	CMJ loaded		3-4x2-5 MP-MP-30 %		324/0	

Refer-ences	PED-ro Score	Subjects			Training intervention							Results % of change (Effect size)
		n	Training Level	Age	Training method	D/F (w)	Resistance exercises	Power Exercises	Set/Rep (RT) % 1RM	Set/Rep (Power)	Volume (RT/ Power)	
		12 (m/f)	power training	20,5 ± 3,7	PLYO	7x3		Rebound jumps		5-8x5	0/615	
Villareal et al., (2013)	4	12 (m)	Sport student; no competitive athletes; active in sports like soccer, running and swimming; no experience in strength and power training	20,4 ± 2,1	COMB / BCL	7x3	Full-squats; squats-power; CMJ loaded	Rebound jumps	3-4x4-6	5-8x5	948/ 615	1RM squat COMB 20,2 % (1,12) RT 11,1 % (0,81) RT 17,2 % (0,82) RT 14,4 % (0,87) PLYO 6,8 % (0,49) 15m sprint (only % change) COMB 0,8 % RT -0,8 % RT -1,4 % RT 0,8 % PLYO 0,7 % 30m sprint (only % change) COMB -0,2 % RT -0,1 % RT -0,3 % RT -0,7 % PLYO -0,9 %
		12 (m)		20,4 ± 2,1	RT	7x3	Full-squats		3-4x3-6 60-86 %		302/0	
		12 (m)		20,4 ± 2,1	RT	7x3	Squats		3-4x2-6 MP-MP+30%		319/0	
		12 (m)		20,4 ± 2,1	RT	7x3	CMJ loaded		3-4x2-5 MP-MP-30 %		324/0	
		12 (m)		20,4 ± 2,1	PLYO	7x3		Rebound jumps		5-8x5	0/615	
Faude et al., (2013)	3	8 (m)	Third swiss league soccer players of; CLRL performed technic and tactical training; no experience in strength and	22,6 ± 2,4	CL	7x2	Session 1: unilateral loaded half-squats Session 2 (2 out of): loaded half-squats, loaded calve raises, loaded lateral half squats,	2-Dif. Sessions: single leg hurdle jumps, DJ, 5m sprints, high straight jumps, lateral jumps, zig zag sprints, bounding	4-6x4-5 50-90 %	4-6x5- n.c.	322/ n.c.	1RM squat CL 18,2 % (1,36) CTRL 0,7 % (0,04) CMJ CL 3,0 % (0,27) CTRL -7,4 % (-1,34) DJ CL 5,6 % (0,35) CTRL -3,6 % (-0,28) 10m sprint CL 0,0 % (0,00) CTRL 2,3 % (0,69)

References	PEDro Score	Subjects: n	Subjects: Training Level	Subjects: Age	Training intervention: Training method	D/F (w)	Resistance exercises	Power Exercises	Set/Rep (RT) % 1RM	Set/Rep (Power)	Volume (RT/ Power)	Results % of change (Effect size)
			power training				loaded step-ups	jumps, ball headers				30m sprint CTRL 2,3 % (0,57) CL 0,2 % (0,08) Agility (T-Test)
		8 (m)		23,1 ± 2,7	CTRL	7x0					0/0	CTRL 1,7 % (0,70) CL -4,1 % (-0,66) CTRL -2,1 % (-0,53)
Franco-Marquez et al., (2015)	2	18 (m)	Spanish first division U-15 soccer players; no experience in strength and power training	14,7 ± 0,5	COMB	6x2	Squats (velocity based training)	CMJ, step phase triple jumps, change of directions, 20m sprints	2-3x 12-24 45-58 %	3-8*x2	204/980	1RM squat COMB 28,8 % (1,20) CTRL 2,3 % (0,12) CMJ COMB 9,0 % (0,55) CTRL 0,6 % (0,05)
		20 (m)		14,7 ± 0,5	CTRL	6x0					0/0	10m sprint COMB -1,0 % (-0,28) CTRL 0,0 % (0,00) 20m sprint COMB -1,1 % (-0,33) CTRL 0,0 % (0,00)
Garcia-Pinillos et al., (2014)	5	17 (m)	Semi-professional soccer academy players; no experience in strength and power training	15,5 ± 1,3	CL	12x2	Isometric 90° squats	Jump from seated position, single leg jumps alternated right and left	4-10x40 seconds	4-10*x6	n.c./ 540	CMJ CL 7,1 % (0,57) CTRL 2,2 % (0,32) 5m sprint CL -15,0 % (-1,18) CTRL -12,0 % (-1,11) 10m sprint
		13 (m)		16,4 ± 1,3	CTRL	12x0					0/0	CL -13,4 % (-1,17) CTRL -7,4 % (-1,09) 20m sprint CL -8,4 % (-1,17) CTRL -5,6 % (-1,06)

Refer-ences	PED-ro Score	Subjects			Training intervention							Results % of change (Effect size)
		n	Training Level	Age	Training method	D/F (w)	Resistance exercises	Power Exercises	Set/Rep (RT) % 1RM	Set/Rep (Power)	Volume (RT/ Power)	
												30m sprint CL -6,3 % (-0,96) CTRL -3,8 % (-0,87)
Juarez et al., (2009)	4	8 (m)	Sport students, habitually active (5–6 hours per week) not strength trained	19,3 ± 1,4	COMB	8x2	Squats	VJ, hurdle jumps, drop jumps, bench jumps, 20m sprints	2-3x4-8 70-85 %	2-3*2-5*	94/n.c.	1RM squat COMB 9,9 % (0,52) BKP 8,7 % (0,56) SJ COMB 11,5 % (0,76) BKP 12,3 % (0,96) CMJ COMB 11,8 % (0,82) BKP 5,4 % (0,40) 5m sprint COMB -6,0 % (-1,30) BKP -5,6 % (-1,35) 10m sprint COMB -3,8 % (-1,56) BKP -3,4 % (-1,06) 15m sprint COMB -2,9 % (-1,28) BKP -2,3 % (-0,85) 20m sprint COMB -2,9 % (-0,87) BKP -2,3 % (-0,70)
		8 (m)		20,0 ± 1,9	BKP	8x2	Squats	VJ, hurdle jumps, drop jumps, bench jumps, 20m sprints	2-3x4-8 70-85 %	2-3*2-5*	94/n.c.	
Kotzmanidis et al., (2005)	3	12 (m)	Healthy soccer players; 4 years of training age and tanner stage 5; CTRL group	17,1 ± 1,1	COMB	9x2	Half-squats, step-ups, leg-curls	Sprints 30m	4x3-8 80-95 %	4-6x 30m	1416/ n.c.	1RM squat COMB 8,7 % (0,60) RT 10,0 % (0,87) CTRL 1,5 % (0,15) SJ COMB 7,8 % (0,65) RT 1,9 % (0,14) CTRL 1,0 % (0,10)

References	PEDro Score	Subjects			Training intervention							Results % of change (Effect size)
		n	Training Level	Age	Training method	D/F (w)	Resistance exercises	Power Exercises	Set/Rep (RT) % 1RM	Set/Rep (Power)	Volume (RT/ Power)	
		11 (m)	are moderately active sport student; no experience in strength and power training;	17,1 ± 1,1	RT	9x2	Half-squats, step-ups, leg-curls		4x3-8 80-95 %			CMJ COMB 6,7 % (0,56) RT 0,9 % (0,07) CTRL -0,2 % (-0,02) DJ COMB 5,5 % (0,28) RT 2,6 % (0,08) CTRL 3,3 % (0,19) 30m sprint COMB -3,5 % (-0,93) RT -0,5 % (-0,12) CTRL -0,4 % (-0,09)
		12 (m)		17,8 ± 0,3	CTRL	9x0					0/0	
Lloyd et al., (2016)	4	10 (m)	Active school kids; physical education–based activities; no experience in strength and power training	16,2 ± 0,3	BCL	6x2	Back-squat, lunges	Different VJ and HJ	3x10 70-75 %	2-5x 3-10	720/ 486	SJ BCL 12,7 % (0,74) RT 6,8 % (0,42) PLYO 1,2 % (0,06) CTRL 0,0 % (0,00) 10m sprint BCL -5,3 % (-0,96) RT -5,3 % (-0,96) PLYO 0,0 % (0,00) CTRL 0,0 % (0,00) 20m sprint BCL -7,1 % (-0,96) RT -3,6 % (-0,48) PLYO -3,7 % (-0,32) CTRL 0,0 % (0,00)
		10 (m)		16,3 ± 0,3	RT	6x2	Back-squat, lunges, step-ups, leg press		3x10 70-75 %		1440/0	
		10 (m)		16,2 ± 0,2	PLYO	6x2		Different VJ and HJ		2-4*x 3-10*	0/958	
		10 (m)		16,2 ± 0,3	CTRL	6x0					0/0	

References	PEDro Score	Subjects			Training intervention							Results % of change (Effect size)
		n	Training Level	Age	Training method	D/F (w)	Resistance exercises	Power Exercises	Set/Rep (RT) % 1RM	Set/Rep (Power)	Volume (RT/ Power)	
Hammami et al., (2017)	3	16 (m)	Soccer player; experience in strength training; familiarization trials for 2 weeks; 4-5 soccer training + 1 match/week; CTRL group soccer training	16,2 ± 0,6	CL	8x2	Back-squats; as/ descending set; 70 %3x8; 80 %5x4; 85 %4x3; 90 %3x3	Weeks 1-4 CMJ, weeks 5-8 1xCMJ+15m sprints	15x3-8 70-90 %	15x4 (+sprint for weeks 5-8)	1080/ 960	1RM squat CL 41,0 % (4,24) RT 23,9 % (3,69) CTRL 6,1 % (0,38) SJ CL 23,4 % (2,72) RT 11,2 % (1,74) CTRL -3,1 % (-0,21) CMJ CL 25,3 % (2,74) RT 12,7 % (1,14) CTRL -2,4 % (-0,14) 5m sprint CL -11,4 % (-4,97) RT -9,8 % (-2,10) CTRL -2,6 % (-0,38) 10m sprint CL -7,5 % (-0,73) RT -8,4 % (-1,45) CTRL -1,0 % (-0,14) 20m sprint CL -8,4 % (-2,21) RT -5,5 % (-4,96) CTRL 0,0 % (0,00) 30m sprint CL -7,4 % (-3,08) RT -7,2 % (-2,99) CTRL -0,7 % (-0,09) 40m sprint CL -9,1 % (-2,88) RT -5,9 % (-2,82) CTRL -1,5 % (-0,21)
		16 (m)		16,0 ± 0,5	RT	8x2	Back-squat; as/ descending set; 70 %3x8; 80 %5x4; 85 %4x3; 90 %3x3		15x3-8 70-90 %		1080/0	
		16 (m)		16,8 ± 0,2	CTRL	8x0					0/0	

Refer-ences	PED-ro Score	Subjects			Training intervention							Results % of change (Effect size)
		n	Training Level	Age	Training method	D/F (w)	Resistance exercises	Power Exercises	Set/Rep (RT) % 1RM	Set/Rep (Power)	Volume (RT/ Power)	
												Agility (S180°) CL -5,3 % (-1,81) RT -3,5 % (-2,98) CTRL -0,1 % (-0,03) Agility (4x5m) CL -7,2 % (-2,45) RT -2,2 % (-1,13) CTRL -0,5 % (-0,16) Agility (9-3-6-3-9m) CL -5,0 % (-1,63) RT -4,2 % (-2,70) CTRL -0,6 % (-0,15) Agility (RCOD) CL -5,6 % (-2,34) RT -5,2 % (-2,05) CTRL -8,0 % (-2,13)
Wallenta et al., (2016)	3	6 (m)	Elite soccer players; no information about experience in strength and power training	18,0 ± 1,3	CL	6x2	Squats	CMJ and 20m sprints	3x5 60-70 %	3x4	180/ 144 (without sprint)	1RM squat CL 7,4 % (0,22) BKP 7,9 % (0,37) CMJ CL 0,8 % (0,03) BKP 1,0 % (0,06) 5m sprint CL -1,0 % (-0,18) BKP -2,0 % (-0,46) 10m sprint CL -1,7 % (-0,37) BKP -1,7 % (-0,61) 30m sprint CL -1,5 % (-0,24) BKP -1,2 % (-0,32)
		6 (m)		18,5 ± 1,6	BKP	6x2	Squats	CMJ and 20m sprints	6x5 60-70 %	6x4	180/ 144 (without sprint)	

References	PEDro Score	Subjects: n	Subjects: Training Level	Subjects: Age	Training intervention: Training method	D/F (w)	Resistance exercises	Power Exercises	Set/Rep (RT) % 1RM	Set/Rep (Power)	Volume (RT/ Power)	Results % of change (Effect size)
												Agility (T-Test) CL -1,9 % (-0,62) BKP -2,5 % (-0,64)
Veliz et al., (2015)	4	11 (f)	Spanish first division water polo players; no experience in strength and power training	26,4 ± 4,3	COMB	16x 2	Full-squats; Split-squats	CMJ loaded + CMJ	3-4x6 velocity based	3-6*x 4-6*	1344/ 1028	1RM squat COMB 21,0 % (2,23) CTRL 2,8 % (0,35) CMJ COMB 8,7 % (0,83) CTRL 2,4 % (0,28)
		10 (f)		26,4 ± 4,3	CTRL	16x 0					0/0	
Veliz et al., (2014)	4	16 (m)	Spanish first division water polo players; no experience in strength and power training	20,4 ± 5,1	COMB	16x 2	Full-squats;	CMJ loaded + CMJ	3-4x6 velocity based	3x4-5*	672/ 928	1RM squat COMB 14,2 % (0,66) CTRL 3,0 % (0,17) CMJ COMB 6,9 % (0,48) CTRL 2,5 % (0,13)
		11 (m)		20,4 ± 5,1	CTRL	16x 0					0/0	
Tsimahidis et al., (2010)	3	13 (m)	Junior basketball players; no experience in strength and power training	18,0 ± 1,2	CL	10x 2	Half-squats	30m sprints	5x5-8 80-85 %	5x30m	650/ n. c.	1RM squat CL 29,1 % (4,75) CTRL 1,2 % (0,22) SJ CL 12,9 % (1,06) CTRL 1,7 % (0,20) CMJ CL 14,9 % (1,24) CTRL 1,3 % (0,13) DJ CL 14,1 % (1,38) CTRL 2,0 % (0,21)
		13 (m)		18,0 ± 0,7	CTRL	10x 2					0/0	

References	PEDro Score	Subjects			Training intervention							Results % of change (Effect size)
		n	Training Level	Age	Training method	D/F (w)	Resistance exercises	Power Exercises	Set/Rep (RT) % 1RM	Set/Rep (Power)	Volume (RT/ Power)	
Talpey et al., (2016)	4	9 (m)	Active male; sports like football, basketball, rugby or soccer; at least one year strength and power training experience	21,4 ± 3,5	CL	9x2	Half-squats	SJ	3-4x4-6* 80-90 %	3-4*x4	303/ 240	1RM squat CL 24,4 % (1,00) RevCOMB 23,4 % (1,08) CMJ CL 8,1 % (0,74) RevCOMB 9,5 % (0,81) 10m sprint CL -1,0 % (-0,23) RevCMOB 2,0 % (-0,27) 20m sprint CL -0,9 % (-0,24) RevCOMB -0,3 % (-0,05)
		11 (m)		20,9 ± 3,6	Rev COMB	9x2	Half-squats	SJ	3-4x4-6* 80-90 %	3-4*x4	303/ 248	
Stasinaki et al., (2015)	4	9 (m)	Moderately trained sport students; no experience in strength and power training	21,9 ± 2,3	CL	6x3	Leg press; smith machine box-squats	Loaded leg press throws; loaded SJ and DJ were alternated throw sessions	2x6 85 %	4x8 30 % DJ without external load	432/ 576	1RM squat CL 34,3 % (1,34) COMP 26,5 % (2,90) CTRL -1,2 % (-0,09) 1RM leg press CL 28,5 % (1,71) COMP 17,8 % (1,47) CTRL -1,6 % (-0,11) CMJ CL -0,2 % (-0,01) COMP 4,5 % (0,43) CTRL -1,2 % (-0,09)
		9 (m)		22,3 ± 2,7	COMP	6x3	Leg press; smith machine box-squats	Loaded leg press throws; loaded SJ; DJ	2x6 85 %	4x8 30 % DJ without external load	432/ 576	
		7 (m)		21,3 ± 1,5	CTRL	6x0					0/0	

Refer-ences	PED-ro Score	Subjects			Training intervention							Results % of change (Effect size)
		n	Training Level	Age	Training method	D/F (w)	Resistance exercises	Power Exercises	Set/Rep (RT) % 1RM	Set/Rep (Power)	Volume (RT/ Power)	
Smith et al., (2014)	4	8 (m/f)	Sport students; moderate/ vigorous training last 3 months; no experience in strength and power training	24,5 ± 4,5	CL	6x3	Squats	CMJ	3x5 85 %	3x5	270/ 270	CMJ CL 10,6 % (0,44) CL 9,1 % (0,35) CTRL 4,3 % (0,22)
		11 (m/f)		24,5 ± 4,5	CL	6x3	Kettlebell swings	CMJ	3x5 depend-ing on swing height	3x5	270/ 270	
		9 (m/f)		24,5 ± 4,5	CTRL	6x0					0/0	
Ronnestad et al., (2008)	4	8 (m)	Norwegian professional soccer player (Premier League); all subjects had experience with strength and power training	23,0 ± 2,0	COMB	7x2	Half-squats; hip flexion	Step-jumps; CMJ hurdle; single leg jumps	3-5x3-6 85-90 %	2-4x 5-10	352/ 476	1RM squat COMB 22,9 % (1,98) RT 25,9 % (2,75) CTRL 2,8 % (0,30) CMJ COMB 1,9 % (0,12) RT 5,0 % (0,86) CTRL -0,8 % (-0,09) SJ COMB 9,1 % (0,54) RT 6,9 % (0,56) CTRL -3,6 % (-0,33) 10m sprint COMB -1,1 % (-0,34) RT -1,7 % (-0,54) CTRL 0,0 % (0,00)
		6 (m)		22,0 ± 2,5	RT	7x2	Half-squats; hip flexion		3-5x3-6 85-90 %	2-4x 5-10	352/0	
		7 (m)		23,0 ± 1,5	CTRL	7x0					0/0	

References	PEDro Score	Subjects: n	Subjects: Training Level	Subjects: Age	Training intervention: Training method	D/F (w)	Resistance exercises	Power Exercises	Set/Rep (RT) % 1RM	Set/Rep (Power)	Volume (RT/ Power)	Results % of change (Effect size)
												30-40m sprint COMB -0,8 % (-0,17) RT -0,8 % (-0,20) CTRL -1,7 % (-0,73) 40m sprint COMB -1,1 % (-0,31) RT -1,3 % (-0,39) CTRL -0,9 % (-0,57)
Mihalik et al., (2008)	3	15 (5m/10f)	Division one volleyball players; experience in jumping exercises	20,3 ± 2,2	BCL	4x2	Squats; lunges; deadlifts	DJ; split-SJ; double leg bounds	3x6 85 %	3x6	432/ 432	CMJ BCL 5,6 % (0,29) COMP 9,8 % (0,08)
		16 (6m/10f)		20,9 ± 2,4	COMP	4x2	Squats; lunges; deadlifts	DJ; split-SJ; double leg bound	3x6 85 %	3x6	432/ 432	
Alves et al., (2010)	3	9 (m)	Portuguese elite soccer player; 2-week adaption period for all players; no experience in strength and power training	17,4 ± 0,6	CL	6x1	Squats 90°; calf ext.; leg extensions	5m skippings+5m sprints; 8VJ+3 ball headers; 3 DJ with headers	3x6 80-100 %	6 Exercises	108/ n.c.	SJ CL 12,6 % (0,71) CL 9,6 % (0,82) CTRL -0,7 % (-0,08) CMJ CL 0,2 % (0,01) CL 2,4 % (0,20) CTRL -2,6 % (-0,33) 5m sprint CL -9,2 % (-1,77) CL -6,2 % (-1,87) CTRL -1,8 % (-0,31)
		8 (m)		17,4 ± 0,6	CL	6x2	Squats 90°; calf ext.; leg extensions	5m skippings+5m sprint; 8VJ+3 ball headers; 3 DJ with headers	3x6 80-100 %	6 Exercises	216/ n.c.	

References	PED-ro Score	Subjects			Training intervention							Results % of change (Effect size)
		n	Training Level	Age	Training method	D/F (w)	Resistance exercises	Power Exercises	Set/Rep (RT) % 1RM	Set/Rep (Power)	Volume (RT/ Power)	
		6 (m)		17,4 ± 0,6	CTRL	6x0					0/0	15m sprint CL -7,0 % (-1,80) CL 0,8 % (0,22) CTRL -1,2 % (-0,54) Agility (505 test) CL -1,3 % (-0,28) CL 0,0 % (0,00) CTRL 0,8 % (0,15)
MacDonald et al., (2012)	4	10 (m)	Recreationally trained college-aged men; strength training experience at least 6 months	21,7 ± 3,4	CL	6x2	Squats (smith machine); romanian deadlifts; calf rises	Lateral jumps over 12-in; DJ 12-in up to 18-in; box jumps double 12-in to single 6-in	3x3-6 45-90 %	3x3-7	183/ 165	1RM squat CL 51,3 % (1,84) RT 45,0 % (1,08) PLYO 29,9 % (1,36)
		11(m)		21,7 ± 3,4	RT	6x2	Squat (smith machine); romanian deadlift; calf rise		3x3-6 45-90 %		183/0	
		9 (m)		21,7 ± 3,4	PLYO	6x2		Lateral jumps over 12-in; DJ 12-in up to 18-in; box jumps double 12-in to single 6-in		3x3-7	0/165	

Refer-ences	PED-ro Score	Subjects			Training intervention							Results % of change (Effect size)
		n	Training Level	Age	Training method	D/F (w)	Resistance exercises	Power Exercises	Set/Rep (RT) % 1RM	Set/Rep (Power)	Volume (RT/ Power)	
Lyttle et al., (1996)	3	11 (m)	Sports on regional level like track athletes, rugby, swimmers; no experience in strength and power training	23,8 ± 5,4	COMB	8x2	Squats (range of motion 80-180°)	DJ	1-3x6-10 80-85 %	1-2x2-6	248/ n.c.	1RM squat COMB 14,6 % (0,75) PLYO 14,2 % (0,59) CTRL 2,7 % (0,11) CMJ COMB 10,6 % (0,52) PLYO 7,5 % (0,42) CTRL 0,0 % (0,00) SJ COMB 16,6 % (0,64) PLYO 18,3 % (0,90) CTRL 0,6 % (0,03) 40m sprint COMB -0,7 % (-0,18) PLYO 1,3 % (0,22) CTRL -0,5 % (-0,17)
		11 (m)		23,9 ± 6,4	PLYO	8x2		SJ	2-6x8		0/372	
		11 (m)		20,6 ± 3,4	CTRL	8x2					0/0	
Torres-Torrelo et al., (2017)	5	12 (m)	Spanish third division futsal player; no experience in strength and power training	22,9 ± 4,6	BCL	6x2	Full-squats (velocity based)	Change of directions (sek)	2-3x4-6 45-58 %	2-4x10sec	160/ n.c.	1RM squat BCL 12,3 % (0,71) RT 16,0 % (1,13) CTRL -1,0 % (-0,04) CMJ BCL 5,3 % (0,42) RT 5,8 % (0,42) CTRL -0,3 % (-0,02) 10m sprint BCL -1,2 % (-0,23) RT -2,3 % (-0,11) CTRL 0,6 % (0,14) 20m sprint BCL -1,0 % (-0,25) RT -1,3 % (-0,43) CTRL 0,7 % (0,25)
		12 (m)		23,8 ± 2,4	RT	6x2	Full-squats		2-3x4-6 45-58 %		160/0	
		10 (m)		24,7 ± 4,7	CTRL	6x2					0/0	

Refer-ences	PED-ro Score	Subjects			Training intervention							Results % of change (Effect size)
		n	Training Level	Age	Training method	D/F (w)	Resistance exercises	Power Exercises	Set/Rep (RT) % 1RM	Set/Rep (Power)	Volume (RT/ Power)	
												Agility (COD) BCL -1,6 % (-0,42) RT -1,9 % (-0,52) CTRL 1,7 % (0,38)
Voelzke et al., (2012)	4	8 (m)	German first national division volleyball; had familiarization period	24,7 ± 4,7	CL	5x2	Squats; Calf rises;	Clean; CMJ; SJ; DJ; VJ; hurdle jumps	3x5 87 %	3x6	150/ 180	SJ CL 6,6 % (0,36) CTRL 0,0 % (0,00) CMJ CL 5,9 % (0,31) CTRL 3,1 % (0,17)
		8 (m)		24,7 ± 4,7	EMS+ PLYO	5x2	EMS	Clean; CMJ; SJ; DJ; VJ; hurdle jumps	24x5sec 30-60 mA	3x6	n.c./ 180	
Kobal et al., (2016)	3	12 (m)	Elite soccer players; first division championship ; no experience in strength and power training	18,9 ± 0,6	RevBCL	8x2	Half-squats	DJ 30-45 cm	3-5x6-10 60-80 %	3-5x 10-12	220/ 328	1RM squat RevBCL 47,3 % (2,34) BCL 45,5 % (6,12) CL 52,7 % (4,04) CMJ RevBCL 13,3 % (1,03) BCL 14,3 % (1,07) CL 14,8 % (1,41)
		13 (m)		18,9 ± 0,6	BCL	8x2	Half-squats	DJ 30-45 cm	3-5x6-10 60-80 %	3-5x 10-12	220/ 328	
		13 (m)		18,9 ± 0,6	CL	8x2	Half-squats	DJ 30-45 cm	3-5x6-10 60-80 %	3-5x 10-12	220/ 328	

m male; f female; Age data are presented as mean ± standard deviation (SD); CL contrast loads; BCL block contrast loads; COMB combined loads; COMP compound loads; RevBCL reverse block contrast loads; RevCOMB reverse combined loads; RT resistance training; PLYO plyometric training; CTRL control group; CMJ countermovement jump; SJ squat jump; DJ drop jump; VJ vertical jump; HJ horizontal jump; 1RM one repetition maximum; COD change of direction; set sets; rep repetitions; D/F duration of intervention/frequency of training per week over the intervention period; w week; Tue tuesday; Thu thursday; n.c. not calculable; n. m. no mean;

5. Discussion

5.1 Complex Training vs. Non-Training

To enhance power output and sport specific performance, complex training (CL, BCL and COMB) methods seem to be superior to non-training CTRL groups (figure 10 vs. figure 11).

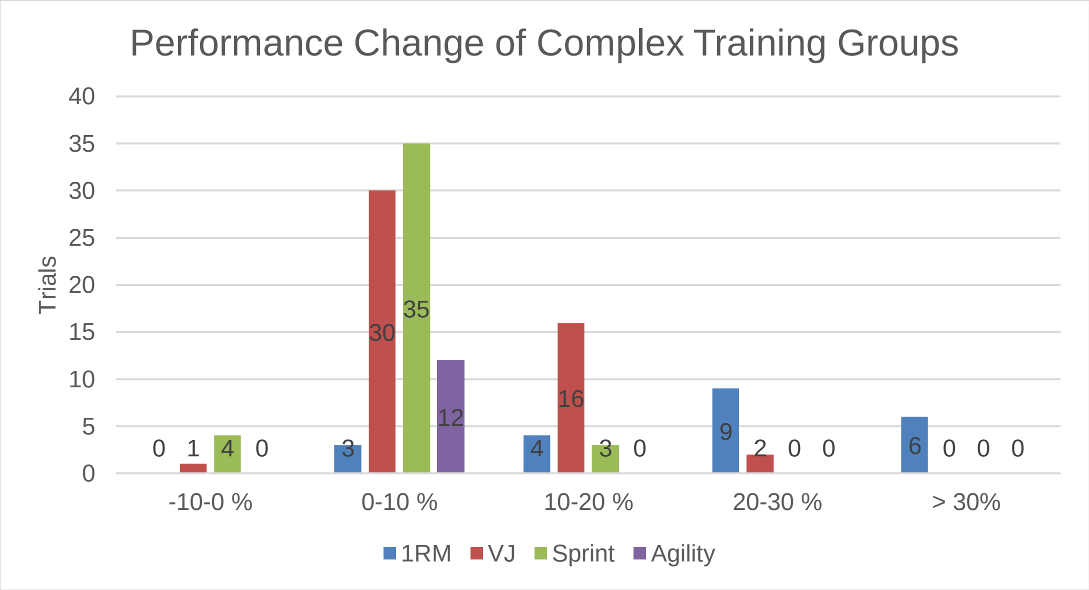

Figure 10: Percentage change of performance after complex training

Strength performance

All trials which performed complex training lead to improvements of the squat 1RM ranging from 7,4 % change (ES=0,22; Wallenta et al., 2016) to a maximum of 52,7 % (ES=4,04) in the study of Kobal et al., (2016).

In comparison, most of the CRTL groups displayed only small non-significant improvements in 1RM, with the highest change found by Hammami and colleagues (2017; 6,1 % and ES=0,38). Two trials even found a slightly decrease of maximum strength after CTRL (Torres-Torrelo et al., 2017; Stasinaki et al., 2015).

Jump performance

Most of the included trials reported a one form of vertical jump (i.e.: CMJ, SJ, DJ) as outcome parameter. All complex training groups, except one (Stasinaki et al., 2015), showed an improvement of 0,2 - 25,3 % change (ES= 0,01 - 2,74). Specifically, Stasinaki and colleagues (2015) reported a decrease in CL group for the CMJ (-0,2 % change, ES= -0,01). Therefore, the authors stated that the missing benefit could be related to the missing experience in strength training and furthermore that kinematics of training intervention and outcome measurement has been slightly different. This result is in line with the hypothesis of Bishop (2009) that stronger athletes result in a higher benefit to a CL training intervention in comparison to weaker athletes. In contrast to that, Tsimahidis and colleagues (2010) reported significant improvements for the SJ (12,9 % change and ES= 1,06 for) for the CL for the untrained CL group.

In comparison, the non-training CTRL subjects showed a decrease in change of -7,4 % - 5,7 % (ES= -1,34 to 0,33) for different vertical jumps. It can be concluded that CTRL trials resulted in no significant changes over the observed period.

Sprint performance

Included studies evaluated sprint performance over various distances (5m – 60m). Most of the studies revealed improvements of 0 - 12 % change (ES= 0,07 - 4,97) in sprint time. In contrast Faude et al., (2013) could not find improvements for 10 m and 30 m. Also Alves et al., (2010) and Villareal et al., (2013) reported no improvements for 15 m sprint time at the end of their interventions.

Faude and colleagues (2013) stated that sprint time was probably not affected because of the in-season testing of pre-tests. The tests were carried out three weeks after the beginning of the competitive season and participants probably yield a ceiling effect over the pre-season period (last three weeks focus on speed tasks). Furthermore, the authors suggest a lack of transfer from athletic training to sprint, due to the low volume of specific tasks in power related exercises.

In contrast, most of CTRL groups showed no meaningful improvements, except Garcia Pinillos and colleagues (2014). In their study, sprint time for both CL and CTRL group improved significantly ($p<0,01$). It could be hypothesised that the control group received a training stimulus in their common soccer training.

Agility performance

Nine studies examined the effect of a complex training on agility performance. All complex training interventions showed a reduction in agility time between -7,2 % - 0,0 % (ES= 0,00 - 2,45). Hammami and colleagues (2017) examined several tests and present the highest change in time from -7,2 % to -5,0 % (ES= 1,63 - 2,45) for two of their agility tests. Across all studies control groups consistently showed no significant ($p< 0,05$) reduction in agility time (ranging from -2,1% - 1,7% with ES= -0,38 - 0,53).

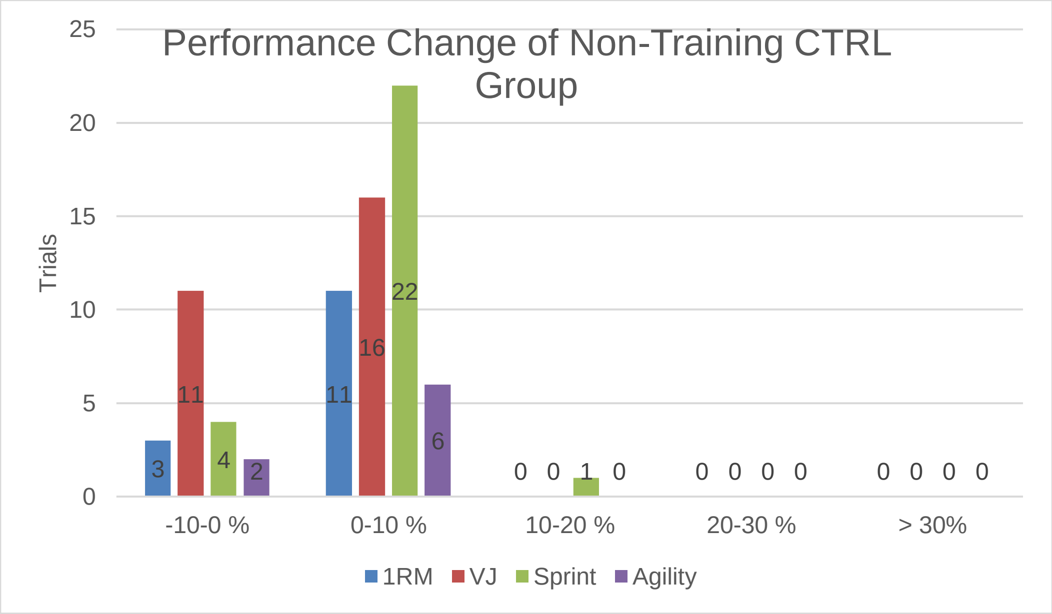

Figure 11: Percentage change of performance after non-training CTRL

5.2 Complex Training vs. Non-Combined Alternative Training Methods

As described earlier complex training seems to be effective to enhance different outcomes parameters. Alternative training interventions without any combinations (RT, PLYO and OLY) seem to be also effective to improve strength, jump, sprint and agility performance (see figure 12). It can be concluded that alternative training interventions without any combinations show similar improvements as complex training, although this statement needs to be confirmed through meta-analytic calculations.

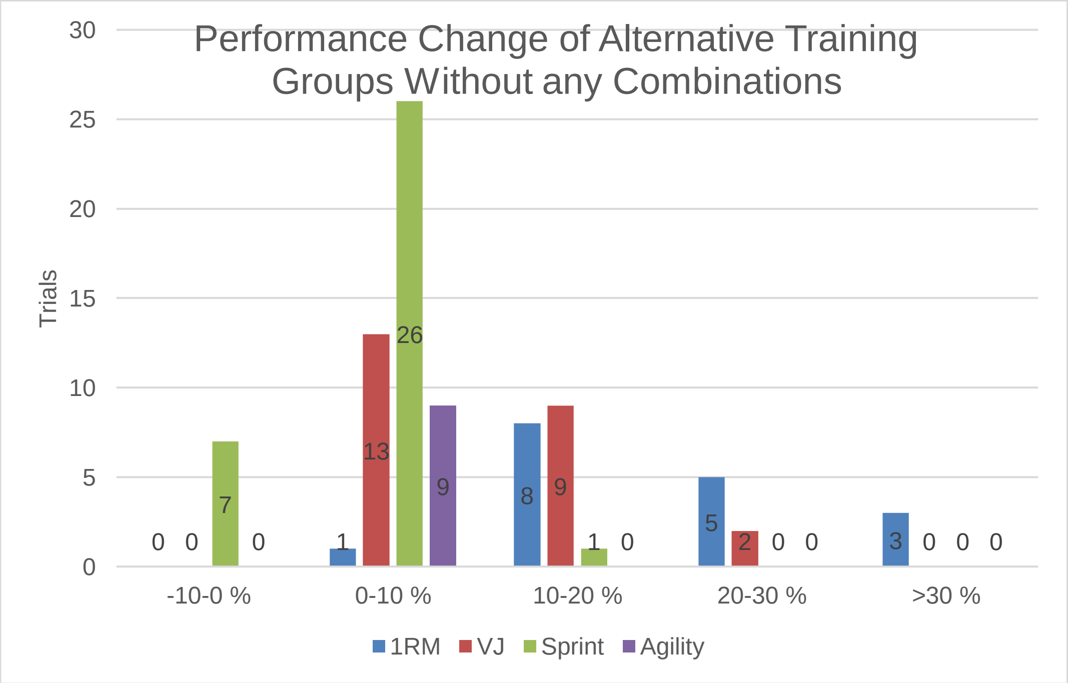

Figure 12: Percentage change of performance after non-combined alternative training

Strength performance

All single training methods of the included studies which evaluated 1RM for squat and leg press (RT and PLYO) showed increases from 6,8 % - 48,9 % (ES= 0,49 - 3,69). RT seems to be superior to PLYO to improve 1RM. In contrast to that, MacDonald (2012) found no significant group interaction for PLYO, RT and CL after 6 weeks of intervention.

The highest increase in 1RM was found by that Arazi and colleagues (2014). Their untrained subjects improved dramatically (48,9 %, ES= 3,41). This could be because the athletes were untrained at the beginning of the study. It is well known that high increases in strength at the beginning of a training intervention are based on neural adaptations (Folland and Williams, 2007).

In contrast to that, MacDonald et al. (2012) found similar improvements in resistance trained sport students. The RT increased their strength by 45 % (ES= 1,08) and the PLYO could improve their squat by 29,9 % (ES= 1,36). Pre-strength values for RT group (127,14 ± 41,43 kg and a bodyweight of 85.34 ±22.14) and for the PT group (112,14 ± 26,43 kg and a bodyweight of 82.63 ± 10.80) confirmed resistance training experience of the subjects.

Jump Performance

Alike improvements of 1RM the non-combined alternative groups (RT, PLYO and OLY) reported improvements of various vertical jump variables of 0,4 % - 20,3 % (ES= 0,03 - 1,74). Subjects of all groups showed similar performance adaptions, therefore no training intervention seems to be superior. The highest ES of 1,74 was shown by Hammami et al., (2017) for the RT intervention. Also OLY exercises seem to be effective for improving CMJ and SJ (ES= 0,69 and ES= 0,97, respectively). In the study of Suchomel and colleagues (2017) these findings could be confirmed and the authors hypothesised that different weightlifting derivatives are highly effective to improve RFD.

Sprint performance

Except Hammami and colleagues (2017) most of the authors which evaluated sprint performance showed moderate improvements for sprint time with a change of 0,0 % to -15,7 % (ES= 0,0 - 1,52). Also, some studies failed to improve sprint time from pre to post testing (Dodd and Brent 2007; Lyttle et al., 1996; Lloyd et al., 2015). Hammami et al., (2017) examined high decreases for 20m (ES= 4,96), for 30m (ES= 2,99) and for 40m (ES= 2,82) in sprint time for the RT training group.

The CT group, showed even higher improvements for 5m, 30m and 40m (ES= 4,97, ES= 3,08, and ES= 2,88, respectively). However, no significant differences between these groups could be found. The high transfer of strength gains to sprint improvements are confirmed by the meta-analysis of Seitz and colleagues (2014).

Agility Performance

Only four trials evaluated agility performance after RT or PLYO training. Most of these intervention groups showed improvements for agility tests ranging from 0,0 % to -7,7 % change (ES= 0,00 - 2,98). Arazi and colleagues (2014) presented a somewhat higher ES after RT or PLYO in comparison to CL or COMP, but no significant differences were found between training methods. Improvements of agility are hypothesised to be affected by the development of a high power output and RFD, therefore also RT training interventions are able to improve agility performance (Sheppard and Young, 2006).

5.3 Complex Training vs. Combined Alternative Training Methods

Nine trials of the included studies carried out alternative combined training interventions (COMP, BKP, RevBCL, RevCL, EMS+PLYO). In all groups and throughout all outcome variables improvements could be found. In contrast to the previous chapters, this chapter will not discuss each outcome variable separately. The author will focus on an in depth analysis of each training method instead.

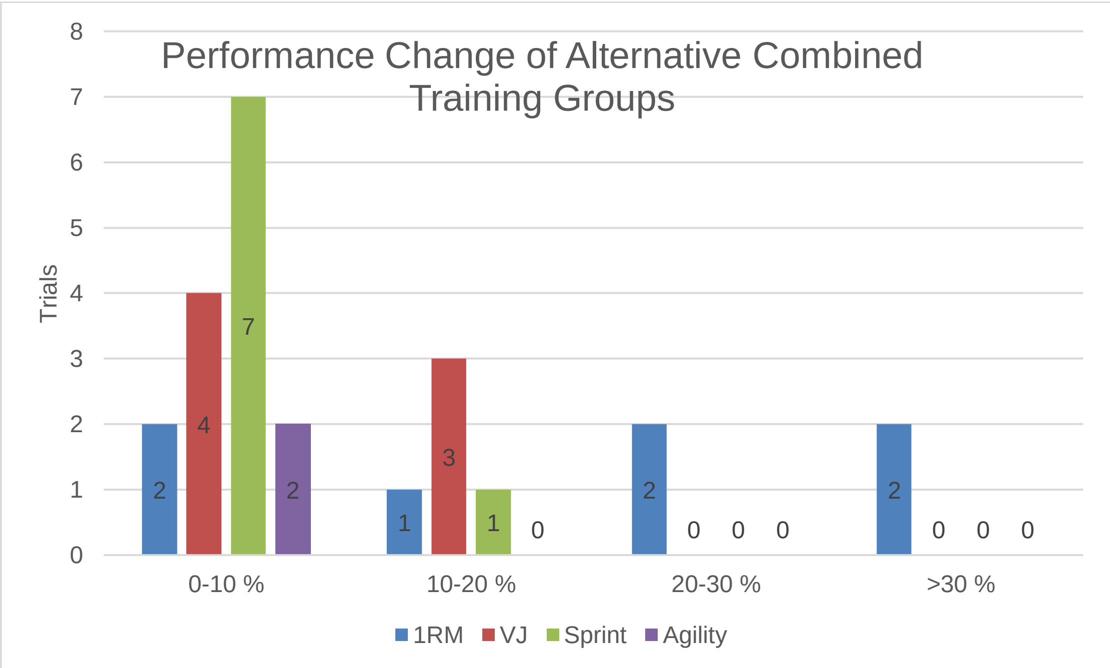

Figure 13: Percentage change of performance after alternative combined training

Compound training

Three interventions tested a COMP training group. The trials reported improvements for all outcome variables (ES= 0,08 - 2,90).

Similar to Mihalik et al. (2008), Stasinaki et al. (2015) reported only moderate changes for CMJ of 4,5 % (ES= 0,43). In comparison, the volume equated CL resulted in a slight decrease of -0,2 % (ES=0,01). This can be due to the fact that subjects trained DJs but have been tested on the CMJ. In contrast both groups showed high improvements for 1RM squat. Also Arazi and colleagues (2014) used equated volumes for COMP and CL. Both groups performed significant better for post-test, but no significant group interaction was found.

Reverse complex training

In theory, this training method cannot use the effect of PAP because of the reverse sequence (power before strength). Two trials used RevBCL and one RevCL training models. All of these trials used equated volumes and measured jump and strength parameters. Overall, reverse complex training methods show an improvement of 7,3 % to 47,3% (ES= 0,56 - 3,13). Alemdaroglu and colleagues (2013) pointed out significant ($p < 0,05$) improvements for SJ and CMJ after a CL, BCL and RevBCL training but no significant group interaction were found. Furthermore, the authors did not find gender differences.

In line with Alemdaroglu et al. (2013) Kobal and colleagues (2016) reported significant ($p < 0,05$) improvements for squat 1RM and CMJ but did not find any significant group interactions. Nevertheless, CL resulted in higher effect sizes (ES= 6,12 vs. ES= 2,34) for the 1RM squat in comparison to the RevBCL ($p < 0,05$).

Talpey and colleagues (2016) compared a CL and a RevCL training approach and stated that both groups showed improvement in strength and vertical jump performance. In contrast to most of the included trials subjects of Talpey et al. (2016) had a high squat strength level of about 1,7 times their bodyweight. Nevertheless, the subjects in both groups (CL and RevCL) increased their strength significantly ($p<0,01$) to 2,11 times their bodyweight. Significant improvements were found for the same outcomes (1RM and VJ) except for running VJ after RevCL. There the authors found a significant difference in the favour of RevCL.

Overall the qualitative comparison of complex training and reverse complex training showed no relevant differences. Therefore, it is not possible to give recommendations on which is the best training method.

Block periodisation

Two studies (Wallenta et al., 2016; Juarez et al., 2009) evaluated the effect of a complex training protocol (COMB and CT) in comparison to a BKP of strength and power contents. BKP groups showed moderate improvements of 1,0 % to 12,3 % change (ES= 0,06 to 0,96) for jump and 1RM squat. For sprint the trials showed only small improvements of -1,2 % to -5,6 % (ES= 0,32 - 1,35).

Juarez and colleagues (2009) showed significant (p= <0,05) improvements for sprint (5m, 10m, 15m, 20m), CMJ, SJ and 1RM squat for COMB. In contrast the BKP improved significant (p= <0,05) for sprint (5m, 10m), SJ and 1RM back squat but no significant differences between COMB and BKP training groups were found. Additionally, the study evaluated the effects of a detraining of two weeks (POST 2) at the end of the training. The authors showed a significant decrease for CMJ and sprint (15m and 20m) performance for the COMB group between POST1 and POST2. In comparison, the BKP training group showed no significant decrease.

Wallenta and colleagues (2016) examined CL and BKP with equated volume. CL significantly enhanced 1RM and VJ performance but could not improve the sprint time. In contrast BKP improved 1RMand sprint time (5m, 10m, 30m). Nevertheless, no significant group interaction could be observed. Taken all together, it is too early to draw definite conclusions from these studies. Future studies should address this.

Untraditional combined training model

Two of the included studies used “untraditional” combined training methods. Voelzke and colleagues (2012) for example examined the effects of a combined EMS and power training compared to a CL training intervention. EMS group improved CMJ, DJ, reach height, 15m lateral, 5m and 10m straight sprint time significantly (p< 0,05). Furthermore, a significant group interaction for 5m straight sprint time in the favour of combined EMS training was found. Nevertheless, CL training showed significant (p< 0,05) improvements for SJ and reach height (kind of VJ) from pre to post testing. Authors noted that CL training seems to primarily improve voluntary concentric movement patterns and EMS adaptions are based on adaptions of the RFD and the SSC. Furthermore, the authors stated that a combined EMS training intervention could be an interesting method for athletes with a high training level and a limited amount of time in the preseason period (Voelzke et al., 2012).

5.4 Contrast Load vs. Block Contrast Load vs. Combined Load

Four of the included trials examined the effect of two different complex training methods (Alemdaroglu et al., 2013; Smith et al., 2014; Kobal et a., 2016; Juarez et al., 2009).

Alemdaroglu and colleagues (2013) evaluated CL in comparison to BCL. Regarding the effect sizes, CL groups showed a higher improvement in comparison to the BCL group (CMJ: ES= 1,25 vs. 0,82 for male and ES= 1,65 vs. 0,05 for female; SJ: ES= 0,93 vs. 0,28 for male and ES= 0,72 vs. 0,15 for female). However, no significant difference between groups and genders were observed. Similarly, Kobal and colleagues (2016) could not find a group difference between CL and BCL. Nevertheless, BCL showed higher 1RM squat enhancements (ES= 4,04 vs. 6,12) and CL improved CMJ slightly better (ES= 1,41 vs.1,07).

Smith and colleagues (2014) examined the effects of two volume equated trials, one group used a squat as strength exercise and the other one used the kettlebell swing for the strength training part. Both groups failed to improve VJ in comparison to the non-training control group. Authors noted that the small sample size and the low training volume could be a reason for missing effects.

5.5 Complex Training - Differences due to Age Group, Training Level and Training Volume

It should be noted that included studies are highly heterogenous regarding subject characteristics, duration and frequency, load used and total training volume.

Training volume and load

The high standard deviation of the total volume reflects the heterogeneity of the included studies (mean ± SD for total Volume of resistance training were 628,8 ± 676,7 and for power training 529,3 ± 487,6). Subjects in the study of Veliz and colleagues (2015) trained with the highest volume of 1344 for resistance training and about 1028 for power training over a period of 16 weeks and 32 sessions. In contrast, athletes in the study of Juarez and colleagues (2009) trained with lowest total resistance training volume of 94. Volume of power exercises could not be calculated for this investigation because they used sprints in their training program. Anyway, the volume for power exercises also seemed to be very low (Juarez et al., 2009). Interestingly, both investigations reported similar effects for their COMB group (significant $p \leq 0,05$ for CMJ, 1RM squat and for other outcome values).

Alves and colleagues (2010) investigated the effect of different volumes for two CL protocols. Interestingly, the authors found no significant differences for sprint time in the training group with one CL training session/week compared to two sessions/week. However, both groups showed a significant improvement for sprint (5m, 15m) and SJ.

Alves and colleagues (2010) used high loads of 80-100 % 1RM and Wallenta and colleagues (2016) utilised light loads of about 60-70 % 1RM. Both trials included professional athletes and utilised similar volume. However, subjects from Alves and colleagues (2010) reached similar results in CMJ and somewhat better ES for sprint than those athletes, who participated in the trial of Wallenta and colleagues (2016).

In Conclusion, it is not possible to detect a tendency for volume, load and its effect on sports performance. Meta-analytic calculations could potentially help here.

Training level and age

It seems that there is no consensus in the literature on the use of strength and power exercises (and their combination) in different subjects (trained, untrained, strong, weak, fast, slow, etc.). Cormie and colleagues (2011) as well as Bishop (2009) hypothesised that a complex training method seems to be contraindicated for athletes with poor strength levels. In contrast Juarez and colleagues (2009) quote that a complex training could be an opportunity to develop strength and power in untrained individuals. In Line with that Lloyd and colleagues (2016) tested pre and post peak height velocity (PHV) boys and described BCL intervention for post PHV (without strength experience) as most efficient method to enhance 1RM, sprint and jump performance. For the pre PHV age group, authors suggest bigger improvements with a PLYO training intervention. Nevertheless, Lloyd et al. (2016) investigated children and adolescents, therefore results should be interpreted with caution.

Strength level

It seems not clear if the strength level is contraindicated for a complex training because also subjects with a low 1RM in squat showed similar improvements throughout COMB in comparison to BKP. Nevertheless, authors stated that probably significant group interaction for COMB could be reached due to a higher strength level (Juarez et al., 2009). In the line to this findings Kobal and colleagues (2016) mentioned to two main reasons why untrained athletes also benefit from a complex training. First, due to the increased neuromuscular adaptions in conjunction to perform resistance and power exercises in one session. Second, could be related to the missing experience of strength training of included subjects.

Consequently, complex training seems to be an interesting training method for different training levels. However, a connection of strength level to given load, frequency and volume in complex training cannot be identified.

Type of muscle contraction

Seitz and Haff (2015), as well Wilson and colleagues (2013) suggest performing movements in a dynamic eccentric-concentric pattern to generate a high PAP effect. Therefore, included trials that examined strength training with velocity controlled system, result only in moderate improvements for jump or sprint performances (ES= 0,23 - 0,83). In contrast authors showed for this contraction type high improvement to 1RM squat (ES= 2,23; Franco-Marquez et al., 2015; Veliz et al., 2014; Veliz et al., 2015; Torres-Torrelo et al., 2017). Therefore, a velocity based training intervention seems to be effective for 1RM enhancements, but transfer to jump or sprint performance is somehow restricted. Nevertheless, Garcia-Pinillos and colleagues (2014) used isometric contraction in their strength training and showed also high ES for sprint performance (ES= 0,57) and sprint (ES= 1,18 for 5m; ES= 1,17 for 10m; ES= 1,17 for 20m; ES= 0,96 30m) performances.

6. Conclusion

The purpose of this review was to evaluate the effects of a complex training approach on athletes sport specific performance compared to CTRL and alternative training methods. Alternative training methods were categorised in training methods performed separately (i.e.: RT, PLYO, OLY) and 2.) combined alternative training methods (i.e.: COMP, RevCOMB, BKP). The precise definition of all training methods can be found in chapter 2.2.1.

Right at the start of the conclusion, some limitations should be noted. First, the inconsistent definition in the literature causes confusion. Many authors use the same terms for different combined training protocols. Therefore, the author of this thesis proposed a model to define the different combined training methods. Second, the included studies are highly heterogenous. The investigations studied a wide range of subjects (children, adolescents, adults, trained, untrained, etc.) and training interventions sometimes highly varied in duration, volume and exercises applied. Therefore, generalised conclusion should be treated with some caution. Third, many research papers have poor methodological quality (see PEDro score) and failed to provide highly relevant information. Future studies should address these issues.

It should also be noted that standardisation of study methodology is somewhat hard in this topic. One reason for this is that multiple combinations of power and strength training are possible (See also figure 2). Cormie and colleagues (2011) for example state that four main training methods can be used to develop power (ballistic-, plyometric, resistance- and olympic style training). These methods can be done separately or in combination with each other. If we assume that a maximum of two training methods can be combined, we end up having 10 different options for training (4 basic training methods and 6 possible combinations; see table 5 for illustration).

Table 4: Training methods (adapted from Cormie et al., 2011)

Combination of training methods				
Training methods	Ballistic	Plyometric	Resistance	Olympic Style
Ballistic	x	1	2	3
Plyometric		X	4	5
Resistance			X	6
Olympic Style				X

One should keep in mind that the combinations could be further multiplied due to combinations used (CL, RevCL, etc.). Therefore, for the purpose of this review we summed up possible variations (CL, BCL, COMB, RevCL, RevBCL, RevCOMB).

Taken all together, this systematic review shows improvements for all combinations and no preferred training method could be identified. However, to maximise the transfer to sports performance, the findings suggest that training interventions should consist of movements similar to those used in competition (Faued et al., 2013; Stasinaki et al., 2015; Franco-Marquez et al., 2015; Dodd and Brent 2007).

In addition, “untraditional” combination models could be of interest for researcher and coaches. Voelzke and colleagues (2012) examined the effects to a complex training including EMS and power exercises and found exceptionally high increases of various performance measures. The authors stated that this training intervention could be an interesting approach for high trained athletes and a limited time in the preparation period. Furthermore, this review does not include upper body outcome measures / complex training. However, various authors examined complex training effects to upper body performance and found improvements in performance (Inovero and Pagaduan, 2015; Tillaar and Marques, 2011; Liu 2003).

In conclusion, it can be stated that complex training is an effective method to improve jump, sprint, strength and agility performance of athletes with different background. However, it is still unclear if complex training (CL, BCT, COMB) is superior to alternative combined (RevCL, RevBCL, RevCOMB) or isolated (RT, PLYO, OLY) training methods. It is therefore necessary to conduct further research on complex training. Intervention studies of high methodological quality are warranted. Additionally, results of the present systematic review could be extended by quantitative methods (i.e.: meta-analysis).

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